Cambridge University Press

8

Cambridge science for the Victorian Curriculum

Authors
Evan Roberts
Christopher Humphreys
Victoria Shaw

Contributors
Jonathan Blair
Erin Checkley
Sarah Chuck
Laura Swann

ISBN 978-1-108-61069-8

Cambridge University Press

CAMBRIDGE
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre, New Delhi – 110025, India

79 Anson Road, #06–04/06, Singapore 079906

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781108610698

First published 2019
20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

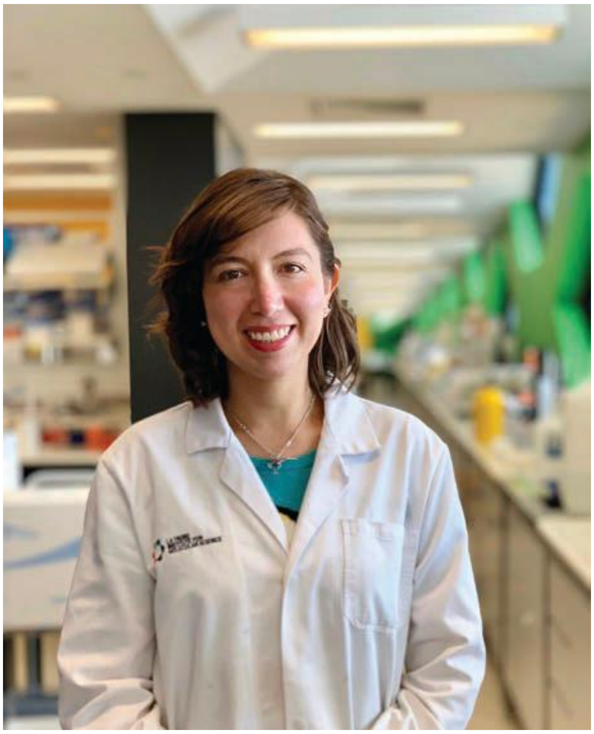
Cover designed by Cameron McPhail
Text designed by Shaun Jury
Typeset by QBS Learning
Printed in China by C & C Offset Printing Co. Ltd.

A catalogue record for this book is available from the National Library of Australia at www.nla.gov.au

ISBN 978-1-108-61069-8 Paperback

Additional resources for this publication at www.cambridge.edu.au/GO

Welcome



Some bacteria develop resistance to all antibiotics that are commonly used to treat them. This means that infection by these types of bacteria is a threat to public health. They are also extremely common and millions of cases are reported annually worldwide. Finding an alternative way to treat these infections is crucial for everyone.

The research I am currently conducting is concerned with these kinds of bacterial infections. Using an approach that involves the use of molecules or substances obtained from sharks, we are trying to develop an alternative way to treat this and other infections caused by bacteria that represent a serious threat to human health.

I find what I do extremely exciting and rewarding, not only because of everything I have learned since working in this field, but also because of the satisfaction of knowing that I am trying to do something to improve the quality of life of many people.

Gabriela Constanza Martinez Ortiz completed a Bachelor of Biology at the National Autonomous University of Mexico (UNAM) and did her Honours year at the Centre for Scientific Research and Higher Education at Ensenada (CICESE). After graduating as the top student of her class she started working at a pharmaceutical company, called PROBIOMED, in Mexico City. She moved to Melbourne a few years later, to study a Master of Biotechnology and Bioinformatics at La Trobe University. After completing her Masters as the top student, she started a PhD at La Trobe University, which she plans to have completed by the time you are reading this!

Gabriela is also a keen scuba diver, enjoys underwater photography and has an interest in conservation of ocean environments.

ISBN 978-1-108-61069-8

Cambridge University Press

Contents

ISBN 978-1-108-61069-8 Cambridge University Press

ISBN 978-1-108-61069-8

Cambridge University Press

Authors and contributors

Evan Roberts

Evan Roberts is a keen biologist and, prior to teaching, worked in conservation and environmental management. He has taught in both public and private schools and is dedicated to instilling his passion for science into his students. He believes that, just like science, education should be dynamic, exciting and forever changing to keep up with the world around us.

Christopher Humphreys

Chris Humphreys is currently Head of Mathematics and Physics at a tertiary college for international students. He graduated from Nottingham University in the UK and completed his MSc in Physics at the University of Waikato in New Zealand. He has over thirty years' experience as a teacher in state and private schools in the UK, New Zealand and Australia.

Victoria Shaw

Victoria Shaw has been committed to sharing her love for science with Year 7–12 students for the past 18 years and previously studied pharmacology. She was Head of Science at an independent school for a few years and volunteers as an educator for Wildlife Victoria. She has also been an assessor for the VCAA and IBO and runs workshops in Biology and Psychology.

ISBN 978-1-108-61069-8

Cambridge University Press

Jonathan Blair

Jonathan Blair graduated from the University of New South Wales with a Bachelor in Science, majoring in Pharmacology. He has worked in both research and commercial laboratories, specialising in cardiac regeneration and vaccine manufacturing, respectively. Jonathan is currently working as a laboratory technician for an independent school.

Erin Checkley

Erin Checkley has taught Biology, Junior Science and Mathematics at a Catholic secondary college for the past six years. While completing her Masters of Education at The University of Melbourne, she developed a passion for curriculum development, and aims to instil a sense of curiosity and critical thinking skills in students. She previously worked as a cardiorespiratory and sports physiotherapist.

Sarah Chuck

Sarah Chuck teaches Science in Years 7–10. She completed a Biomedical Science degree at Monash University and a Masters of Teaching Practice at RMIT. During her studies, Sarah worked in a genetics laboratory at the Australian Regenerative Medicine Institute, modelling disease in organisms, such as the zebrafish. She hopes students will also find their experiences in science to be extremely interesting and rewarding.

Laura Swann

Laura Swann completed Bachelor degrees in Science and Education at Monash University and has been teaching Years 7–12 for 13 years. Her passion is teaching Physics, and she also enjoys conducting Physics lessons with primary and ELC students. She has been an assessor for the VCAA and hopes to continue inspiring young people to pursue their interests in science.

The publisher would like to thank Mark Birney, Paulo da Silva, Isaac Pang, Dr Sydney Boydell, Dr Roger Slade, Harry Leather, Jan Leather and Ariel Laughlin for their help in reviewing and contributing to this title.

How to use this book

Overview of the print book

Did you know?

These are short facts that contain interesting information.

Quick check

These provide quick checks for recalling facts and understanding content.

Explore!

Students are encouraged to conduct research online to find and interpret information.

Try this

Short activities encourage a hands-on approach to concepts that are currently being covered.

Glossary definitions of key terms are provided next to where the key term first appears in the chapter.

VIDEO
Videos are found in the Interactive Textbook.

WIDGET
Widgets are found in the Interactive Textbook.

Practical

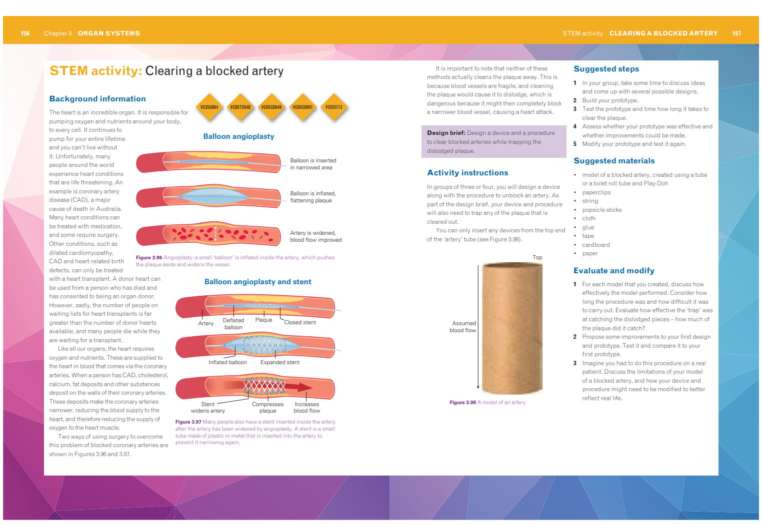
Practical investigations consolidate student learning.

Science as a human endeavour

These are recent developments in the particular area of science being covered. They may also show how ideas in science have changed over the years through human discovery and inventions.

Section questions

Review questions to check students' understanding and application of the section content.



STEM activities encourage students to collaboratively come up with design and build solutions to problems and challenges.

ISBN 978-1-108-61069-8 Cambridge University Press

Overview of the Interactive Textbook (ITB)

The **Interactive Textbook (ITB)** is an online HTML version of the print textbook powered by the Edjin platform, included with the print book or available as a separate digital-only product.

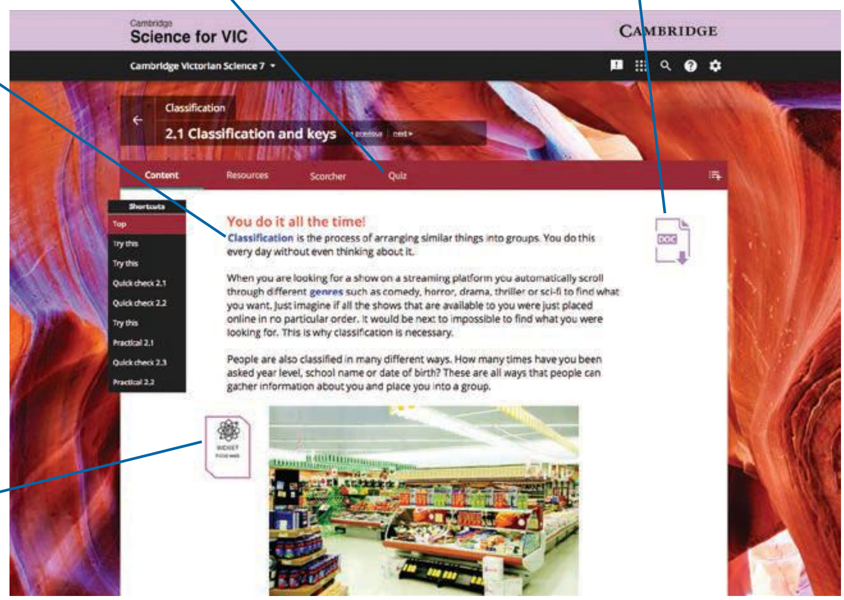
Definitions pop up for key terms in the text

Quizzes contain automarked questions that enable students to quickly check their understanding

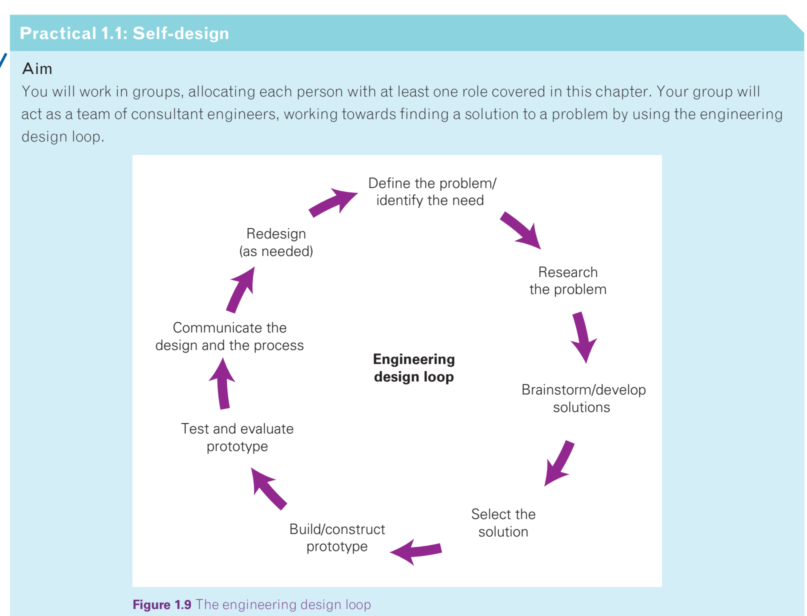
Worksheets are provided as downloadable Word documents

Videos summarise, clarify or extend student knowledge

Widgets are accompanied by questions that encourage independent learning and observations



Practicals are available as a Word document download, with sample answers and guides for teachers in the Online Teaching Suite



Practical 1.1: Self-design

Aim

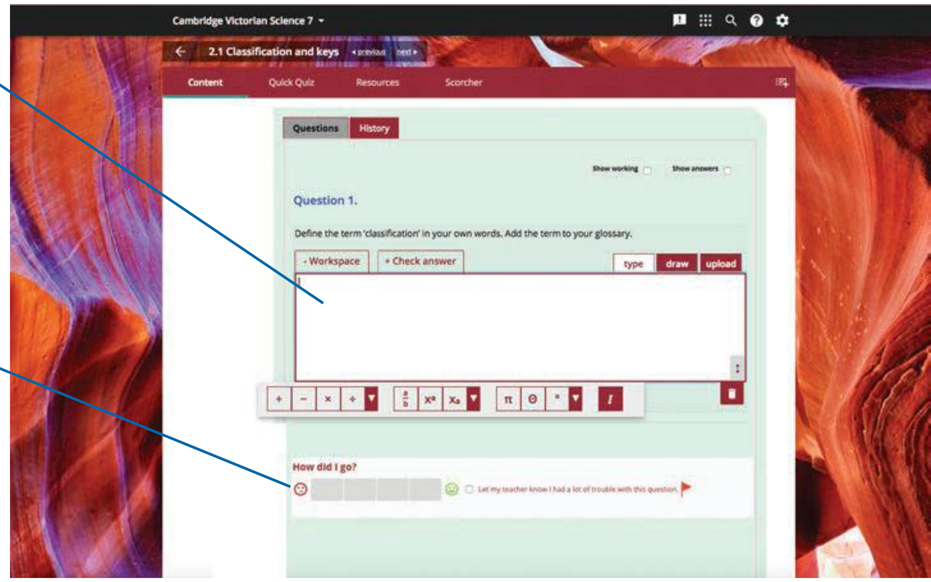
You will work in groups, allocating each person with at least one role covered in this chapter. Your group will act as a team of consultant engineers, working towards finding a solution to a problem by using the engineering design loop.

Figure 1.9 The engineering design loop

ISBN 978-1-108-61069-8

Workspaces enable students to enter working and answers online and to save them. Input is by typing, handwriting and drawing, or by uploading images of writing or drawing.

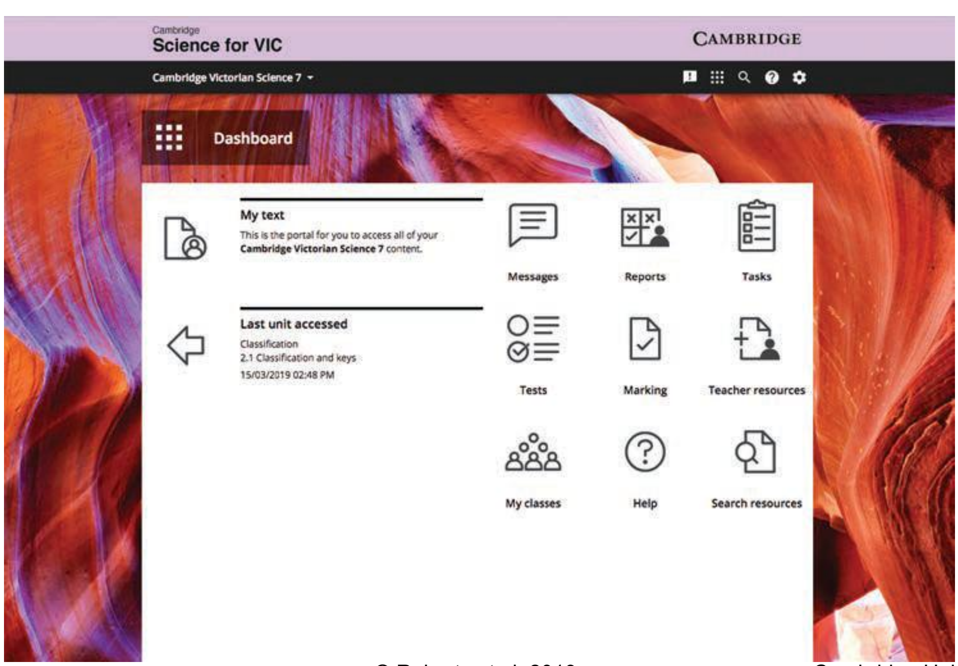
Self-assessment tools enable students to check answers, mark their own work, and rate their confidence level in their work. This helps develop responsibility for learning and communicates progress and performance to the teacher. Student accounts can be linked to the learning management system used by the teacher in the Online Teaching Suite.



Overview of the Online Teaching Suite (OTS)

The Online Teaching Suite is automatically enabled with a teacher account and is integrated with the teacher's copy of the Interactive Textbook. All the assets and resources are in one place for easy access. The features include:

- **The Edjin learning management** system with class and student analytics and reports, and communication tools.
- Teacher's view of a **student's working and self-assessment**.
- **Chapter tests** and **worksheets** with answers as PDFs and editable Word documents.
- Editable **curriculum grids** and **teaching programs**.
- **Teacher notes** and downloadable Word document **guides** to Practicals and STEM activities



ISBN 978-1-108-61069-8

Cambridge University Press

Acknowledgements

The author and publisher wish to thank the following sources for permission to reproduce material:

Cover: © Getty Images / ArtMari

Images: © Getty Images / Monty Rakusen, Chapter 1 Opener / shorrocks, 1.3 / mauro_grigollo, 1.7 / Fernan Federici, Chapter 2 Opener / Dr. Keith Wheeler, Table 2.1 / Westend61, 2.4 / Rpsycho, 2.6 / Science photo Library, 2.7 / Magda Turzanska, Science PL, 2.10 / Sebastian Kaulitzki, 2.11 / Bigmouse108, 1.12, 2.13 / ttsz, 2.13, 2.32, 3.39, 3.41, 6.6, 6.12 / Aloysius Leng, 2.14 / SCIEPRO, Science Photo Library, 2.15 (t-l), 2.19 (t-l), 2.20 / Yury Prokepoenko, 2.15 (b) / Kateryna Kon / Science PL, 2.16 (L), 2.21, 2.23, 2.28, 2.41, 3.2, 3.59 / Ed Reschke, 2.15 (t-r) / Michael Masters, 2.16 (R), / BSIP, 2.17 / Klaus Vedfelt, 2.17 / Dlumen, 2.19 / yangna, 2.19 / Andrew Merry, 2.20 / ai_yoshi, 2.21 / hidesy, 2.22 / CristianDXB, 2.24 / normaals, 2.26 / Temet, 2.28 / Ed Reschke, 2.5, 2.14 (t-r), 2.29, 2.33, 3.26, 3.40, 4.31 / Oliver Strewe, 2.30 / image Source, 2.31 / Kevin Wells, 2.36 / Bradley Grove, 2.37 (t) / Arterra, 2.37 (c) / TorriPhoto, 2.37 (b) / Fernando Camino, 2.38 / Astrid & Hanns – Frieder Michler, Science Photo Library, 2.39 (t) / Roland Birke, 2.39 (c) / Luayana, 2.40 / Rachen Buosa, 2.42, 2.43 / Youst, 2.44 / ChesireCat, 2.45 / BSIP / UIG, 2.46 / JGI / Jamie Grill, 2.49 / UIG, 2.50 / PeopleImages, 2.51 / Fahroni, 2.52 / Andres Brookes, 2.54 / Oliver Ross, 2.55 / J Westrich, 2.56 / Bigmouse108, 2.57 / Alfred Pasieka, Science PL, 2.58 / Oliver Burston, STEM activity: Design a city (image 2) / Sebastian Kaulitzki, 2.9 / PeterHermesFurian, p.64 / Jeff Rotman, p.101 / temet, 3.38 / fstop123, p.147 / SuperFroyd, p. 321 / Andrezj Wojcicki / Science PL, Chapter 3 Opener / Pixologic Studio / Science PL, 3.1, 3.58, 3.59, 3.15 / KTS Design / Science PL, 3.3 / tudmeak, istock, 3.4 / Astrid & Hanns-Frieder Michler Science PL, 3.6 / S. Kaulitzki / Science PL, 3.7, 3.8 / Sam Diephuis, 3.9 / Jeff Rotman, 3.11 / Science Photo Library - Leonello Calvetti, 3.11 / Science Photo Library - Leonello CalvettiI, 3.12 / Wetcake, 3.13, 3.14 / Gustavo Miranda Holley, 3.17 / PhotoAlto / Odilon Dimier, 3.19 / Emil Von Maltitz, 3.20 / David Malan, 3.22 / Dr Jeremy Burgess / Science Photo Library, 3.23 / Dorling Kindersley, 3.27 / olga_sweet, 3.27 / Paul Starosta, 3.29 / davemhunt photography, 3.33 / Jacobs Stock Photography, 3.33 / Elisa Lara, 3.36 / Temet, 3.37 / SCIEPRO, 3.43/ Juan Gartner, 3.44, 4.42 / Stocktrek Images, 3.45 / Suedhang, 3.45 / twomeows, 3.48 / Dimitry Ageev, 3.49 / Science PL, 3.50 / Compassionate Eye Foundation, 3.51 / 4FR, 3.51 / MedicalRF.com, 3.53 / Image Source, 3.61 / ake1150sb, 3.62 / Adam Gault, 3.63 / youngvet, 3.64 / Nigel Pavitt, 3.67 / Paul Harizan, 3.68 / Oli Scarff, 3.73 / R. Dirscherl, 3.74 / R. Reinhard, 3.75 / John White Photos, 3.76 / B. Way, 3.78 / B. Diego, 3.79 / uchar, 3.82 / magicmine, 3.83 / O. Franken, 3.84 / D. Zoo, 3.85 / vshivkova, 3.88 (L) / S. Kaulitzki, 3.89 / M. Vuillermoz, 3.90 / A. Gault, 3.91 / C. Ryan, 3.92 / ZEPHYR, 3.94 / solar22, 3.96, 3.97 / Lemon_tm, 3.98 / BlackJack3D, Chapter 4 Opener / Sarah Jones (Debut Art), 4.1 / S Cesareo, 4.3 / Buena Vista Images, 4.4 / S. Gorton, 4.5 / SeaTops, 4.6 / M. Leggero, 4.8 / J. Burton, 4.9 / Sudowoodo, 4.10 / Kaengurus, 4.14 / C. Howes, 4.18 / Auscape, 4.20 / N. McIntyre, 4.22 / M. Novak, 4.24 / R. Thongbun, 4.28 / sdominick, 4.29 / F. Tanneau, 4.37 / Oksana Osypenko, 4.30 / P. Gadd, 4.32 / slavadubrovin, 4.33 / Joshua McCullough / K. SeptimiusKrogh, 4.3 / M. Oppenheim, 4.38 / F. Köhntopp, 4.39 / Frank Köhntopp, 4.40 / FLPA / Bob Gibbons, 4.41 / C. Wojtkowski, 4.41 / K. Summers, 4.43 / T. Vucic, 4.44 / V. Jovanovic, 4.45 / D. Delimont, 4.46 / BBC Universal, 4.47 / Oxford Scientific, 4.48 / double_p, 4.49 / A. Roberts, 4.50 / D. Torckler, 4.51 / PietroPazzi, 4.52 / A. Alekandravicius, 4.53 / M. Schewe – Behnisch, 4.54 / MoD Photos , 4.55 / Ogphoto, 4.56 / D. Grizelj, Chapter 5 Opener / M. Fernandez Diaz, 5.5 / nikolos, 5.6 / B. Davies Photosightfaces, 5.7 / Alfred Pasieka / Science PL, 5.10, 5.12 / ThomasVogel, 5.11 / A. Lambert Photography, 5.13 / WestLight, 5.16 / NurPhoto, 5.19 / A. Au-Yeung, 5.19 / Tom Merton, 5.19 / pamspix, 5.22 / imagestock, 5.23 / Reda&Co., 5.26 / Toxitz, 5.27 / D. Panteva Photography, 5.28 / J, Banagan, 5.31 / Cavan Images, Chapter 6 Opener / N. Bodrova, 6.1 / G. Tsartsianidis, 6.1 / N. Langan, 6.1 / Lyubov8, 6.1 /M. Falinski, 6.3 / Tchareon, 6.4 / Tetra Images, 6.8 / E. J. Bergin, 6.9 / celsopupo, 6.10 / Detlef van Ravenswaay Picture Press, 6.11 / Skittles Candy, 6.13 /Westend61, 6.14 / Kevin Studio, 6.14 / B. Ginsberg, 6.15 / SheraleeS, 6.16 / fotokostic, 6.16 / Venerala, 6.18 / C. M. Mossop, 6.19 / Ddurrich, 6.20 / H. Shooter, D. Kindersley, 6.21 / V. Kokorin, 6.22 / J. Jordan, 6.23 / DuncanL, 6.24 / X. Han, 6.25 / Seldon Scene Photog. 6.25 / Hero Images, 6.25 / S. Kaulitzki, Sciene PL, 6.26 / M. Brunner, 6.27 / S. Gauldwell, 6.28 / N. Beckerman, 6.30 / Anadolu Agency, 6.31 / explosivekeeper, 6.32 / Saravuth-photohut, 6.33 / NatalieIme, 6.34 / Martyn F. Chillmaid / Science PL, 6.35 / L. Lauren, 6.36 / PhotoPlus Mag., 6.37 / solidcolours, 6.38 / L. Schulz, 6.40 / 3DScuptor, 6.44 / M. Bottigelli, Chapter 7 Opener / Ross M Horowitz, 7.1 / Watcha, 7.2 / Mina De La O, 7.3 / Blanchi Costela, 7.3 / 31moonlight31, 7.6 / D. Van Ravenswaay, 7.7 / K. Spencer, 7.9 / Auscape / UIG, 7.9 / Totajla, 7.11 / QAI Publishing, 7.12 / Stuart McCall, 7.14 / Prisma by Dukas, 7.15 / P. Tanupatarachai, 7.16 / Australian Scenics, 7.17 / Onfokus, 7.18 / D. Silverman, 7.20 / Science & Society Picture Library, 7.22 / Reload_Studio, 7.24 / ullstein bild, 7.25 / audioworm, 7.26 / Auscape, 7.27 / VvoeVale, 7.28 / Roco Roldn, 7.29 / milicenta, 7.30 / G. Van der Knijff LP Images, 7.31 / C. Keates, 7.32 / J. Cancalosi, Oxford Scientific, 7.33 / Dorling Kindersley, 7.34, 7.60 (3-t), 7.61 (4, 9) / J. Seaton Callahan, 7.35 / Andyworks, 7.36 / elnavegante, 7.37 / CLU, 7.38 / Tomek budujedomek, 7.39 / Inner_Vision, 7.40 / benedek, 7.41 / R. Brook Science PL, 7.42 / T. Grist, Moment, 7.43 / Unidentified, D. Kindersley, 7.43 / Weedesign, 7.43 / by sonmez, 7.44 / FokinOl, 7.46, 7.61 (1) / A_Pobedimskiy, 7.46 / Krezofen, 7.47 / KatarzynaBialasiewicz, 7.47 / W. West, 7.48 / De Agnotsi, 7.50, 7.61 (10) / Coldmoon _photo, 7.52 / AlasdairJames, 7.52 / jxfzsy, 7.52 / VvoeVale, 7.53 / W. Andrew, 7.54 / UIG, 7.56 / D. G. Houser, 7.57 / okanmetin, 7.57, 7.61 (2) / Moha El-Jaw, 7.57 / g-miner, 7.58 / studiocasper, 7.60 / Tyscon1, 7.60 / VvoeVale, 7.61 (6) / jxfzsy, 7.61 (7) / D. Sambaus / Science PL, 7.61 (11) / Harry Taylor, 7.61 (12) / Arterra, 7.64 / Scientifica, 7.65 / VvoeVale, 7.66 / Givaga, 7.67 / A. Wojcik, 7.68 / mabus13, 7.70 / Monty Rakusen, 7.71, 7.73 / nattanan726, 7.72 / A. Cooper, 7.74 / ClaraNila, 7.78 / sdominick, 7.77 / pixelfit, 7.79 / Holger Leue, 7.80 / S. Standbridge, 7.8 / Tobias Titz, 7.83 / Ted Mead, 7.84 / A. Copson, 7.85 / J. Guerrero, 7.86 / M. Campanella, 7.87 / O. Campbell, Chapter 8 Opener / P. Campbell, 8.2 / S. Bieliński, 8.2 / Icon Sportswire, 8.1 / M. Ahmed, 8.4 / G. Fatia, 8.4 / Pool, 8.5 / Wladimir Bulgar / SPL, 8.6 / Kristian Dowling, 8.8 / Yarra Riviera, 8.10 / J. W. Banagan, 8.10 / M. Dodge, 8.15 / R. Cianfione, 8.14 / Time Life Pictures, 8.16 / M. Gottschalk, 8.16 / A. Scott, 8.17 / N. Killeen, 8.18 / P. Rovere, 8.20 / Gerenme, 8.22 / Auscape, 8.23 / Yonghao Wu, 8.24 / Kolostock, 8.25 / A. Breakey, 8.29 / H. Kingsnorth, 8.31 / M. Harrington, 8.23 / nikkytok, 8.376 / CreativImages, 8.38 / sanjeri, 8.41 / R. Cianfione, 8.43 / Jetlinerimages, 8.45 / VW Pics, 8.48 / The Age, 8.50 / IndiaPictures, 8.52 / S. Barbour, 8.53 / Godong, 8.54 / Carl Court, 8.55 / G. Diaz Melendrez, 8.56 / VvoeVale, 8.57 / Eco Images, 8.58 / Chase Dekker Wild-Life Images, 8.61 / Sean Gallup, 8.62 / W. West, 8.63 / gumboot, 8.64 / R. Cianfione, 8.67 / Lisa Maree Williams, 8.69 / Education Images, 8.73 / G. Omble, 8.75 / UIA, 8.76, 9.13 / Loop Iages, 8.77 / J. Lamb, 8.78 / Monty Rakusen, 8.79 / Mimadeo, 8.80 / rpeters86, 8.31 / Artsiom, 8.82 / David Giral Photography, 8.32 / Mads Perch, Chapter 9 Opener / elenabs, 9.2 / MaboHH, 9.3 / sergeyryzhov, 9.3 / P. Chesley, 9.5 / VW Pics, 9.6 / M. Dodge, 9.7 / Construction Photography / Avalon, 9.9 / K. Nogi, 9.10 / Ute Grabwosky, 9.11, 9.17 / Anadolu Agency, 9.12 / Hulton, 9.14 / Brooks Kraft, 9.15 / helovi, 9.16 / D. Kindersley, 9.19 / G. Mieth, 9.21 / wander luster, 9.23 / L. Morgan, 9.22 / K. Anna, 9.24 / SOPA Images, 9.27 / Photo 12, 9.28 / Sam Yeh, 9.30 / media photos, 9.32 / Travelpix Ltd, 9.34 / MyLoupe, 9.37 / B. Machet, 9.44 / MirageC, 9.48 / R. B. Rovillos, 9.49 / J. Frazier, 9.51 / Charles Gupton, 9.52 / Nigel Killeen, 9.60 / US Dept. of Defence, Science PL, 9.61 / Auscape 9.62 / H. Habbick Visions, Science PL, 9.63 / R. Alexander, 9.66 / S. J. Cohen, 9.67 / S. Dudelson, 9.67 / Rhythm Magazine, 9.69 / Jupiterimages, 9.70 / MediaProduction, 9.71 / Jennifer_Sharp, 9.73 / A. Khatri's Photography, 9.74 / Jena Ardell, 9.77 / MCT, 9.79 / J. Bavosi / Science PL, 9.80 / mikroman6, 9.81 / J. Holmes – King, Science PL, 9.81 / M. Rakusen, 9.82 / F. Cirou, 9.83 / O. Wirtinger / Corbis / VCG, 9.84 / Kiroyuki Ito, 9.87; © Alamy, PA images, 2.25 / Annelies Leeuw, 3.69 / Nature PL, 4.7 / Minden Pictures, 4.12 / National Geographic Image Collection, 4.13; © Jarek Tuszyński / CC 3.0 Unported license, 4.27; Courtesy: TNAU, 4.35; Dr. Fred Hossler, Visuals Unlimited / Science PL, 3.28; © David Zarouk, Ben-Gurion University, 3.65; © Ruth Gosling, 7.13; © Minerals Council of Australia, 7.76; Mini Brains: EMBO Journal. 2016 .Gabriel E, Wason A, Ramani A, Gooi LM, Keller P, Pozniakovsky A, Poser I, Noack F, Telugu NS, Calegari F, Šarić T, Hescheler J, Hyman AA, Gottardo M, Callaini G, Alkuraya FS, Gopalakrishnan J. EMBO J. 2016. Reproduced with permission from EMBO & Uni Prof. Jay Gopalakrishnan PhD Laboratory for Centrosome and Cytoskeleton Biology Institute of Human Genetics, Universitätsstr 1, Universitätsklinikum Heinrich-Heine-Universität Düsseldorf, 3.88 (C,R); CC 4.0 International license, 7.45; © Mark Stone / University of Washington, 9.8; © Binghamton University Distinguished Professor Ron Cohen, 9.72.

Every effort has been made to trace and acknowledge copyright. The publisher apologises for any accidental infringement and welcomes information that would redress this situation.

VCAA - The Victoria Curriculum F-10 content elements are © VCAA, reproduced by permission. Victoria Curriculum F-10 elements are accurate at the time of publication. The VCAA does not endorse or make any warranties regarding this resource. The Victorian Curriculum F-10 and related content can be accessed directly at the VCAA website.

Please be aware that this publication may contain images of Aboriginal and Torres Strait Islander peoples now deceased. Several variations of Aboriginal and Torres Strait Islander terms and spellings may also appear; no disrespect is intended. Please note that the terms 'Indigenous Australians' and 'Aboriginal and Torres Strait Islander peoples' may be used interchangeably in this publication.

Chapter 1 **Being scientific**

Chapter introduction

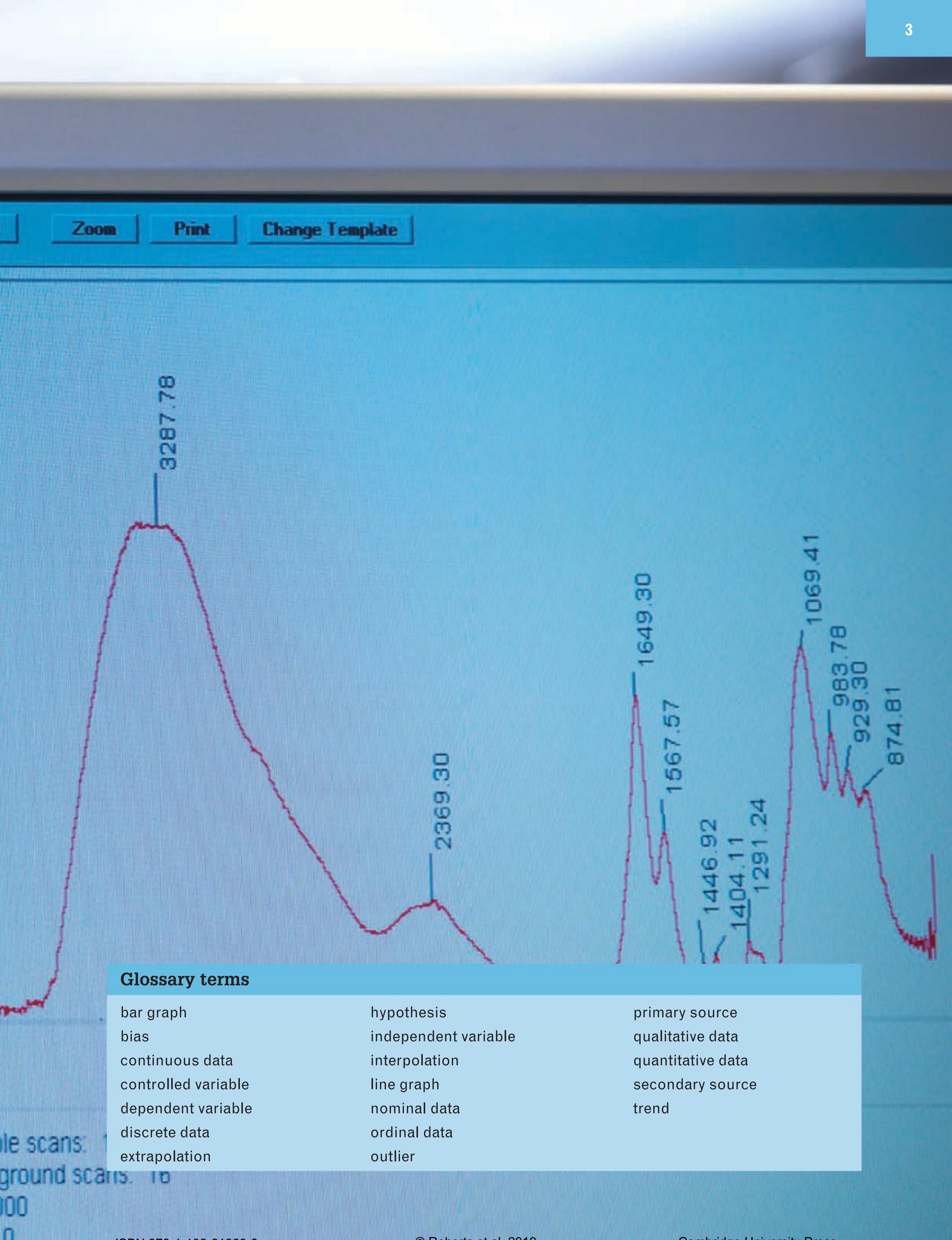
By now, you know a bit about science as a discipline and the many different fields that scientists work within. In this chapter, you will be introduced to the scientific method, which is a type of framework for how science is practised. You will focus on carrying out research and analysing sources of data, learn how to record and process your own experimental data, and discover how to communicate your scientific findings to the world.

Curriculum

Identify questions, problems and claims that can be investigated scientifically and make predictions based on scientific knowledge (VCSIS107)	1.1
Construct and use a range of representations including graphs, keys and models to record and summarise data from students' own investigations and secondary sources, and to represent and analyse patterns and relationships (VCSIS110)	1.2
Use scientific knowledge and findings from investigations to identify relationships, evaluate claims and draw conclusions (VCSIS111)	1.2
Reflect on the method used to investigate a question or solve a problem, including evaluating the quality of the data collected, and identify improvements to the method (VCSIS112)	1.1
Communicate ideas, findings and solutions to problems including identifying impacts and limitations of conclusions and using appropriate scientific language and representations (VCSIS113)	1.3

Victorian Curriculum F–10 © VCAA (2016)

ISBN 978-1-108-61069-8



Glossary terms

bar graph	hypothesis	primary source
bias	independent variable	qualitative data
continuous data	interpolation	quantitative data
controlled variable	line graph	secondary source
dependent variable	nominal data	trend
discrete data	ordinal data	
extrapolation	outlier	

ISBN 978-1-108-61069-8

Cambridge University Press

1.1 The scientific method: questioning, predicting and conducting

WORKSHEET

The scientific method: review

Last year you looked at what science is, lab safety, how scientists gather data and how to use certain pieces of equipment. You were also briefly introduced to the scientific method.

Remember that the scientific method is a framework for how to plan, conduct and report on scientific research. The steps in the scientific method are shown here.

The scientific method

STEP 1: OBSERVE AND ASK QUESTIONS
Define a good research question that can be tested.

↓

STEP 2: DO BACKGROUND RESEARCH
Conduct some background research on the question. You will also assess the quality and reliability of your sources of information.

↓

STEP 3: CONSTRUCT A HYPOTHESIS
Construct a hypothesis, which is a testable prediction about the outcome of the experiment. It is an educated guess that is formulated from your research.

↓

STEP 4: TEST BY CONDUCTING AN EXPERIMENT
Test your hypothesis by conducting an experiment. You will need to write a method that is fair and reproducible. It should include both the materials/apparatus used and the procedure in steps.

↓

STEP 5: RECORD AND PROCESS THE DATA
During the experiment, you will collect important data. It might be numerical data or categorical data. You will display this data in a meaningful way, using graphs, tables or diagrams.

↓

STEP 6: ANALYSE THE DATA
Examine the tables and graphs of data. Analysing data can reveal relationships, trends and patterns.

↓

STEP 7: EVALUATE THE DATA AND DRAW CONCLUSIONS
You will draw valid conclusions that relate to the aim and the hypothesis of your experiment. You should refer to the data as evidence to support your conclusions.

↓

STEP 8: COMMUNICATE YOUR FINDINGS
Scientists share their findings with the broader scientific community by writing a scientific report or presenting a scientific poster. Sometimes the conclusions raise more questions, and can lead to further research.

Figure 1.1 The scientific method

ISBN 978-1-108-61069-8 Cambridge University Press

Asking questions

Asking questions is the first step in the scientific process, as there needs to be a question asked before we can try to find an answer. You probably just google most questions you have, but the answers you find online are often the result of a lot of scientific research. A question to research can be about anything, such as: 'Why do people prefer red lollies over green lollies?' or 'Does listening to music help students focus in class?'. Both these questions can lead to a possible experiment.

Brainstorming can be a great way to draw out all possible questions that might be tested.

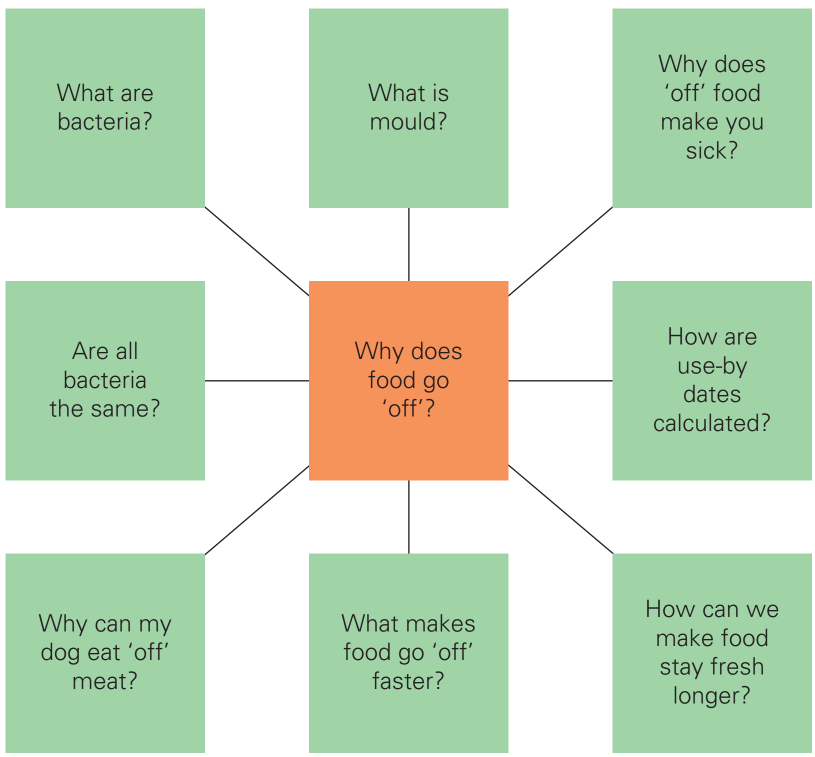


Figure 1.2 Brainstorming can help you develop questions.

Explore! 1.1

Think of a question you would love to know the answer to. The question could be anything at all.

Use the following question starters to help you:

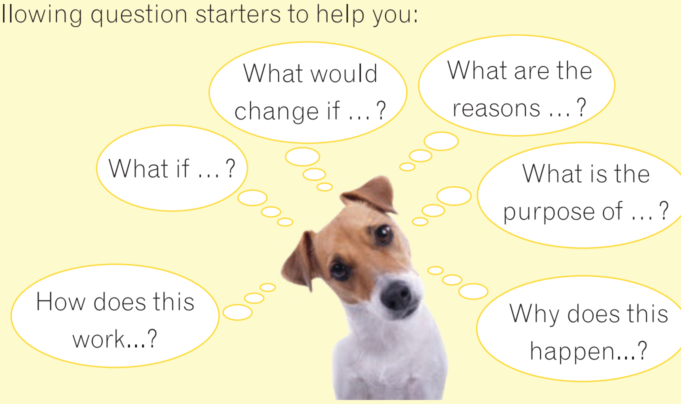


Figure 1.3 Begin by thinking of a question.

ISBN 978-1-108-61069-8

Cambridge University Press

Background research

Now that you have a question to answer, do some research to find out what people already know about the question. For example, say you are investigating the red lolly question. In nature, red generally indicates that a fruit is ripe, and green indicates that it is not ripe. It is more beneficial for animals to eat ripe fruit, and therefore they are attracted to red fruit rather than green fruit. This is one possible explanation for why we are attracted to red foods.

When you are given a task to research, it can seem overwhelming. However, if you follow the steps below, it can make the whole process much easier.

1 Identify key words
↓
2 Develop questions to answer
↓
3 Search for sources of information

1 Identify key words

A simple technique you can use to break down a research question is reading with a pen. See *Try this 1.1* for ways to do this.

2 Develop questions to answer

Questions you could investigate from the inquiry question shown in *Try this 1.1* below are:

1 What is palm oil?
2 What is palm oil used for?
3 Who farms palm oil?
4 Where is Indonesia?
5 Why is palm oil farmed in Indonesia?
6 What is the age range of the 'young people' we are focusing on?
7 How can farming in another country affect Australia?
8 What are the effects of palm oil farming?
9 How do these effects relate to me?

3 Search for sources

Often when we have a question, other people have asked the same question and have conducted some form of research to find answers.

A **primary source** of information is one that comes from your own findings and experiments. A **secondary source** is when you search for other people's research and use their findings.

primary source
a source of information that comes from your own findings or experiments

secondary source
a source of information that comes from someone else's research or findings

There are many types of resources that you can use to gather secondary data.

Try this 1.1

Reading with a pen

While reading about your research question, keep a pen handy.
Underline key words or phrases.
Circle words or phrases you don't understand.
? Put this next to something that raises a question.
! Put this next to something that surprises you.
Write important thoughts in the margin or around the question.

For example:
How does (palm oil) farming in Indonesia affect young people? living in Australia?

ISBN 978-1-108-61069-8 Cambridge University Press

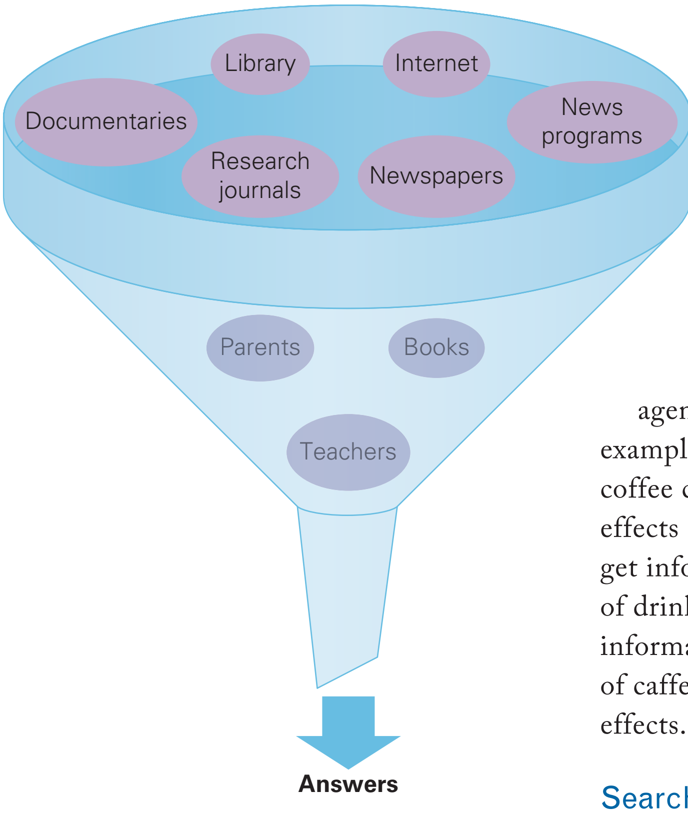


Figure 1.4 Resources for gathering secondary data

Using the internet

The internet is an amazing tool filled with lots of information. The problem is, there is so much information that sometimes it can be hard to find exactly what you are looking for. It can also be hard to decide whether the information you are reading is actually correct and free of **bias**. Information is biased if the writer has let their personal opinion or their own agenda influence their judgement. For example, if you search the website of a coffee company for information about the effects of caffeine, you are more likely to get information that is biased in favour of drinking coffee – there might be less information about the negative effects of caffeine and more about the positive effects.

bias
when a source of information is influenced by personal opinion or judgement

Searching

When searching for information, there are techniques you can use to help refine your search. For example, if you were researching the question, 'What are the effects of palm oil farming?', you might use the techniques listed in Table 1.1.

Search technique	How?	Example
Group words together	Use quotation marks to group search words together	'palm oil farming'
Search for titles or headings	Type: intitle: 'search word'	intitle: 'farming palm oil'
Search for a file type (see Table 1.2 on the following page)	Type: filetype: *abbreviation for file type* 'search word'	filetype: pdf 'palm oil'
Try different spellings	Sometimes words are spelled differently on US websites, so try spelling search words the American way	*colour* (on Australian and UK websites) is spelled *color* on US websites
Try a variety of sources	Google is not designed to bring the most scientific pages to the front of your search, so try other search engines and databases	Google Scholar Library search engines Worldbook Databases your school subscribes to

Table 1.1 Search techniques

ISBN 978-1-108-61069-8 Cambridge University Press

Use	File type
Presentations	ppt, pages, key, pez
Images	jpeg, psd, png, tiff
Documents	pdf, doc, pub

Table 1.2 Common file types and their uses

Secondary sources

When you find some information, you can use the *CRAAP test* to check whether you should use that information. The CRAAP test takes into account the currency, relevance, authority, accuracy and purpose of the information.

When you use the CRAAP test, you give each of these factors a score out of 10 (where 1 = unreliable and 10 = excellent). Table 1.3 explains how to apply the CRAAP test.

	Description	Score
C	**Currency:** How old the information is • When was the information published or posted? • When was the last time the information was updated? • Is any of the information out of date or does it use old terms? • Do the links work?	/10
R	**Relevance:** How well the information matches what you are researching • Does the information answer your question or link to the topic? • Who is the information aimed at? • Is the information worded at an appropriate level for you to understand? • Have you looked at other sources and compared them with this one?	/10
A	**Authority:** The writer of the information • Who is the author/publisher/source/sponsor? • Have the authors stated why they are experts? (Dr/Professor/experience) • What are the author's qualifications in the topic? • Is contact information provided, such as a publisher or email address? • Does the URL reveal anything about the author or the source? • Is the information linked to a biased organisation?	/10
A	**Accuracy:** How correct or truthful the content is • Where does the information come from? • Is the information supported by evidence? • Has the information been reviewed or refereed by an expert? • Can you verify any of the information by checking another source? • Is the writing free of emotion? • Are there spelling, grammar or other errors in the writing?	/10
P	**Purpose:** The reason the information exists • What is the purpose of the information? • Do the authors/sponsors make their intentions or purpose clear? • Is the information fact, opinion or propaganda? • Is the information biased? • Does the writer's point of view appear objective and neutral?	/10
	Total /50 If the source scores: • below 30, you should not use it • 30–34, it is OK • 35–39, it is average • 40–44, it is good • 45–50, it is great	/50

Table 1.3 The CRAAP test

ISBN 978-1-108-61069-8

Try this 1.2

Using the CRAAP test

The aim of this activity is to research an inquiry question and use the CRAAP test to assess the usefulness of the resources you find. Use library resources to complete this activity. You are to handwrite your answers and submit this document for marking. You will be given two lessons in the library to complete this task. Do not use Google to answer the questions.

1 Define the term 'adaptation'.
2 Outline one reason why it is important for animals to have adaptations.
3 Copy and complete the table below.

Australian animal characteristics	Animal 1	Animal 2
Common name		
Scientific name		
Where found in Australia		
Description of habitat		
Description of adaptation		
Type of adaption (behavioural, physiological, structural)		
Outline of how the adaptation allows the animal to survive in its habitat		

4 Compile a sources list.
   a List the search terms you used for searches (at least three terms).
   b Name and score three of your sources.
   c Identify the best source of information you have accessed.
   d Compare the best source to the worst source.

Writing an aim

Now that you have both a question and some research information, you can formulate an aim for your experiment. An *aim* is a mission statement that tells the reader of the scientific report what your experiment will be focusing on. This should be a short statement, no more than two sentences long. For example, in the lolly experiment, the aim could be written like this: 'The aim of this experiment is to find out whether people are attracted more to red foods than to other colours'.

Variables

Next you will need to choose one factor you are going to change, and one factor you are going to measure. These are known as your *experimental variables*. The factor you change is the **independent variable** and the one you measure is the **dependent variable**. Everything else must stay the same, in order to ensure that your experiment tests what it sets out to test. All the variables you keep the same are known as **controlled variables**.

dependent variable the variable in an experiment that you measure

independent variable the variable in an experiment that you manipulate, change or test

controlled variable a variable in an experiment that must be kept constant, so it does not affect the dependent variable

ISBN 978-1-108-61069-8

Cambridge University Press

If you fail to control these variables, they might affect the dependent variable, which would make it not a fair test and might cause you to draw false conclusions.

In the lolly experiment, the variables are as follows:

Independent variable: colour of lolly
Dependent variable: number of lollies eaten
Controlled variables: time taken to eat lollies, type of lolly, starting number of all lollies.

Writing a hypothesis

hypothesis
a prediction, or educated guess, about the effect that the independent variable will have on the dependent variable; a prediction of the outcome of an experiment

You can use the variables in an experiment to make a prediction – this prediction is called the **hypothesis**. The hypothesis is a short statement about the expected effect of the *independent variable* on the *dependent variable*, and it should relate back to the aim of the experiment. You do not need to give a reason for your prediction. Two good ways to set out a hypothesis are shown in Figures 1.5 and 1.6.

Points to remember when writing a hypothesis:

- A hypothesis is a prediction about the outcome of the experiment.
- It must be written as a statement that can be tested.
- Predict how the independent variable will affect the dependant variable.
- Do not use 'I think …'.

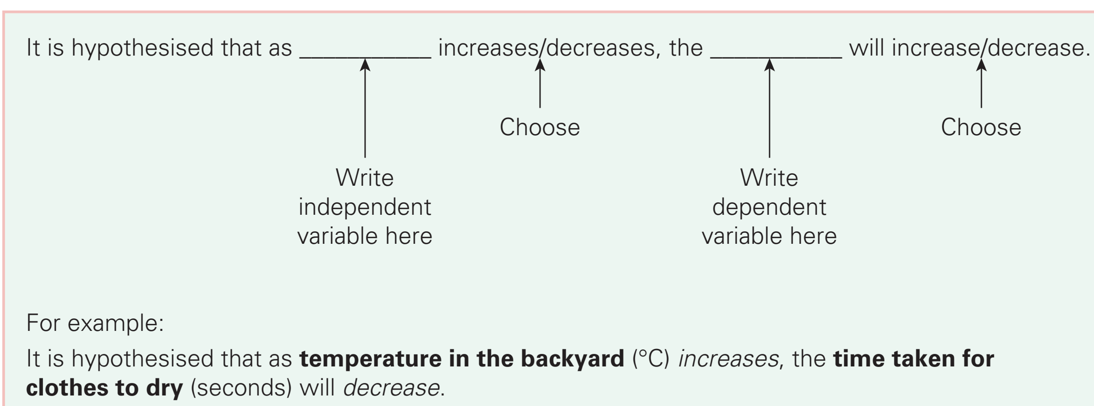


Figure 1.5 Setting out a hypothesis: example 1

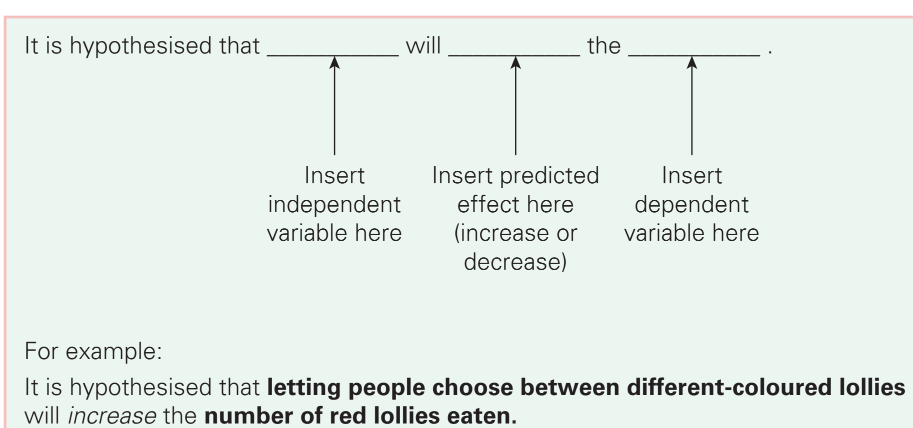


Figure 1.6 Setting out a hypothesis: example 2

ISBN 978-1-108-61069-8 Cambridge University Press

Quick check 1.1

1 Arrange these steps in the order in which they should be done.
- Conduct experiment
- Record and process the results (data)
- Ask a question
- Do background research
- Construct a hypothesis
- Analyse the data
- Communicate your findings
- Evaluate the data and draw conclusions

2 Describe the role of an experimental aim.
3 Define these terms:
a Independent variable b Dependent variable c Controlled variables
4 What must a hypothesis contain?

Practical 1.1: Self design

Bouncing ball activity

Background information

In this experiment you will be measuring the bounce height (in centimetres) of different balls. You may use all the balls in the Materials list, or just a couple. The bounce height is the dependent variable. You will need to identify the other experimental variables.

Aim

To design an experiment using bouncy balls

Materials

- 1 metre ruler
- bouncy ball
- ping pong ball
- tennis ball

Method

1 Decide what you would like to test, and enter this in the table below as the independent variable. Also brainstorm three other variables you will need to keep constant, and enter these as your controlled variables.

Independent variable	
Dependent variable	Ball bounce height (cm)
Controlled variables	

2 Construct a hypothesis for your experiment. Predict how the independent variable will affect the dependent variable.
3 Write detailed step-by-step instructions that explain how to conduct the experiment you have chosen. Remember to include repeat trials for your independent variable, to make the data you collect more reliable.

Results

Record your results in a table. Use the table below as a guide.

Independent variable	**Bounce height (cm)**			
	Trial 1	**Trial 2**	**Trial 3**	**Average**

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Evaluation

1 Explain why you chose the independent variable you focused on.
2 Suggest one more variable you could have controlled.
3 Explain why adding more trials and averaging the results would increase the reliability of the results you collected.

Conclusion

1 Make a claim regarding the effect that your independent variable had on the height of the ball bounce. Begin your sentence with: 'This experiment suggests that … '.
2 Support your claim by using the data you gathered and include potential sources of error. Begin your brief summary with: 'The results show that …' . Include: 'Possible sources of error were …'. Also mention whether or not your hypothesis was supported.
3 Explain how the data supports your claim. Begin your sentence with: 'This means that …'.

Writing a method

A method is a detailed description of the process involved in an experiment. It is a set of step-by-step instructions that will enable anybody to repeat the experiment exactly as you conducted it.

It is important to be as precise as possible, as this will allow you to identify any flaws in your process when you look at your results.

When you are writing a scientific method, think about how you would write the method for making a cake: the baker needs to know exactly how much flour, sugar and butter to add, in which order to add them, how long to cook the cake for and at what temperature, otherwise the cake could be a disaster.

Figure 1.7 Always follow the method exactly!

Points to remember when writing a method:

1 Write the steps in order.
2 Include safety instruction/s.
3 Start each step with a verb.
4 Include specific names of equipment used and quantities measured.
5 Outline what results will be measured and how this will be done.
6 Identify how the results will be presented.
7 Include the number of repeats that will be carried out. (Will averages be taken?)
8 Write in third person (no mention of you/I/we).

When you are writing your method, it is important to decide how many trials you will undertake. A reliable and fair experiment should have at least three trials, so that these can be averaged to minimise the uncertainties of measurements in the results.

ISBN 978-1-108-61069-8

You should also consider how many different levels or situations of the independent variable you want to test. For example, timing how long a substance takes to melt in the fridge, at room temperature, in direct sunlight and in a flame uses four different levels of 'temperature', which is the independent variable. This experiment is therefore said to have four experimental conditions.

Practical 1.2

Writing a method to test the strength of shapes

Background

In this experiment, you will be measuring the strength under compression of different shapes of paper. You may choose any shapes you wish, but they all have to be the same height and made of the same materials (one sheet of A3 paper).

Aim

To measure the strength under compression of different shapes of paper

Materials

- 3 A3 sheets of paper
- 1 piece of cardboard
- several 50 g masses
- sticky tape
- scissors

Method

1 Define your variables for this experiment and list them in a table. Use the table below as a guide.

Independent variable	List the shapes you are testing here
Dependent variable	Strength of the shape (how much weight it can support, in grams)
Controlled variables	Materials used (1 sheet of A3 paper per shape) Height of the shape Method of compression

2 Construct a hypothesis for your experiment. Predict how the independent variable will affect the dependent variable.

3 Write detailed step-by-step instructions that explain how to conduct the experiment you have chosen. Remember to include repeat trials for your independent variable, to make the data you collect more reliable. Here are some possible design ideas.

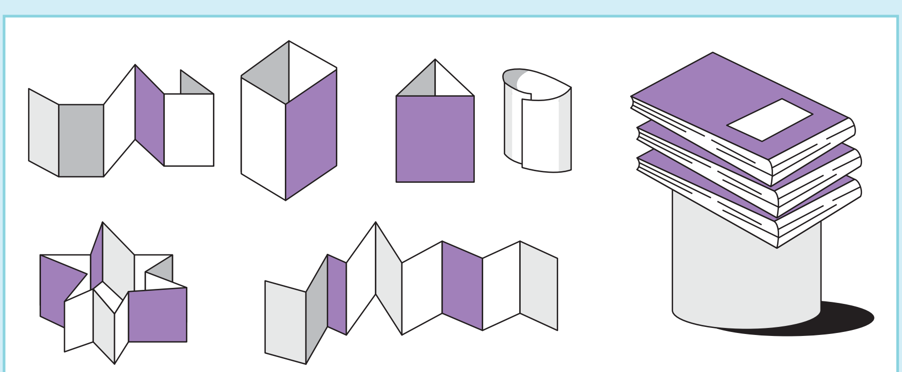


Figure 1.8 Some possible shapes to use (shown at left) and one way to test their strength (shown at right)

continued...

ISBN 978-1-108-61069-8

Cambridge University Press

...continued

Results

Record your results in a table, using the table below as a guide.

Independent variable	Dependent variable			
	Trial 1	Trial 2	Trial 3	Average

Evaluation

1. What was the strongest shape you tested?
2. Did anyone in the class have a stronger shape?
3. Suggest one more variable you controlled or should have controlled.
4. Explain why adding more trials and averaging the results would increase the reliability of the results you collected.

Conclusion

1. Make a claim regarding the strength of different shapes. Begin your sentence with: 'This experiment suggests that … '.
2. Support your claim by using the data you gathered and include potential sources of error. Begin your brief summary with: 'The results show that …' . Include: 'Possible sources of experimental faults were …'. Also mention whether or not your hypothesis was supported.
3. Explain how the data supports your claim. Begin your sentence with: 'This means that …'.

QUIZ

Section 1.1 questions

Remembering

1. Define the three types of experimental variables.
2. State the purpose of the aim.
3. List three starters you could use to develop a question.

Understanding

4. Explain why variables have to be controlled.
5. Explain the domains a CRAAP test assesses, by copying and completing the table.

Domain	What is being assessed?
Currency	
	Is the information fact or opinion? Are the author's intentions clear? Is the information free from bias?
Authority	Who is the author and are they appropriately qualified?
Accuracy	

continued...

ISBN 978-1-108-61069-8

...continued

Applying

6 Explain why a method that includes quantitative measurements should be carried out as accurately as possible.

7 A student wants to see if writing all homework in his diary every day will increase his homework scores. For one term, he records all homework in his diary daily. In the next term, he does not record any homework. He compares his homework scores for each term.
Identify the:
  a independent variable in this experiment
  b dependent variable in this experiment.

Analysing

8 Contrast a primary source of data with a secondary source of data.

Evaluating

9 Erika says her scientific research satisfies the scientific method, because she performed all the steps of the method. She carried out the following steps:
  1 She asked a question.
  2 She conducted an experiment.
  3 She recorded her data.
  4 She analysed her data and created some graphs.
  5 She did some background research to explain her data.
  6 She came up with a hypothesis.
  7 She evaluated the data and found that it supported her hypothesis (she drew a conclusion).
  8 She published a report to communicate her findings.
Assess Erika's claim. Do you agree that she has followed the scientific method? Explain your answer.

1.2 The scientific method: recording, processing and analysing results

As you have already learned, the early steps of the scientific method involve asking a question, doing background research, constructing a hypothesis, and designing and conducting the experiment to test the hypothesis.

Hopefully, the experiment will yield some interesting data. You will need to:

- collect the data during the experiment
- record the data during and after the experiment
- process the data by displaying it in tables and graphs
- analyse the data by looking for patterns.

WORKSHEET

Displaying data in tables

It is a good idea to construct a table before the experiment begins, so you can record the data as you go.

ISBN 978-1-108-61069-8 Cambridge University Press

All tables have:

- a title that describes what is in the table (not 'Results table').
- lines ruled in pencil (if on paper)
- column headings showing the unit that is measured.

Data for all trials should be included in the table, as well as averages, differences or changes (if appropriate to the experiment).

Example of how to set up a table

An example of a table of data is shown in Figure 1.9. The title of this table is: Height of bubbles produced over time when vinegar is mixed with bicarb'.

The values in a table should all be written to the same number of decimal places (or significant figures, if appropriate). In Figure 1.10, the table on the left is correct, but the table on the right is wrong, as the third value, 139, is not given to the same number of decimal places as the other data.

Once you have recorded your data in a table, it is good practice to write a short sentence summarising what the table shows, without drawing any inferences from your data.

For example, from the table in Figure 1.10, you could say:

'The results show that as time (s) increases, the volume of liquid (mL) also increases.'

Evaluating your data

Before you pack away the equipment, check your data to make sure you do not have any gaps or outliers. An **outlier** is a measurement that is very different from the data gathered in your other trials. If you see an outlier, perform that trial again, as the outlier could be the result of faulty procedure.

outlier
an extreme data value that is very different from the other data, and could be the result of faulty procedure

The dependent variable is placed in the top row, and results for each trial are shown.

The independent variable is placed in the left-hand column.

Independent variable: Amount of bicarb (g)	Dependent variable: Height of bubbles (mm)			
	Trial 1	Trial 2	Trial 3	Average
1.0	89	91	90	90
2.0	105	104	106	105
3.0	139	141	140	140
4.0	162	165	159	162

If multiple trials are recorded, then you should also include a column for the average value.

Figure 1.9 How to set up a table of data

Time (s)	Volume of liquid (mL)
1.0	89.1
2.0	105.2
3.0	139.0
4.0	162.5

Time (s)	Volume of liquid (mL)
1.0	89.1
2.0	105.2
3.0	139
4.0	162.5

Figure 1.10 Data values in a column should all have the same number of decimal places.

ISBN 978-1-108-61069-8

Cambridge University Press

Quick check 1.2

1 Identify the mistake in each of the following tables.

Table 1

Time seconds	Temperature
0	40°C
60	50°C
120	60°C
180	70°C

Table 2

Distance (km)	Time (s)
1	66.6
2	140.00
3	293.45
4	603.32

2 Construct a table to show the following data.
Max is making toffee. He is using a thermometer to measure the temperature of the sugar. He measures the temperature after 5 minutes and finds that the temperature of the sugar is 100°C. At 10 minutes it is 108°C, at 15 minutes it is 115°C and at 20 minutes it has reached 122°C.

3 Anna places a bottle of water in a freezer set at different temperatures, and measures how long it takes the water to freeze at each temperature. She records her results in the table below.
Identify the mistake in the table.

Time to freeze (hr)	Freezer temperature (°C)
6	−2
4	−4
3	−6
2	−8

Practical 1.3

Testing paper planes

Background information

In this practical, you will record data from multiple trials in an appropriate results table.

Aim

To test the distance a paper aeroplane can travel when thrown from different heights

Materials

- A4 paper
- measuring tape

Method

1 Define your variables for this experiment using the table below.

Independent variable	
Dependent variable	
Controlled variables	

2 Construct a hypothesis for your experiment. Predict how the independent variable will affect the dependent variable.

3 Follow the steps shown in Figure 1.11 to produce a paper aeroplane using A4 paper.

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

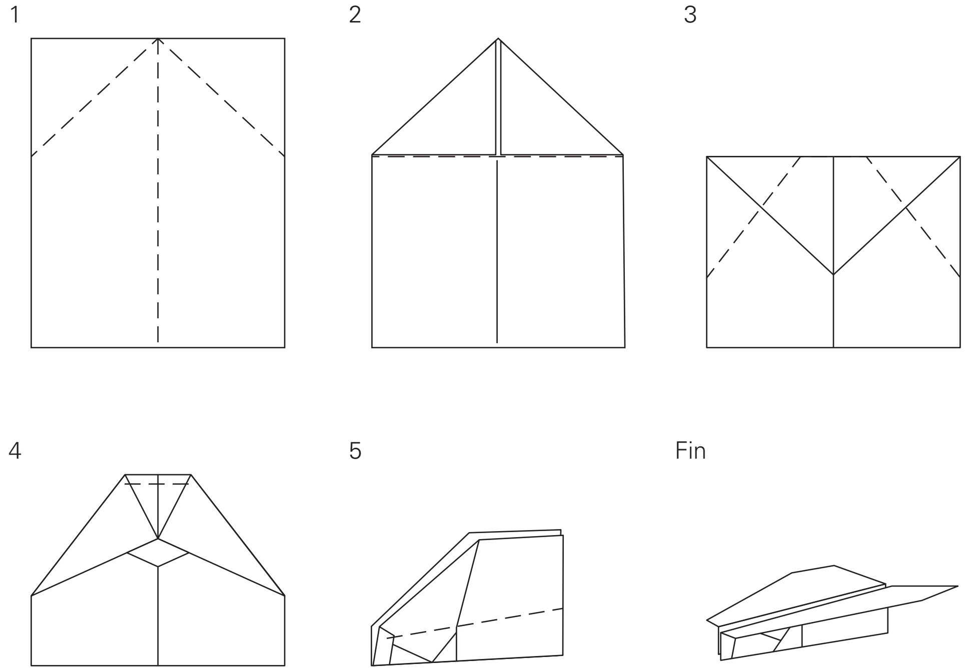


Figure 1.11 How to make the paper aeroplane

4 Choose four different heights to throw the paper aeroplane from.
5 Throw the aeroplane from the first height and measure the distance travelled until it hits the ground.
6 Copy and complete the table in the Results section, and use this to record your results.
7 Repeat throwing from this height for two more trials, recording your result each time.
8 Repeat steps **5–7** for each of the four different heights.
9 Average and record the results.

Results

Record your results in the table, and average the data from the three trials for each height.

Independent variable:	Dependent variable:			
	Trial 1	Trial 2	Trial 3	Average

Evaluation

1 Identify other variables that you should have controlled during the experiment.
2 Identify one variable that you were not able to control, that could have affected your results (one potential source of error).
3 Suggest two other independent variables that you could change, other than height thrown from.
4 Explain the reason for conducting multiple trials and averaging your results.

continued...

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Conclusion

1 Make a claim regarding the distance a paper plane will fly when flown from different heights. Begin your sentence with: 'This experiment suggests that ... '.

2 Support your claim by using the data you gathered and include potential sources of error. Begin your brief summary with: 'The results show that ...' . Include: 'Possible sources of measurement uncertainties or faults were ...'. Also mention whether or not your hypothesis was supported.

3 Explain how the data supports your claim. Begin your sentence with: 'This means that ...'.

Displaying your data in graphs

Now that you have raw data from your experiment, it is important to display the data in a way that shows any possible patterns or trends that your experiment has uncovered.

The type of graph that is appropriate depends on the type of data you have collected. **Quantitative data** (numbers) is classified as either **continuous** or **discrete**. **Qualitative data** (descriptions or worded categories) is classified as either **ordinal** or **nominal**.

quantitative data
data values that are numerical in nature

continuous data
quantitative (numerical) data points that have a value within a range; this type of data is usually measured

discrete data
quantitative (numerical) data points that have whole numbers; this type of data is usually counted

qualitative data
data values that are worded/descriptive/categorical in nature

ordinal data
qualitative (categorical) data where the categories have an order, e.g. small, medium, large

nominal data
qualitative (categorical) data where the categories have no order, e.g. male, female

Quantitative data: continuous vs discrete

Quantitative data relates to numbers. Table 1.4 lists the differences between continuous and discrete quantitative data.

	Continuous data	Discrete data
Features	Usually measured	Usually counted
	Takes any value within a range, e.g. might have decimal places	Usually takes whole-number values
Examples	*Human height* If you measured the height (in metres) of every person in the classroom, the data might look like: 1.75, 1.77, 1.8, 1.835, 1.99 ... The data can be placed in a definitive order. *Other examples:* time, weight, temperature (measured with a thermometer or temperature probe)	*Number of plants* If you counted the number of plant seedlings that grew in an experiment, the data might look like: 1, 0, 5, 8, 17 ... It is impossible to have 1.39 plants. You can only have whole numbers. The data can be placed in a definitive order. *Other examples:* number of siblings, number of crystals formed after a chemical reaction

Table 1.4 The differences between continuous and discrete quantitative data

ISBN 978-1-108-61069-8 Cambridge University Press

Line graphs

A *scatter plot* is a way of displaying how one quantitative variable changes in response to another quantitative variable, by plotting points. When the points are connected, it is called a **line graph**. Line graphs are generally used with continuous data, as they show how the data points continue on from one another.

line graph
a type of graph used to display how a continuous quantitative variable changes over time or in reference to another variable

The lines at the side and bottom of a graph are called the *axes*. When you transfer data from a table, place the independent variable on the *x*-axis (horizontal axis). The dependent variable goes on the *y*-axis (vertical axis).

Time (s)	Speed (m/s)
0	0.0
2	1.4
4	2.6
6	4.4
8	5.6
10	6.6
12	8.2
14	9.6

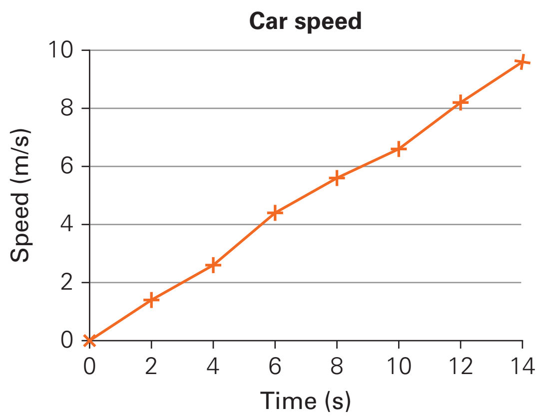


Figure 1.12 Note that in this graph, very small crosses have been used to mark the data points.

Practical 1.4

Pendulum practical

Background information

In this practical, you will gather continuous data and convert it into a line graph.

Aim

To test the effect of string length on the time it takes a pendulum to complete one swing

Materials

- retort stand
- bosshead and clamp
- 120 cm of string
- weight for pendulum
- protractor
- stopwatch
- Blu Tack
- graph paper or graphing application such as *Excel*

Method

1 Define your variables for this experiment and record them using the table below.

Independent variable	
Dependent variable	
Controlled variables	

2 Construct a hypothesis for your experiment. Predict how the independent variable will affect the dependent variable.

continued…

ISBN 978-1-108-61069-8

...continued

3 Attach the weight to the bottom of the piece of string.
4 Tie the string to the bosshead and clamp attached to the retort stand, and measure 20 cm from the join of the bosshead to the base of the weight, as shown in Figure 1.13.
5 Using the protractor, hold the string tight at 45 degrees and release the pendulum.
6 Start the stopwatch as soon as you release the pendulum and count three full swings (across and back, as shown in Figure 1.13.
7 When the pendulum returns for the third time, stop the stopwatch and divide the time by 3.
8 Record the time for one swing in the results table.

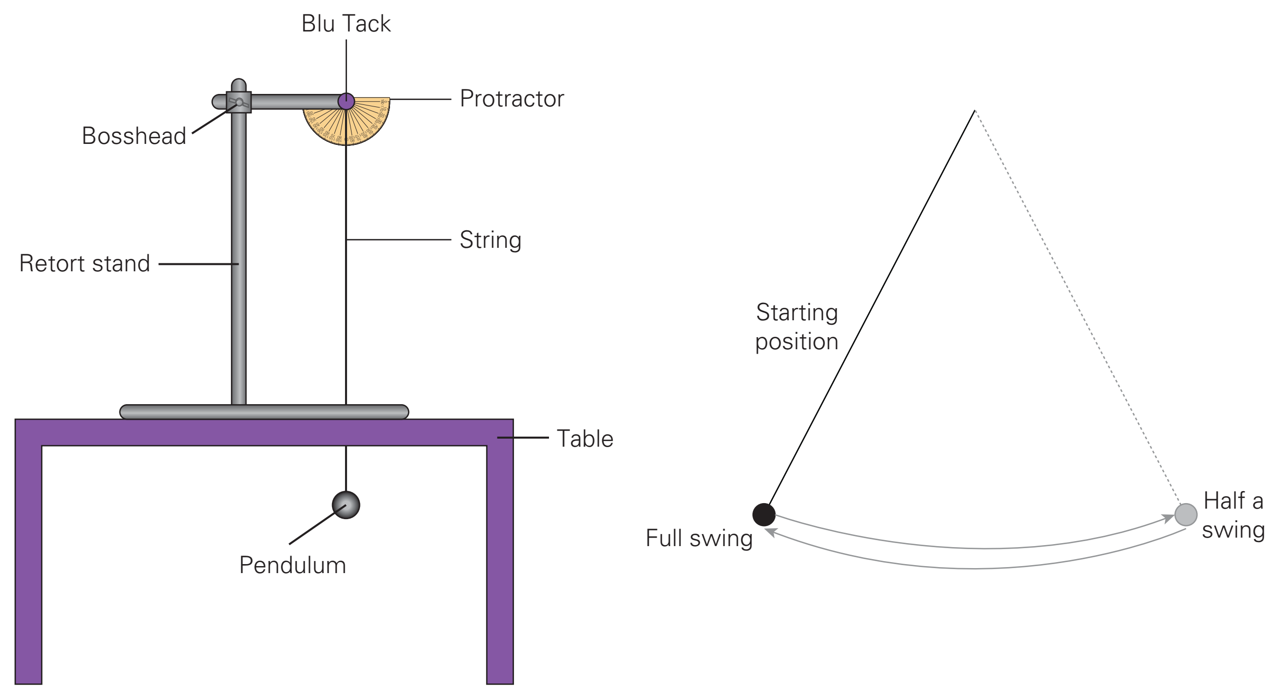


Figure 1.13 Experimental set-up. Left: setting up the pendulum. Right: timing the swing of the pendulum

Results

Copy and complete the table below, to record your results.

Length of string (cm)	Time taken for one whole swing (s)			
	Trial 1	Trial 2	Trial 3	Average
20				
40				
60				
80				
100				

Use the average from each of your trials to produce a line graph. Remember the following points:

- Plot the independent variable on the *x*-axis.
- Plot the dependent variable on the *y*-axis.
- Label each axis with the variable name and the unit of measurement.
- Write a title for the graph.
- Use an even scale (equal spaces between the numbers on the axes).

continued...

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Evaluation

1 Describe the shape of the line of best fit produced in your graph.
2 Explain whether your results supported or disproved your hypothesis.
3 Identify one way in which this experiment could have been improved.

Conclusion

1 Make a claim regarding the length of a pendulum and the time taken for a swing. Begin your sentence with: 'This experiment suggests that ... '.
2 Support your claim by using the data you gathered and include potential sources of measurement uncertainty and faults with your method. Begin your brief summary with: 'The results show that ...' . Include: 'Possible sources of error were ...'. Also mention whether or not your hypothesis was supported.
3 Explain how the data supports your claim. Begin your sentence with: 'This means that ...'.

Qualitative data: ordinal vs nominal

Qualitative data involves categories, scales or descriptions. This type of data is in the form of words (rather than numbers). The differences between ordinal and nominal data are listed in Table 1.5.

Bar graphs

bar graph
a type of graph used to display the frequency of a qualitative variable (category)

A **bar graph** (or column graph) is a way of displaying how a quantitative dependent variable (for example, heart rate) changes in response to a qualitative independent variable (for example, breed of animal). Categories are listed along the x-axis and numbers along the y-axis.

Bar graphs have spaces between the bars – the bars are not positioned next to each other.

An example is shown in Figure 1.14.

	Ordinal data	Nominal data
Features	Categories have a natural order.	Categories do not have a natural order.
Examples	A chemical reaction is performed and the amount of product produced is described as 'low', 'medium' or 'high'. Five trials are completed and the data looks like: low, high, medium, low, low. These categories make sense if they are displayed in a certain order. *Other examples:* month of the year, size of the test tube (small, medium, large), the participant's response on a scale (strongly agree, agree, neutral, disagree, strongly disagree)	A survey is completed for background research and participants are asked to choose their favourite colour from a list. The data might look like: blue, pink, pink, yellow, green, blue. The categories could be displayed in any order. *Other examples:* gender (male or female), blood type (A, B, O, AB), eye colour (blue, brown, green)

Table 1.5 The differences between ordinal and nominal qualitative data

ISBN 978-1-108-61069-8

Animal	Heart rate (beats/min)
Camel	35
Horse	41
Human	70
Rabbit	210
Mouse	670
Rat	750

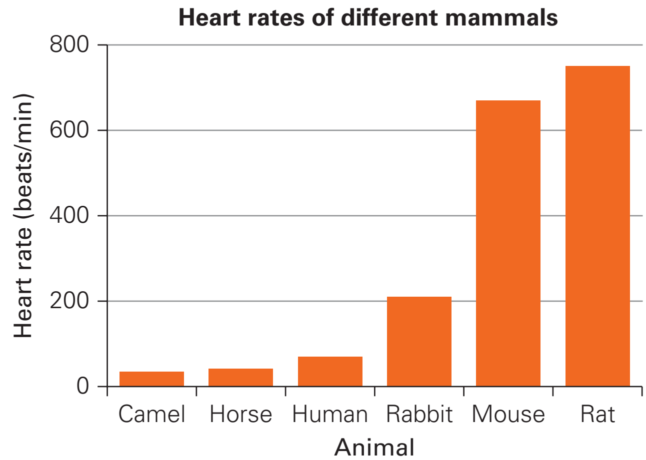


Figure 1.14 A bar graph and its data table

Guidelines for drawing graphs

- Always use a sharp, dark pencil (if drawing on paper).
- Usually the independent variable goes on the *x*-axis and the dependent variable on the *y*-axis. Sometimes you may be asked to plot variables on specific axes in a way that contradicts this rule.
- Axes should be labelled with the quantity being measured and the units. The units should be in brackets after the quantity name – for example, time (s) or volume (L).
- Use the full width of the graph paper (if drawing on paper) and choose a scale that spreads the data points out over most of the grid. If you are measuring quantities where 0 does not mean 'no quantity' (for example, temperature), then you do not have to start the axes at zero. If the range of values does not go to zero (for example, 85–115), then don't start the axes at zero. In this example, you could start the axis at 80 and continue the numbers to 120. If the quantities on both axes go to zero, then the origin (where the axes meet) should be at (0,0).
- The scale needs to increase evenly, preferably with each grid square used to represent multiples of 1, 2, 5 or 10. Do not have breaks in the scale – for example, you can't show 0 to 20 in intervals of 5 and then skip straight to 60.
- Data points can be marked with an 'x', not a dot, because dots (unless surrounded by a small circle) often disappear under a line of best fit. If you are plotting multiple sets of data on the same graph, use different-coloured points for each data set.

Practical 1.5

Insulating water

Background information

In this practical, you will gather data in order to produce a bar graph. You will test the effect of foil, paper and cotton wool as insulating materials, and measure how this affects the cooling rate of water.

Aim

To test the effect of different materials on the cooling rate of water

continued...

ISBN 978-1-108-61069-8

Cambridge University Press

...continued

Materials

- 4 x 250 mL beakers
- kettle
- 4 thermometers
- foil
- cotton wool
- paper
- stopwatch
- elastic band

Method

1 Define your variables for this experiment and record them using the table below. Also include the type of data that each variable will yield.

		Variable yields what type of data?
Independent variable		
Dependent variable		
Controlled variables		N/A

2 Construct a hypothesis for your experiment. Predict how the independent variable will affect the dependent variable.
3 Cover the sides of three beakers with either cotton wool, paper or foil, and use elastic bands to secure the covers in place. Leave one beaker without covering.
4 Place one thermometer in each of the beakers.
5 Boil the kettle and pour 100 mL of boiling water into each of the beakers. Start the stopwatch immediately.
6 Time for 5 minutes using the stopwatch, and then measure and record the temperature of the water in each beaker.
7 Gather data from two more trials, from other groups in your class. Add these to the results table and calculate the average temperature after 5 minutes for each insulating material.

Results

Copy and complete the following table to record your results.

Cover material	Temperature after 5 minutes (°C)			
	Trial 1	Trial 2	Trial 3	Average
Foil				
Paper				
Cotton wool				
No cover				

Create a bar graph for the average data in your results table. Put the independent variable (insulating material) on the *x*-axis and the dependent variable (temperature after 5 minutes) on the *y*-axis.

Evaluation

1 Explain why your results supported or disproved your hypothesis.
2 Suggest a reason for using a beaker with no cover material.
3 Suggest a reason for putting your data into a bar graph, rather than just leaving it in a table.
4 Identify potential sources of measurement uncertainties or experimental faults in this experiment.
5 Suggest one way you could improve the experimental design if you were to repeat this experiment in the future.

continued...

ISBN 978-1-108-61069-8 © Roberts et al. 2019 Cambridge University Press

...continued

Conclusion

1 Make a claim regarding the insulating properties of the materials you tested. Begin your sentence with: 'This experiment suggests that … '.
2 Support your claim by using the data you gathered and include potential sources of error. Begin your brief summary with: 'The results show that … ' . Include: 'Possible sources of error were … '. Also mention whether or not your hypothesis was supported.
3 Explain how the data supports your claim. Begin your sentence with: 'This means that … '.

Analysing data

Analysing data involves examining the tables and graphs and looking for patterns and relationships.

Describing patterns

We refer to patterns in graphs as **trends**. The graphs below show some common trends you might observe and describe.

trend a pattern in a graph that shows the general direction/shape of the relationship between the dependent and independent variables

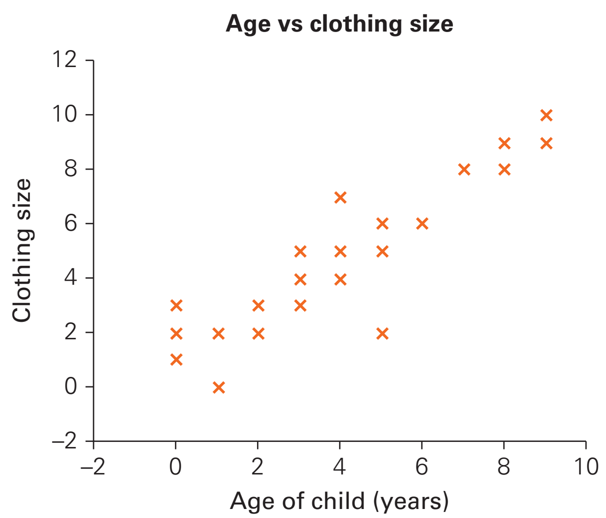


Figure 1.15 This graph shows a steady increase. You would describe this by saying, 'As the age of the child (in years) increases, the size of clothing also tends to increase'.

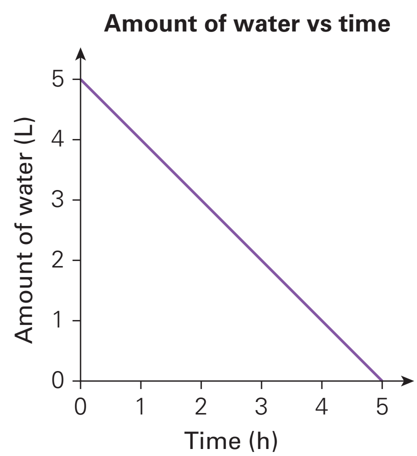


Figure 1.16 This graph shows a steady decrease. You would describe this by saying, 'As time (in hours) increases, the amount of water in the tank (in litres) tends to decrease'.

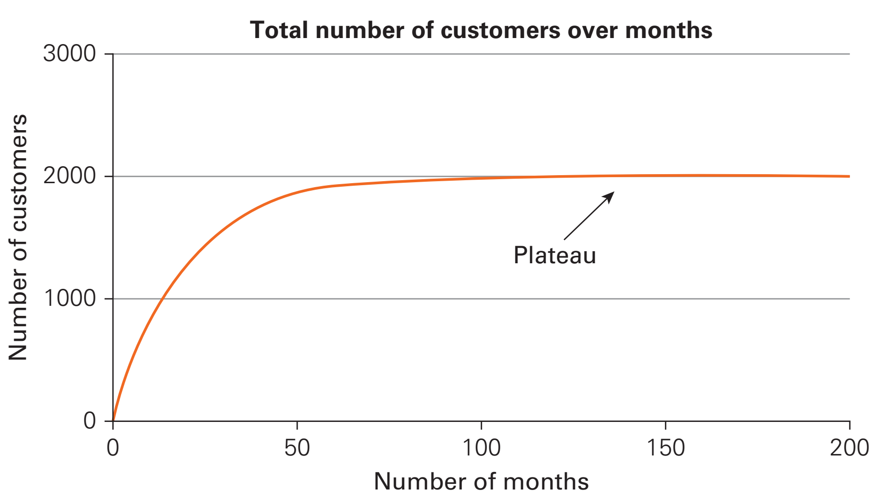


Figure 1.17 This graph shows a rapid increase that reaches a plateau (flat line) and then remains constant. You would describe this by saying, 'Initially during the first 60 months or so, as the number of months increases, the number of customers increases rapidly from 0 to 2000. Then, for the next 100 months, the number of customers remains fairly constant at around 2000'.

ISBN 978-1-108-61069-8 Cambridge University Press

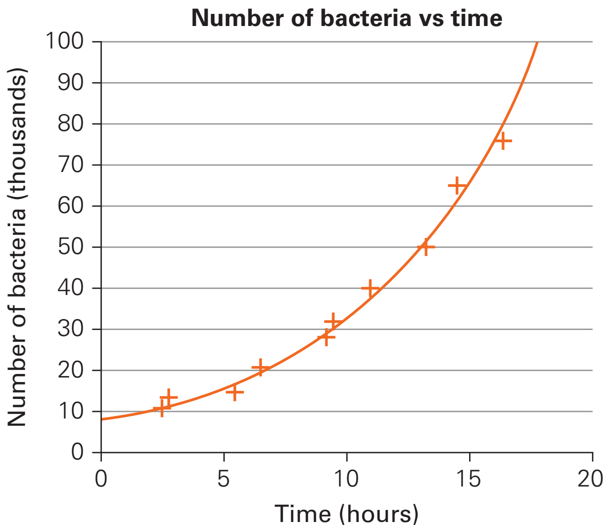


Figure 1.18 This graph shows an exponential increase. For the first 10 hours, the number of bacteria increases slowly from 10 000 to 30 000. After 10 hours, the number of bacteria increases more rapidly.

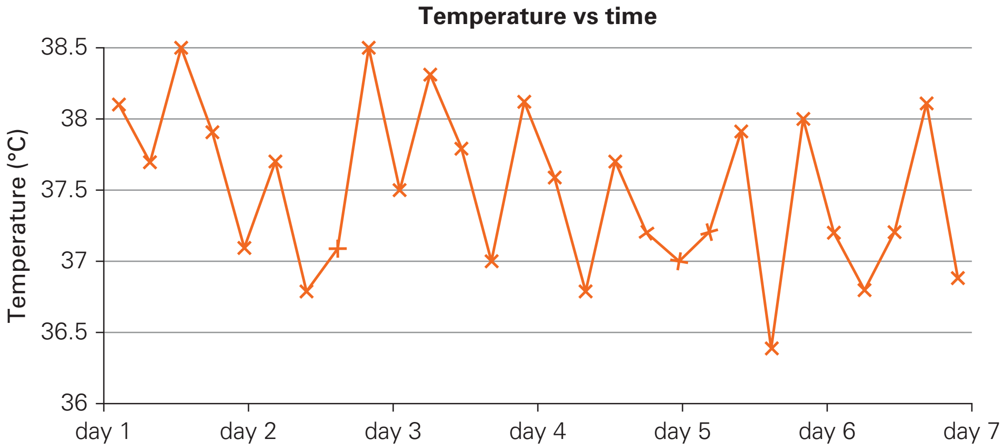


Figure 1.19 This graph doesn't show a clear pattern. There are seemingly random fluctuations over time.

Drawing a line of best fit

Once you have plotted your data, you may see a pattern (trend) in the results, such as a straight line or a curve. To highlight this pattern we can use a curve or line of best fit. Connecting every data point suggests that there are absolutely no errors in the data, whereas a line of best fit approximates the relationship between the two variables. You can also use the line of best fit to predict missing measurements. If you make predictions inside the data set you originally collected, this prediction is called **interpolation** can be reliable in some circumstances, but not always. Care should be taken. If you predict outside the original data set, this prediction is called **extrapolation** and is less reliable.

interpolation
using existing data (such as a line of best fit) within the original data set to make a reliable prediction

extrapolation
using existing data (such as a line of best fit) outside the original data set to make a prediction

When drawing a line of best fit, make sure that there are as many points on one side of the line as on the other. You do not need to join each data point with the line. The line of best fit is like an 'average' that runs smoothly through the middle of the data points and makes the trend obvious.

A line of best fit:

- should be continuous and flow in a general direction
- can be straight, curved or any other shape that fits the data points. Do not try to draw a straight line of best fit over data that is clearly curved
- should not be forced through a (0,0) origin if one is used on the graph
- should not be drawn beyond the range of the data points. It can, however, be linked back to the axes with a dotted or dashed line, as shown in Figure 1.20.

ISBN 978-1-108-61069-8 Cambridge University Press

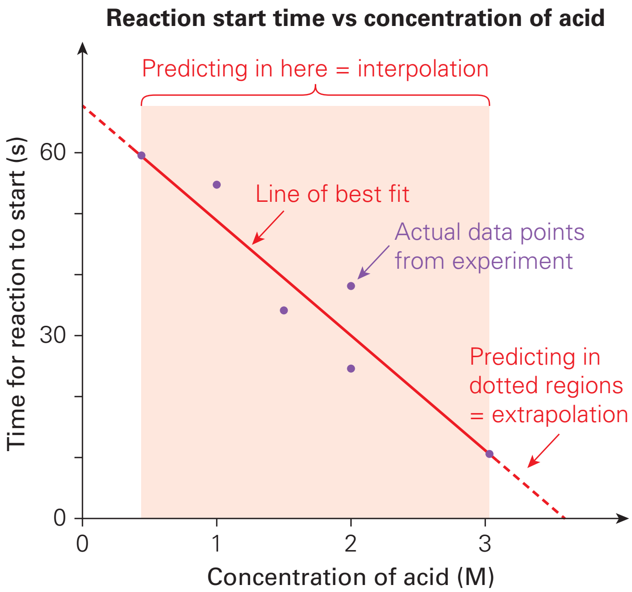


Figure 1.20 A scatter plot with a line of best fit, drawn in red. Note how the line runs through the 'middle' of the data, like an average. The dotted regions are where the line has been continued past the original data set. If you use the line in these regions (for example, to predict the reaction time for 0.1 M acid), then it is extrapolation and is less reliable.

Practical 1.6

Balloon popping

Be careful

Safety glasses are a must for this practical.

Background information

In this practical, you will gather data that can be turned into a scatter graph.

Aim

To test the effect of number of breaths on the circumference of a balloon

Materials

- balloon
- string
- permanent marker
- meter ruler
- safety glasses

Method

1. Lie the balloon flat on the workbench. Using the string, measure the circumference at the widest part of the balloon.
2. Using a permanent marker, draw a line on the balloon to indicate where you took the first measurement.
3. Use one breath to inflate the balloon. Without tying the balloon, measure the circumference along the line you have already drawn.
4. Repeat step **3**, adding more volume to the balloon by one breath at a time, recording your results until the balloon pops.
5. Use your results to draw a line graph.

Results

Record your results in a table like the one below, then use your results to draw a line graph.

Number of breaths	Balloon circumference (cm)
1	
2	
3	
4	
5	

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Evaluation

1 Outline one trend that you observed in your graph.
2 Identify the dependent and independent variables.
3 Identify two controlled variables in this experiment.
4 Suggest possible experimental uncertainties and faults in this experiment.
5 Suggest one way to improve the experimental design, if you were to conduct this experiment again in the future.

Conclusion

1 Make a claim regarding the relationship between number of breaths and balloon circumference. Begin your sentence with: 'This experiment suggests that … '.
2 Support your claim by using the data you gathered and include potential sources of error. Begin your brief summary with: 'The results show that … ' . Include: 'Possible sources of error were … '. Also mention whether or not your hypothesis was supported.
3 Explain how the data supports your claim. Begin your sentence with: 'This means that … '.

QUIZ

Section 1.2 questions

Remembering

1 State where units of measurement go, in a results table.
2 List four features of a correctly drawn results table.
3 Recall the term used when a measurement is repeated.

Understanding

4 Explain what to look for when evaluating your data.
5 Describe where the independent and dependent variables should be placed, in a table.
6 Describe where the independent and dependent variables should be placed, on a graph.

Applying

7 Compare qualitative and quantitative data.
8 Compare continuous and discrete data.

Analysing

9 Identify two things wrong with the following table.

Height dropped	Bounce height (cm)			
	Trial 1	Trial 2	Trial 3	Average
1 m	20	20	20	20
2 m	40.5	41	40	40.5
3 m	80	90	85	85

Evaluating

10 Martin had a bag of lollies of different colours. He found that, when he offered them to friends, he was always left with black lollies. He decided to conduct an experiment to test people's favourite lolly colours. He shared a bag that had 20 of each colour and recorded what was left at the end. From this he worked out how many of each colour had been eaten. The results are shown in the table.

continued...

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Lolly colour	Number of lollies eaten
Black	4
Green	13
Yellow	18
Red	20

a Suggest the type of graph that should be used to represent this data.
b Identify which column would be used as the dependent variable.
c Identify the independent variable in this experiment.

1.3 The scientific method: evaluating and communicating

After you have conducted an experiment, recorded the data in a table and interpreted the data in a graph, it is time to explain what the data is showing. This is done in the discussion and conclusion sections of a scientific report.

Evaluation/discussion

The evaluation or discussion section of your scientific report is where you outline any problems you faced during the experiment and offer suggestions for changes to the method.

Any suggested improvements should include the following information:

- a brief description of the problem encountered
- a description of how the problem affected the results
- a description of how you could improve the experimental method (e.g. use different equipment or change the order of the steps)
- an explanation of how this would improve either the accuracy (e.g. measurements with lower uncertainties lead to more accurate measurement), the reliability (e.g. more trials would improve confidence in the results) or the validity (how well the variables were controlled) of the results.

WORKSHEET

Here is an example.

Some students conducted an investigation into the effect of salt on the boiling point of water. They used a thermometer to measure the temperature at boiling point after salt had been added.

ISBN 978-1-108-61069-8 Cambridge University Press

Description of the problem

The thermometer did not allow accurate readings, because the boiling point is found when the temperature stays the same for a period of time even though more heat is added. Depending on the type of thermometer and the size of the gradations, it may be difficult to see changes on a thermometer.

How the problem affected the results

It was unclear whether the temperature was staying the same, so the students had to make a judgement about when this occurred. This judgement could vary from person to person.

How it could be improved

Using a temperature probe, a data logger or an electronic thermometer could allow more accurate measurements.

Explanation of how this would improve accuracy/reliability/validity

The data collected would be digital and more accurate, as there would be lower measurement uncertainties.

Writing a conclusion

A conclusion is a short paragraph in a scientific report, and should always include three key ideas:

- what claim can be made from the experiment regarding the independent and dependent variables
- the evidence that supports this claim
- an explanation of whether the data supports or disproves the hypothesis.

Remember, a hypothesis is never right or wrong. It is only supported or disproven, which leads to more questions that need to be answered.

Here is an example.

Stuart conducts an experiment to see if taking his dog Jimmy for more walks reduces the number of socks Jimmy destroys.

Stuart's hypothesis is: 'It is hypothesised that the more walks Jimmy has per day, the fewer socks he will destroy.'

Stuart put his results into a graph and produced a line of best fit, shown in Figure 1.21.

From the graph, Stuart developed the following conclusion:

'This experiment suggests that there is a relationship between the number of walks Jimmy has per day and the number of socks he destroys. The line of best fit of the results shows that as the number of walks per day increased, there was a decreasing trend in the number of socks chewed. This supports my hypothesis.'

ISBN 978-1-108-61069-8 Cambridge University Press

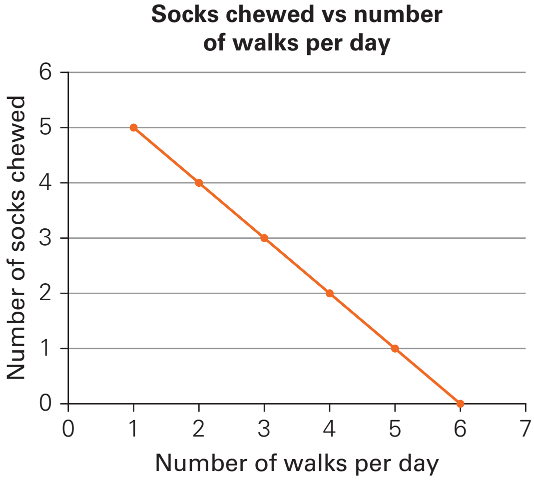


Figure 1.21 Stuart tested his hypothesis and graphed the results.

Try this 1.3

Gen conducted an experiment to see if the distance from a window would affect the growth of her potted plants.

Gen's hypothesis was: 'It is hypothesised that, as distance from the window increases, the growth of the plants will decrease.'

Gen measured her plants before the experiment, placed them at different distances from the window and measured them two months later. She then graphed her results and obtained a line of best fit.

1 Develop a conclusion based on Gen's results.
2 Suggest three controlled variables that Gen would have used, to make this a fair test.
3 Propose two possible causes for the increase in plant height for the plant that was placed 6 m from the window.

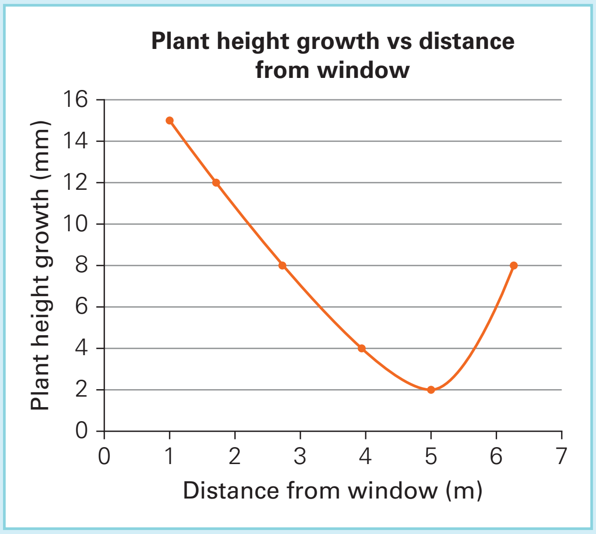


Figure 1.22 Gen's graph

ISBN 978-1-108-61069-8

Cambridge University Press

Communicating your findings

Two common ways of presenting your findings from an experiment are:

- scientific report
- scientific poster.

Both forms show all the steps of the scientific method, and should include:

- the question
- the aim
- variables (independent, dependent and controlled)
- the hypothesis
- a materials/equipment list
- diagrams of the set-up if necessary
- the method used
- a results section (with tables and graphs)
- a discussion/evaluation section
- a conclusion.

An example of a scientific report and a scientific poster are shown on the following two pages.

Scientific report

Each time you conduct an experiment in science, you should construct a scientific report. This is a quick and easy way to document what you have learned, for future revision.

Scientific poster

If you conduct a special experiment or develop a research project, it is a good idea to produce a scientific poster. This will still contain all the relevant parts of the scientific method but it is much more appealing to look at, and will expose a wider audience to your findings.

Positives	Negatives
May contain more detail	May not be very engaging to read
Includes all parts of an experiment	Can be complicated for a 'non-scientific' person to follow
Does not require additional explanation (self contained)	

Table 1.6 The positives and negatives of a scientific report

Positives	Negatives
Can be engaging to look at	May take longer to produce
May increase the number of people who will learn about your experiment	Needs a place to be displayed
Includes all the parts of an experiment	

Table 1.7 The positives and negatives of a scientific poster

ISBN 978-1-108-61069-8 Cambridge University Press

Scientific report

Title: Bouncing ball

Aim

To test the bounce height of a ball being dropped from different heights

Variables

Change: Drop height (cm)

Measure: Bounce height (cm)

Controlled:

Use the same ball

Bounce on the same surface

Same person taking the readings

Hypothesis

The ball will bounce higher (cm) when dropped from a taller height (cm).

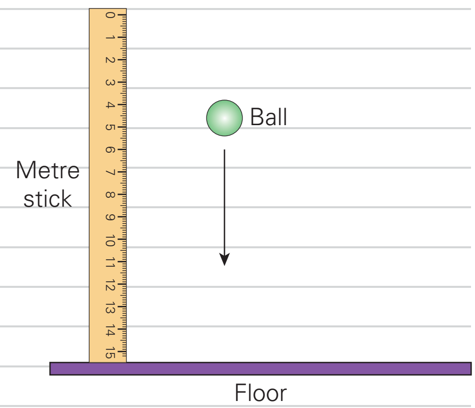
Equipment

1 tennis ball

1 metre ruler

Method:

1 Hold the ruler at a right angle to the floor.
2 Drop the ball from the first height and measure the height of the bounce.
3 Record results in the table and repeat two more times.
4 Repeat steps 2 and 3 for each drop height.
5 Average the results gathered from each trial.



Results

Drop height (cm)	Bounce height (cm)			
	Trial 1	Trial 2	Trial 3	Average
100	75	70	80	75
50	30	35	25	30
25	15	25	20	20

Discussion

The person taking the reading was standing. This meant that the measurement was not accurate. Next time, the person taking the readings should sit on the floor so their eyes are parallel with the ball and the ruler.

Conclusion

The results support the hypothesis: as the height that the ball was dropped from increased, so did the height of the bounce.

ISBN 978-1-108-61069-8

Scientific poster

Title: Bounce heights of a bouncing ball dropped at different heights

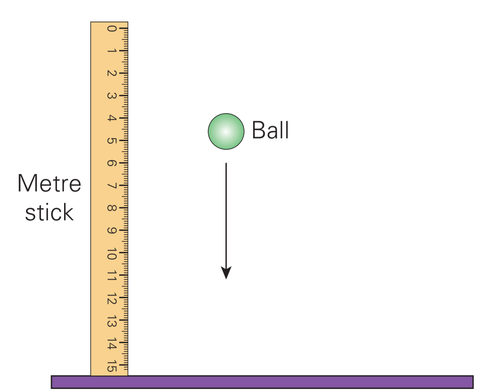
Aim
To test the bounce height of a ball being dropped from different heights

Hypothesis
The ball will bounce higher (cm) when dropped from a taller height (cm).

Variables
Change: Drop height (cm)
Measure: Bounce height (cm)
Controlled:
Use the same ball
Bounce on the same surface
Same person taking the readings

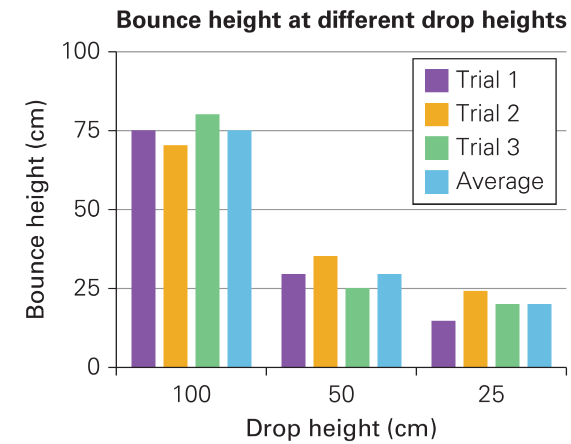
Equipment
1 tennis ball
1 metre ruler

Method:
1 Hold the ruler at a right angle to the floor.
2 Drop the ball from the first height and measure the height of the bounce.
3 Record results in the table and repeat two more times.
4 Repeat steps 2 and 3 for each drop height.
5 Average the results gathered from each trial.



Results

Drop height (cm)	Bounce height (cm)			
	Trial 1	Trial 2	Trial 3	Average
100	75	70	80	75
50	30	35	25	30
25	15	25	20	20



Discussion
The person taking the reading was standing. This meant that the measurement was not accurate. Next time the person taking the readings should sit on the floor so their eyes are parallel with the ball and the ruler.

Conclusion
The results support the hypothesis: as the height that the ball was dropped from increased, so did the height of the bounce.

ISBN 978-1-108-61069-8

Section 1.3 questions

QUIZ

Remembering

1 Name the part of a scientific report that states whether the hypothesis was supported.

2 Name the part of a scientific report where you can talk about problems you faced and changes you would make.

Understanding

3 Explain how to draw a line of best fit.

4 Explain why graphs are used.

Applying

5 Compare the use of a scientific report with that of a scientific poster.

Analysing

6 Identify the general trend shown in the graph in Figure 1.23.

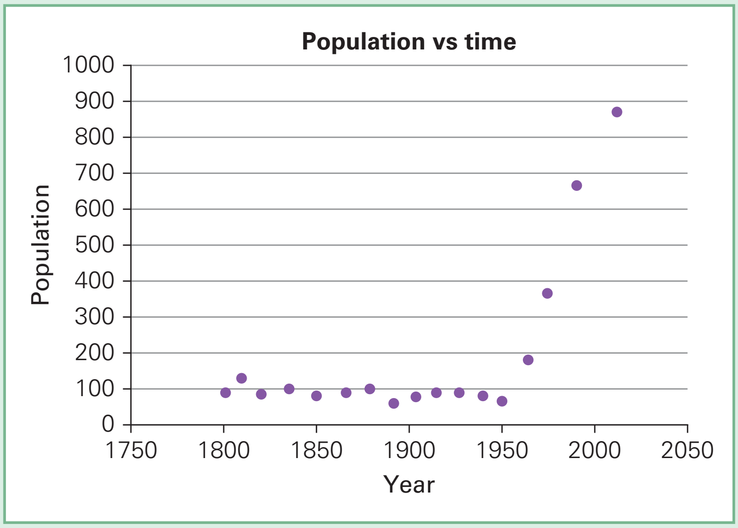


Figure 1.23

7 Identify the general trend in the graph shown in Figure 1.24.

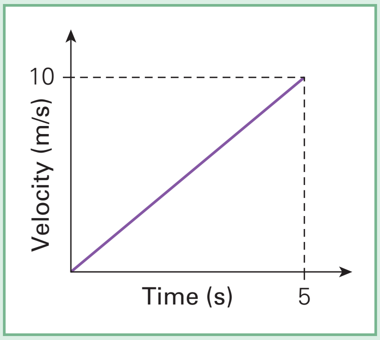


Figure 1.24

Evaluating

8 Use this table of data to answer the questions below.

Time (s)	Temperature (°C)			
	Trial 1	Trial 2	Trial 3	Average
60	80	83	82	
120	63	66	65	
180	30	32	65	

a Calculate the average for the results in the table.

b Identify the outlier in the results.

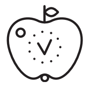
c Suggest the appropriate type of graph for this data.

d Draw a graph for the data presented above.

ISBN 978-1-108-61069-8

Cambridge University Press

Review questions



Remembering

1 When conducting background research, what is the difference between a primary source and a secondary source?
2 List what should be included in a hypothesis.
3 List what should be included in a conclusion.
4 The CRAAP test assesses the quality of a secondary source of information. State what the letters stand for.
5 Define the terms 'independent variable', 'dependent variable' and 'controlled variables'.

Understanding

6 Classify the type of data in each of the following data sets.
  a age of students: 12, 13, 13, 14, 12, 18
  b name of chemical compounds: copper chloride, lithium chloride, sodium chloride
  c heat output: high, low, high, low, moderate, high
  d time taken for a reaction to occur (seconds): 8.51, 3.29, 5.59, 1.24, 1.27
  e location of a pot plant: full sunlight, partial sunlight, shade, darkroom
7 Explain how a well-constructed bar graph should look.

Applying

8 Students were timed on how long they spent on chapter review questions, and then their exam score was recorded. The results were graphed and are shown in Figure 1.25.

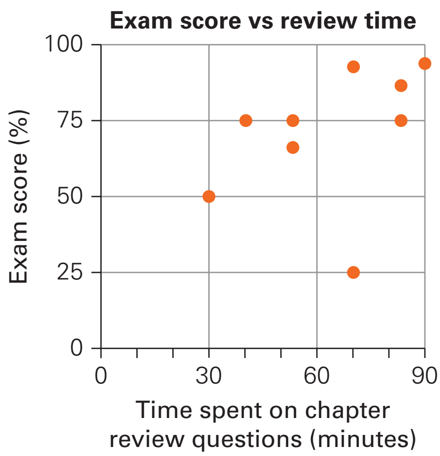


Figure 1.25

  a What is the independent variable and what is the dependent variable?
  b Analyse the data and identify which data point appears to be an outlier.
  c Describe this person's performance in terms of the independent and dependent variables.
  d Describe the pattern evident in the data.
9 Organise these steps of the scientific method into the correct order.
  Do background research
  Construct a hypothesis
  Communicate your findings
  Record and process the data into tables and graphs
  Ask a question
  Conduct an experiment
  Analyse the data and look for patterns
  Evaluate the data and form conclusions

ISBN 978-1-108-61069-8

Analysing

10 Copy and complete the table, to compare the advantages and disadvantages of presenting your scientific findings in a scientific poster versus a scientific report.

	Advantages	Disadvantages
Poster		
Report		

11 Inspect this table of experimental data, and identify two errors in how it has been constructed.

New growth in plant (cm)	Amount of water provided to plant daily
0	0 mL
1	10 mL
3	20 mL
8	50 mL
1	100 mL

Evaluating

12 Estimate values using the scatter plot of data below.

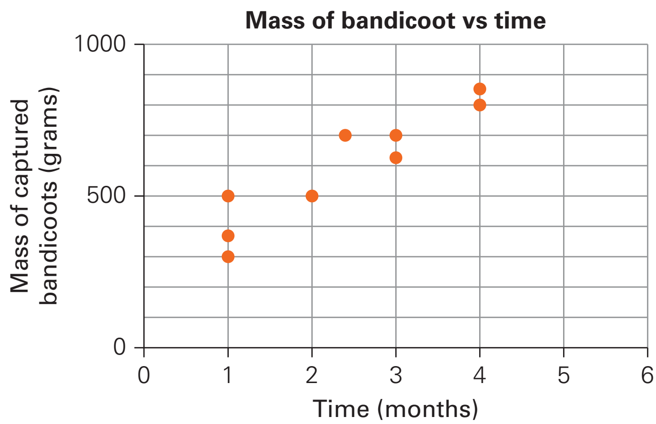
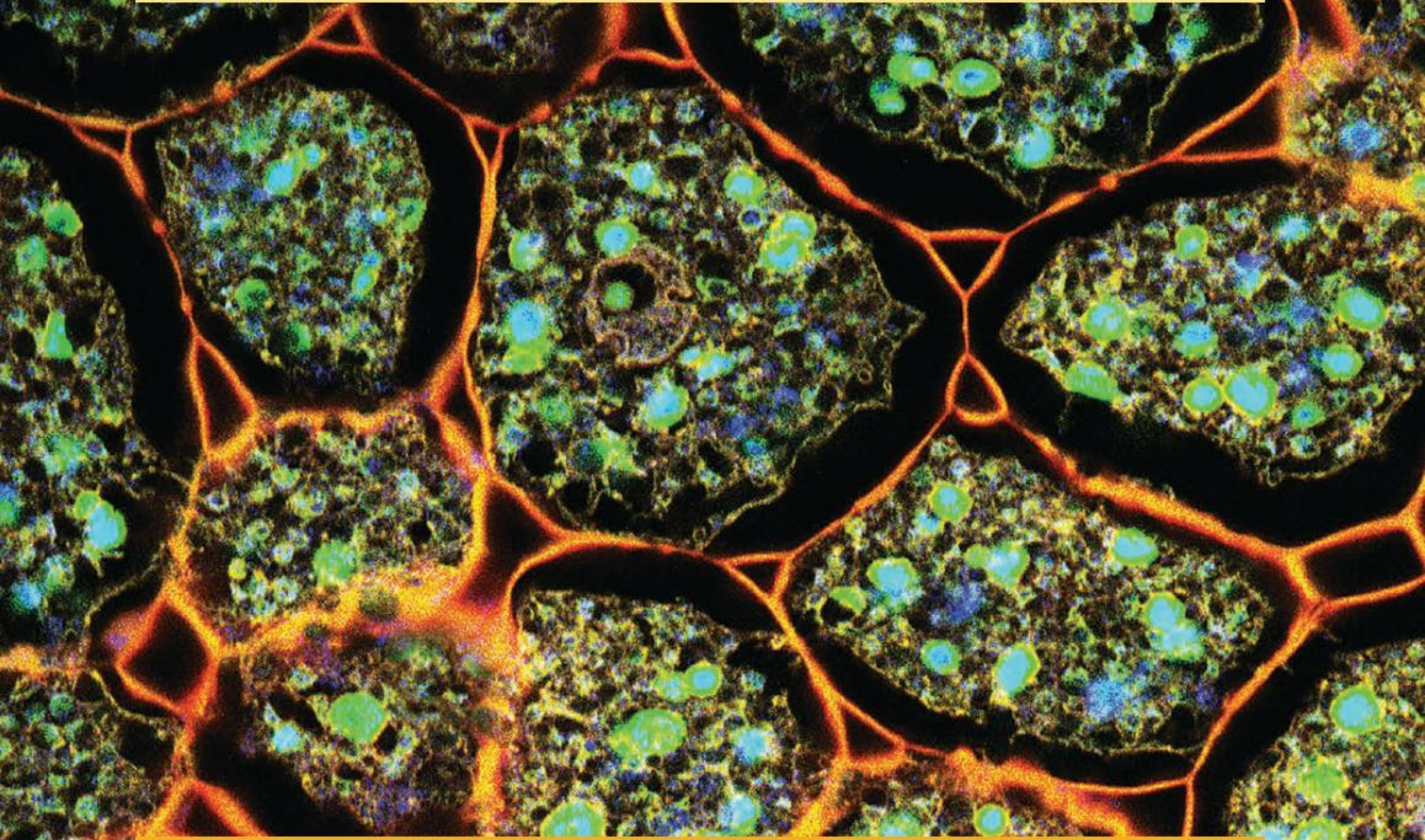


Figure 1.26

- **a** What were the masses of the two bandicoots captured after 3 months?
- **b** When was a 500 gram bandicoot captured for the first time?
- **c** Draw a line of best fit for the data. Use this line of best fit to predict the mass of a bandicoot captured after 6 months.
- **d** Propose a reason why there appears to be an increasing trend.

ISBN 978-1-108-61069-8 Cambridge University Press

Chapter 2 Cells



Chapter introduction

Everything can be broken down into its smallest components. A house is made of bricks, pipes and wires; cakes are made of flour, eggs and sugar; and all living organisms are made of cells. Cells are the basic building blocks of life, meaning that they are the smallest unit that can, potentially at least, carry out the processes that we know all living things do, such as moving, producing energy, sensing their environment, growth, repair, excretion and consumption of nutrients. In this chapter, you will explore the basic components of cells and the many types of cells that can be found in the natural world.

Curriculum

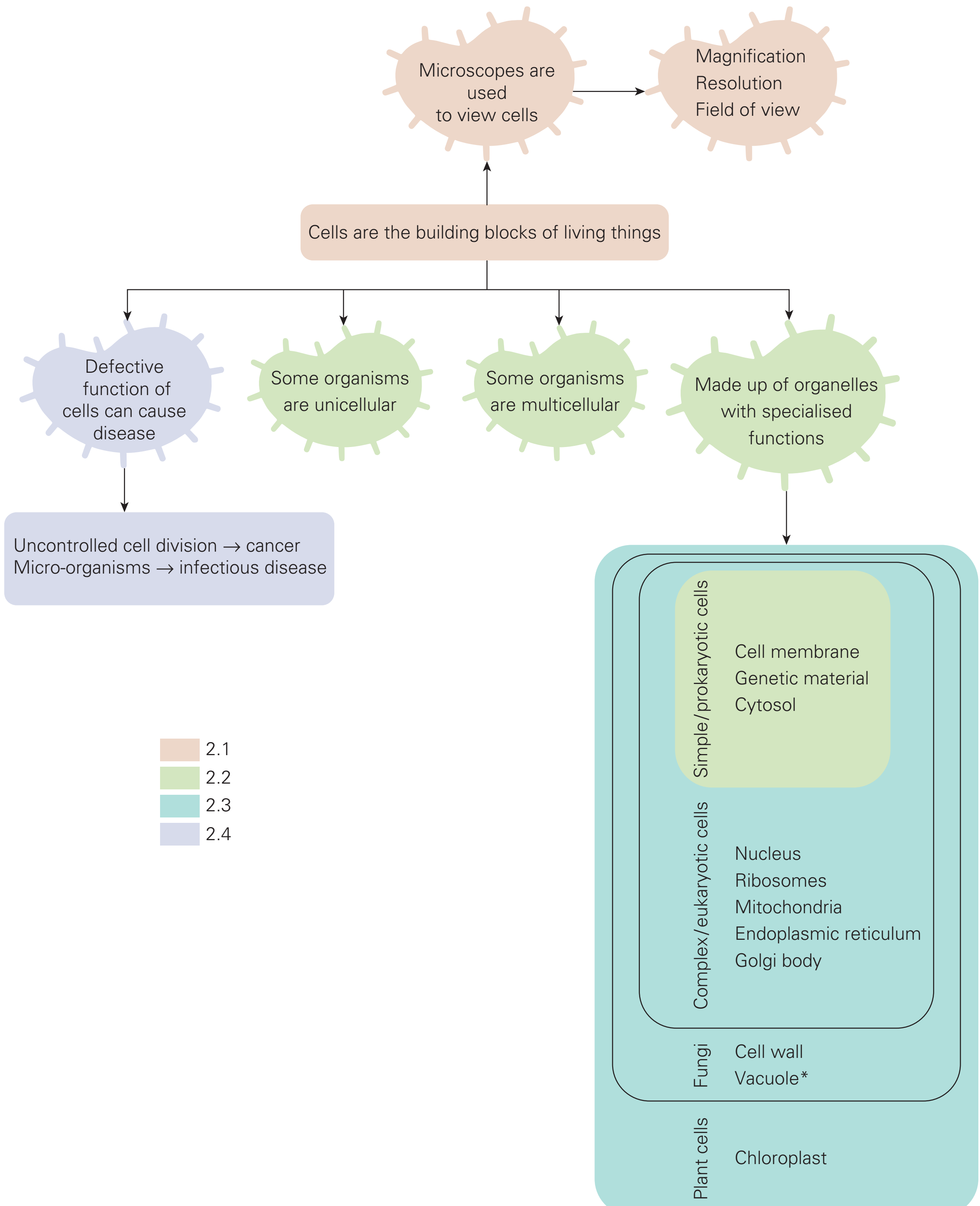
Cells are the basic units of living things and have specialised structures and functions (VCSSU092)	
• examining a variety of cells using a light microscope, by digital technology or by viewing a simulation	2.1, 2.3
• distinguishing plant cells from animal and fungal cells	2.3
• identifying structures within cells and describing their function	2.2
• recognising that some organisms consist of a single cell	2.2, 2.3

Victorian Curriculum F–10 © VCAA (2016)

Glossary terms

antibiotic
bacteria
binary fission
cell membrane
cell wall
chloroplast
cytosol
endoplasmic reticulum
genetic material
Golgi body
mitochondrion
mitosis
multicellular
nucleus
pluripotent stem cell
protist
ribosome
unicellular
vacuole

Concept map



*some bacterial, protist and animal calls have vacuoles

ISBN 978-1-108-61069-8

Cambridge University Press

2.1 Microscopes and cells

The microscope

Throughout this chapter you will explore cells, their structure and function. However, you would not have been able to learn this information without the invention of the microscope. It all began about 500 years ago, when scientists used hand-held magnifying glasses to view small macroscopic specimens – these were large enough to be visible to the naked eye. Scientists wished to view smaller and smaller specimens, and soon found that using two lenses together enabled them to do so. This discovery led to the invention of the first light microscope. The light microscope that you use today in school is not very different from those used by scientists hundreds of years ago, although the technology used to produce today's lenses is more advanced and enables us to see things at higher magnifications.

WORKSHEET

Did you know? 2.1

The scientist who first discovered single-celled organisms was Antonie van Leeuwenhoek. He called these organisms 'animalcules', meaning 'little animals'.

We now call these animalcules 'micro-organisms'.

Figure 2.1 Animalcules

Explore! 2.1

The history of the microscope

In 1665, Robert Hooke published a book based on his observations of the microscopic world. He was able to do this because he had built a compound microscope with a twist-operated focusing mechanism – this had never been seen before. He further improved the microscope by placing a water flask beside the microscope to focus light from an oil-lamp onto his specimens to illuminate them brightly.

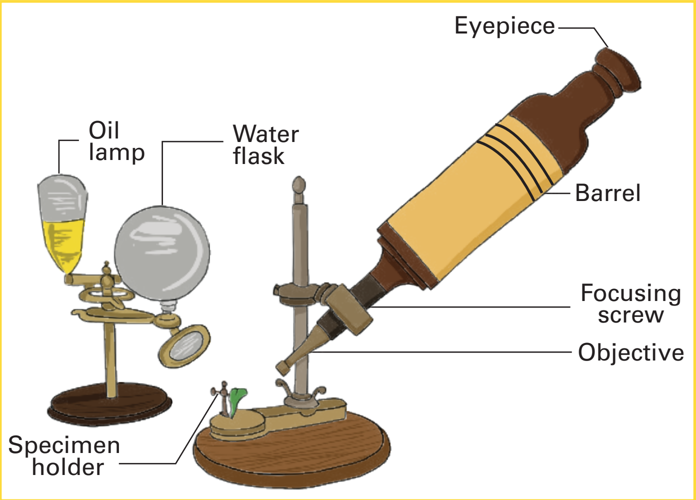


Figure 2.2 The Hooke microscope (circa 1660)

1. Find out about the role of each of the following scientists in the development of the microscope: Robert Hooke, Antonie van Leeuwenhoek, Frits Zernike, Marvin Minsky, Ernst Ruska, Gerd Binnig and Heinrich Rohrer.
2. Using A3 paper, draw an annotated timeline showing who developed what and when.

ISBN 978-1-108-61069-8

Parts of a microscope

Although some microscopes are more advanced than others, most of those you will use at school are light microscopes that have the same basic components. The microscopes you will use have at least two lenses: the eyepiece lens and the objective lens. They also have a light source, a stage on which to place specimens, and knobs to adjust the focus. The monocular microscope shown here is for use with one eye. Binocular microscopes can be used with both eyes.

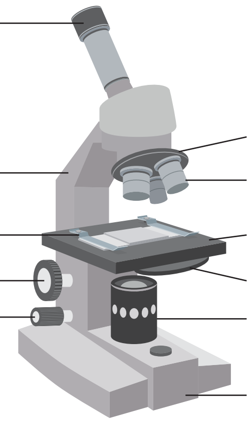


Figure 2.3 The parts of a monocular microscope

Try this 2.1

Parts of the microscope

Draw up a table with the parts of a microscope in the left column. Find out the function of each part, and put this information in the right column.

Microscope terms

When you use a microscope, you will often encounter special terms. Table 2.1 summarises some key terms.

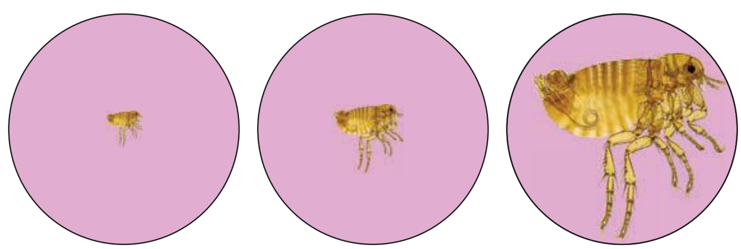
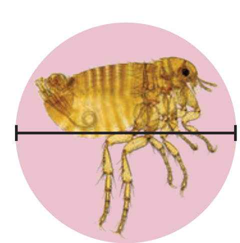
Term	Definition	Image
Magnification	How much the image of the specimen or object is increased in size (i.e. how much you are zooming in)	 Low magnification; Medium magnification; High magnification
Resolution	How detailed and clear the image is (i.e. how easy it is to tell two separate objects apart)	 Poor resolution; Better resolution; Best resolution
Field of view (FOV)	How much of the object you can see when you look through the eyepiece	 Human flea

Table 2.1 Some key terms used in microscopy

ISBN 978-1-108-61069-8

Advances in technology

Binocular light microscopes

Binocular microscopes have an eyepiece for each eye. There are two types: simple binocular microscopes have one light path from the specimen, which is split and led to both eyepieces, so each eye has the same view. The image looks flat (2D). Stereoscopic ('stereo') microscopes, which are much more expensive, lead two separate light paths from the specimen to each eye, so they have different views, the image has depth (3D). This is useful for manipulating or dissecting specimens, and the magnification does not have to be very large.

Light microscopes are limited in their usefulness. They can magnify a specimen up to 1500×, which is enough to make a **bacterium** visible. However, the resolution at this magnification is not very high, and so light microscopes do not enable you to view anything smaller than bacteria in any great detail.

bacteria
very small organisms with prokaryote cells that are found everywhere and are the cause of many diseases

In order to see things that are smaller than bacteria, scientists invented a different type of microscope, called an *electron microscope*. This microscope uses tiny particles called electrons, instead of light, to view an object.

Electron microscopes have a magnification of around 10 million times and very high resolution. Since the invention of the electron microscope in 1933, we have been able to observe the structure of extremely small objects in high detail. There are now two types of electron microscope:

- transmission electron microscope (TEM) – the specimen to be viewed is sliced very finely and the internal structure can be seen
- scanning electron microscope (SEM) – the specimen to be viewed is not sliced, and the external surface can be viewed.

Unfortunately, electron microscopes are extremely expensive and all specimens that are observed have to be prepared in a way that kills them.

Figure 2.4 An electron microscope

Types of microscope

Explore! 2.2

1 Do some research into the different types of microscope that are used today: light microscope, stereo microscope and electron microscope.
2 Copy and complete the following table.

Type of microscope	Magnification	Resolution	Advantages	Disadvantages	Example of what can be seen
Monocular light microscope					
Stereoscopic light microscope					
Electron microscope					

The different types of microscope and their characteristics

ISBN 978-1-108-61069-8

Cambridge University Press

Quick check 2.1

1. Compare the maximum magnification of the light microscope, the stereo microscope and the electron microscope.
2. State what micro-organisms were originally called.
3. Define the following key terms, in your own words: magnification, resolution, field of view.
4. Name the different types of microscope, in order from most powerful to least powerful.

Science as a human endeavour 2.1

Using your smartphone as a microscope

Most cameras on smartphones are not designed to produce high-resolution microscopic images. Researchers in the USA recently published their work on an attachment they had designed to place over the smartphone lens to increase the resolution and the visibility of tiny details of the images they take, down to a scale of approximately one-millionth of a metre. The new attachment uses artificial intelligence to create the level of resolution and colour required for laboratory analysis.

This attachment could help bring high-quality medical analysis into resource-poor regions, where people do not have access to expensive technologies. In addition, the attachment can be produced with a 3-D printer, at less than $100 each.

Practical 2.1

Using a microscope

Aim

To become proficient in using a microscope

Materials

- light microscope
- newspaper
- scissors
- glass microscope slide
- sticky tape

Be careful

Ensure that the microscope is carried appropriately. Carry it with one hand holding the arm and one hand under the base. Do not use the coarse focus knob to cause the objective lens to touch the glass slide and damage it.

Method

1. Cut one word out of a newspaper.
2. Attach the word to the centre of a glass slide, using sticky tape.
3. Set the lowest magnification or smallest objective lens in place. Turn the coarse focus knob until it is as close to the stage as it will go.
4. Place the slide on the stage of the microscope and secure it in place with the clips.
5. Using the coarse focus knob, focus on the word.
6. Draw what you can see in the field of view at this lowest magnification. Record the magnification next to your drawing. In order to calculate the magnification, you will need to multiply the magnification of the eyepiece lens by the magnification of the objective lens. For example, if the eyepiece is 10× magnification and the objective lens is 4× magnification, then the overall magnification is $10 \times 4 = 40\times$.
7. Try moving the stage left and right, forwards and backwards, and note what you observe about the movement of the image.
8. Repeat steps **3–6** for each of the optical lenses. You no longer use the coarse focus knob to focus now; use only the fine focus knob.

continued…

ISBN 978-1-108-61069-8

...continued

Results

Your results will consist of:

- your drawings of the field of view using the different objective lenses. Include the magnification of each drawing.
- your notes about what happens when you move the stage left and right, forwards and backwards.

Evaluation

1. Explain what happened to the word when viewed under the microscope at low magnification.
2. Describe what happened when you increased the magnification using the different objective lenses.
3. Describe what you observed as you moved the slide – did the word go in the same direction as the direction in which you moved the slide?
4. What did you notice about the orientation of the letters in the word? Were they the right way up? Back to front? Explain.
5. As the magnification of an image increases, the resolution decreases. State the magnification at which you would have had the lowest resolution.
6. Explain what happened to the field of view as you increased the magnification of the objective lens.
7. Outline a safety precaution you would use when observing a specimen using the highest magnification objective lens.
8. Summarise the advantages and disadvantages of using a light microscope.

Cell theory

As you read earlier, a scientist called Robert Hooke built a compound microscope that lit up the specimen he was viewing. Because of this invention, in 1665 he was able to observe that a dead cork plant appeared to be made of small blocks. He named these blocks 'cells' because they looked like the small identical 'cells' that monks lived in at the time.

Nearly 200 years later, after many other scientists had observed and catalogued many more types of cells, a *cell theory* was proposed.

This first cell theory stated that:

- Cells make up all living things.
- Cells are the basic building blocks of all living things.
- All cells form spontaneously from their environment, in a similar way to crystals forming.

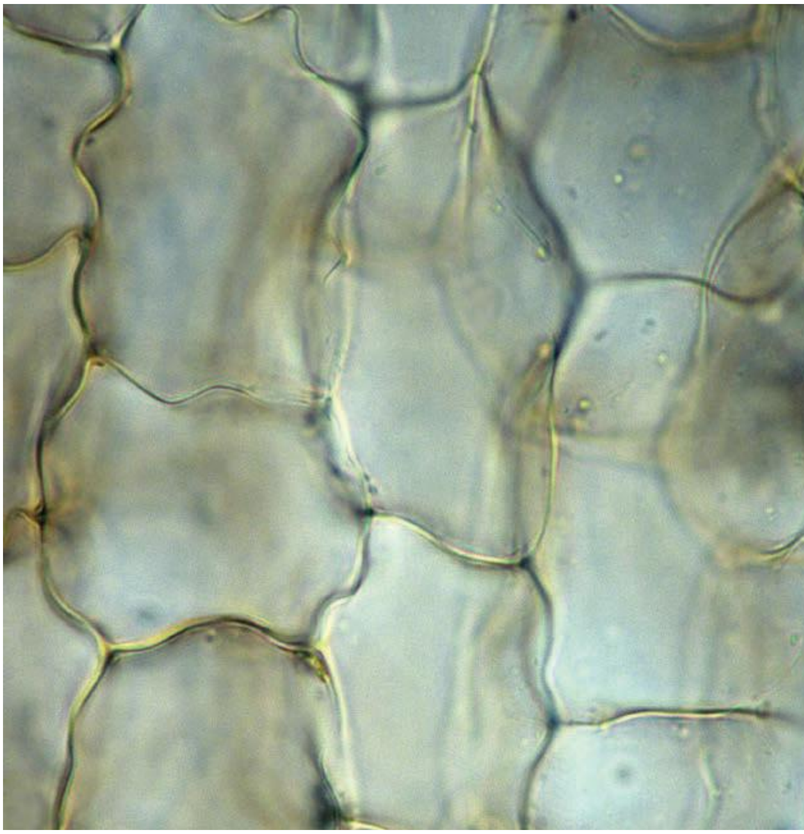


Figure 2.5 Cork cells as Hooke would have observed them

ISBN 978-1-108-61069-8 Cambridge University Press

The third part of this theory we now know to be incorrect, as cells do not just pop into existence. Modern cell theory states that:

- Cells make up all living things.
- Cells are the basic building blocks of all living things.
- All new cells are produced from existing cells.
- All cells contain genetic information, which is passed from cell to cell during cell division.

Size of a cell

Cells are extremely small and most cells cannot be seen with the naked eye. That is why it was not until the invention of the microscope, around 350 years ago, that we even knew cells existed. If you take a look at your arm you can see skin and hair, but it is impossible to see the individual skin cells. Anything that you need a microscope to be able to see clearly can be described as *microscopic*.

You many wonder why cells come in many sizes. The main reason is simple: their size depends on their job. Red blood cells are flat and small, and carry oxygen in your blood to different parts of your body. When mature, they don't have a **nucleus**, and so there is more space to carry haemoglobin, a red compound that holds oxygen. Being flat and small allows the red blood cells to squeeze through tiny blood vessels, in order to deliver oxygen throughout your body.

nucleus
part of a cell that contains the genetic material

Did you know? 2.2

Egg cells
Cells come in many shapes and sizes. The largest cells in the world are eggs – an unfertilised egg is a single cell. Each egg holds the genetic information for the female of the species, and if fertilised will eventually grow into a new individual. Egg cells are 'macro' cells. Macro means that they can be seen with the naked eye – that is, without a microscope.

Figure 2.6 The largest cells in the world are eggs, and the largest of all is the ostrich egg.

Figure 2.7 Red blood cells

Quick check 2.2

1. Name the largest cell in the world.
2. Compare the terms 'micro' and 'macro'.
3. Explain why cells come in many shapes and sizes.

ISBN 978-1-108-61069-8 Cambridge University Press

Try this 2.2

Cell size

In science, it is important to use appropriate units when measuring different objects. You would not measure the size of a bedroom in kilometres, or the size of an ant in metres. Therefore, when you measure cells, it is important to use a very small unit. This is usually a micrometre (μm). A micrometre is 1000 times smaller than a millimetre (mm).

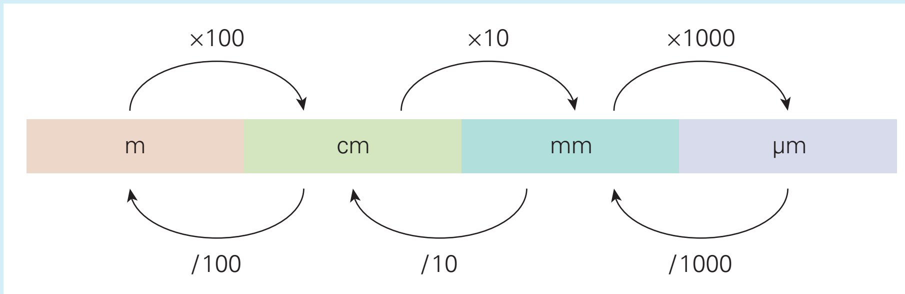
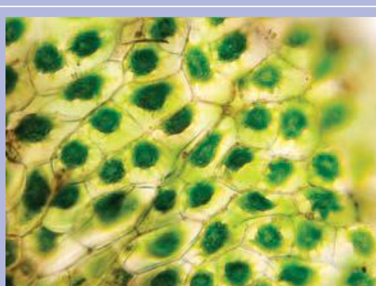
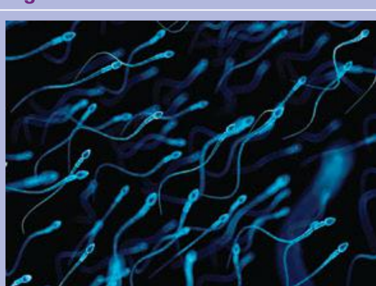


Figure 2.8 Conversions needed for different measurements

Using Figure 2.8, convert the cell sizes below into millimetres (mm) or micrometres (μm).

Cell type	Size (mm)	Size (μm)
 **Figure 2.9** Red blood cells	0.0065	
 **Figure 2.10** Plant cells on leaf surface		100
 **Figure 2.11** Sperm cells	0.05	

ISBN 978-1-108-61069-8 Cambridge University Press

Practical 2.2

Estimating size

Aim
To use a microscope to estimate the size of objects

Materials
- light microscope
- transparent ruler
- sesame seeds, poppy seeds, salt crystals, fennel seeds
- glass slides

Be careful

Ensure that the microscope is carried appropriately. Carry it with one hand holding the arm and one hand under the base. Do not use the coarse focus knob to cause the objective lens to touch the glass slide and damage it.

Method
Part 1: Calculating size

1. Estimate the size of each of the objects using your naked eye, and record your estimate in the results table (shown in the Results section).
2. Using a ruler, attempt to measure each object to the closest millimetre (mm), and record your measurement in the table.
3. Place the transparent ruler on the stage of the microscope.
4. Starting on the lowest magnification, focus on the ruler.
5. Measure the diameter of the area you can see under the microscope (field of view) using the ruler. Record this measurement in the field of view (FOV) table (shown in the Results section).
6. Calculate the FOV size in micrometres (μm) by multiplying the measurement in millimetres you recorded in step **5** by 1000.
7. Calculate the FOV for each of the higher magnifications, by repeating steps **4–6**.

Part 2: Estimating the size of the object

8. Place your first object or specimen on a glass slide and then place the slide on the stage of the microscope.
9. Focus on the object using the lowest magnification objective lens.
10. Estimate how many of those objects would fit in a straight line across the middle of the FOV. For example, perhaps 20 poppy seeds look like they would fit across the centre in a line.
11. Divide the total FOV size that you have already calculated (in Part 1) by the estimated number that will fit across the FOV. For example, if in Part 1 you found the FOV at the low magnification was 10 mm, which you converted to 10 000 μm, then your calculation would be 10 000/20 = 500. That is, each poppy seed is 500 μm in size.
12. Record your estimated size for the specimen in the results table.
13. Repeat steps **8–12** for each object.

Results
Copy the two tables below and use them to record your results.

Magnification (eyepiece lens × objective lens)	FOV size (mm)	FOV size (μm) (mm × 1000)

Field of view (FOV) table

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Object	Estimated size (Part 1)	Measured size (Part 1)	Number of times it would fit across the FOV	FOV diameter size	Estimated size of object (FOV/ number of times object fits across)
Sesame seed					
Poppy seed					
Fennel seed					
Salt crystal					

Results table

Evaluation

1 Compare your observed, measured and magnified estimated size results.
2 Explain how you could increase the accuracy of your results.
3 Sometimes FOV is calculated using a mini-grid instead of a ruler. A mini-grid has extremely thin lines that can show μm. Suggest why a mini-grid would produce more accurate results than a ruler when estimating size.

Conclusion

1 Make a claim about using a microscope to estimate size. Begin your sentence with: 'This experiment suggests that the size of an object ... '.
2 Support your claim by using the data you gathered and include potential sources of error. Begin your brief summary with: 'The results show that ... '. Include: 'Possible sources of error were ... '.
3 Explain how the data supports your claim. Begin your sentence with: 'This means that ... '.

Section 2.1 questions

QUIZ

Remembering

1 Define the term 'microscopic'.
2 State the modern cell theory.
3 Name what each of the following parts of the microscope does.

Part	Job
Stage	
Eyepiece	
Objective lens	
Coarse focus knob	
Fine focus knob	

Understanding

4 Outline the structure and function of a red blood cell.
5 Summarise the advantages of using:
  a a monocular light microscope
  b a stereo microscope.

continued...

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

6 Outline the contribution of Robert Hooke to our understanding of the cell.

7 Fill in the magnification of the microscope when using the following objective lenses:

Eyepiece	Objective lens	Magnification of specimen
× 10	× 10	
× 10	× 5	
× 10	× 80	

Applying

8 Suggest the reason that different units are used to measure different-sized objects.

9 A nanometre (nm) is 1000 times smaller than a micrometre (μm). Generally, a virus is around 0.0225 μm in size. Calculate this size in nanometres.

10 Summarise why it is important to turn the coarse focus knob until it is as close to the stage as it will go, before putting the slide on the stage. (Think about the safety notes).

11 Copy and complete the following table.

Specimen	Size		
	Nanometres (nm)	Micrometres (μm)	Millimetres (mm)
Atom	0.1		
Bacterium		1	
Virus	35		
Animal cell		10	
Chicken egg			50

Analysing

12 Distinguish between a TEM and an SEM.

13 Demonstrate how you would determine the size of a cell.

14 Classify the following specimens into three groups: those that can be seen easily with the naked eye; those that can be seen with a light microscope; and those that can be seen only with an electron microscope. (Some might belong in more than one group.)

plant cell (100 μm)
frog egg (1 mm)
red blood cell (7 μm)
phytoplankton (2 μm)
chicken egg (50 mm)
virus (35 nm)
bacterium (1 μm)

Evaluating

15 Create a detailed set of step-by-step instructions for a Year 7 student, on how to use a microscope safely.

16 Justify the statement 'the development of microscopes has changed our understanding of cells'.

ISBN 978-1-108-61069-8 Cambridge University Press

2.2 Organelles

All cells

Everything that we classify as living is made up of one or more cells. People, trees, fish and mushrooms are made up of many different cells working together, and are known as **multicellular**. These cells depend on each other and cannot survive alone. Organisms in the kingdoms Bacteria, Protista and Archaea are made of single cells, and are referred to as **unicellular**. Each of these single cells carries out all the processes needed to stay alive, by itself. Generally, unicellular organisms are quite simple and are similar to some of the oldest forms of life found on Earth, whereas multicellular cells are specialised and much more complex.

multicellular
made of many cells

unicellular
made of just one cell

cell membrane
the barrier that separates the inside of the cell from the external environment

genetic material
the code that allows the cell to produce copies of itself and to regulate the functions within the cell

cytosol
the water-based mixture that fills the cell, containing different molecules large and small; many chemical processes that happen within a cell occur in the cytosol

All cells, no matter how simple, contain the same three components:

- a **cell membrane**
- **genetic material**
- **cytosol**.

Quick check 2.3

1 Define these terms and include examples of each: unicellular, multicellular.
2 List the three components of all cells.

WORKSHEET

Organelles

Simple and complex cells

All cells can be grouped into two main categories: *prokaryote* (simple) and *eukaryote* (complex). Prokaryotes are unicellular, while eukaryotes can be unicellular or multicellular. These two categories of cell type are based on the structures found inside each cell. As you read earlier, all cells have a membrane, cytosol and genetic material. Eukaryotic cells are more complex and may also have many membrane-bound structures, including a nucleus, that carry out specific functions. The term 'prokaryote' means 'before (*pro*) nucleus (*karyon*)'. The specialised structures inside cells are known as *organelles*, because they are like 'mini' organs with specific jobs, such as the brain, stomach and heart.

VIDEO
What three components do all cells have in common?

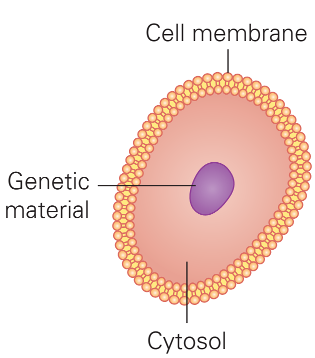


Figure 2.12 All cells, no matter how simple or complex, contain these three components.

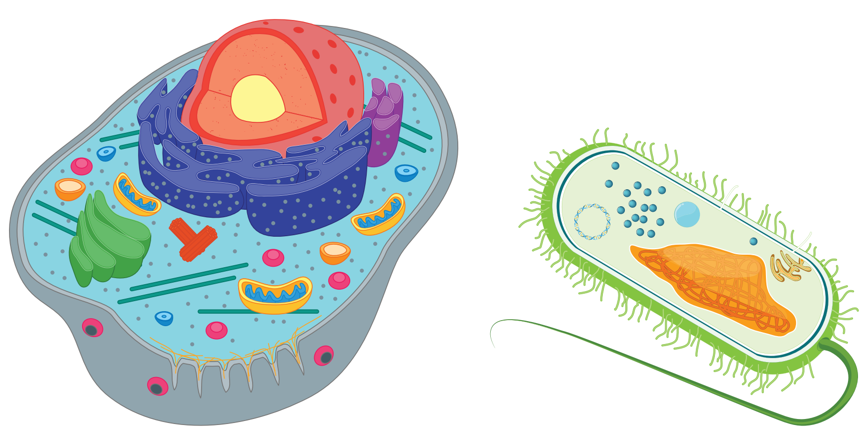


Figure 2.13 Eukaryotic cell (left) vs prokaryotic cell (right). Can you identify the cell membrane, genetic material and cytosol in each cell type?

ISBN 978-1-108-61069-8 Cambridge University Press

Try this 2.3

Prokaryotes vs eukaryotes

For the following list of organisms, identify which are examples of prokaryotic cells and which are examples of eukaryotic cells.

Mushrooms	Archaea	Cyanobacteria	Tapeworms
Grass	Potatoes	Fruit flies	*Escherichia coli*

The cell city

Although all cells contain the structures described previously, only complex eukaryotic cells contain the specialised membrane-bound organelles that you are going to read about in this section. It is helpful to think of the cell as a city. A city has many needs, and each organelle caters for those needs. This idea is developed further in the STEM task for this chapter.

Nucleus

The nucleus is a large structure that holds the genetic material of a cell. It is like the brain of the cell and controls all its functions. In a city, the nucleus would be the top level of government, which keeps all the plans and blueprints and makes all the important decisions.

Figure 2.14 Imagine the cell as a busy city.

Figure 2.15 Top left: Graphic representation of a nucleus. Top right: an electron microscope image of a nucleus within a plant cell. Bottom: The nucleus makes all the major decisions for the cell city.

ISBN 978-1-108-61069-8 Cambridge University Press

Genetic material

The genetic material, or deoxyribonucleic acid (DNA), is found in every cell. DNA is the coded information that makes you who you are and tells every cell what to do.

A DNA molecule is shaped like a twisted ladder, and this shape is called a double helix. In the cell city, DNA would be the plans and blueprints which the top level of government uses to keep everything running smoothly.

Figure 2.16 Left: Graphic representation of a DNA molecule. Right: Senators in discussion in a Federal Parliament

> **Did you know 2.3**
>
> **The Moon and back!**
>
> We have trillions of cells in our body and each one contains DNA. If you lined up the DNA from all your cells, it would reach to the Moon and back approximately 1500 times!

Cell membrane

The cell membrane is a thin double layer of molecules that separates the inside of the cell from its external environment, and controls what enters and leaves the cell. The cell membrane is like a protective border around the cell city, controlling who enters and leaves.

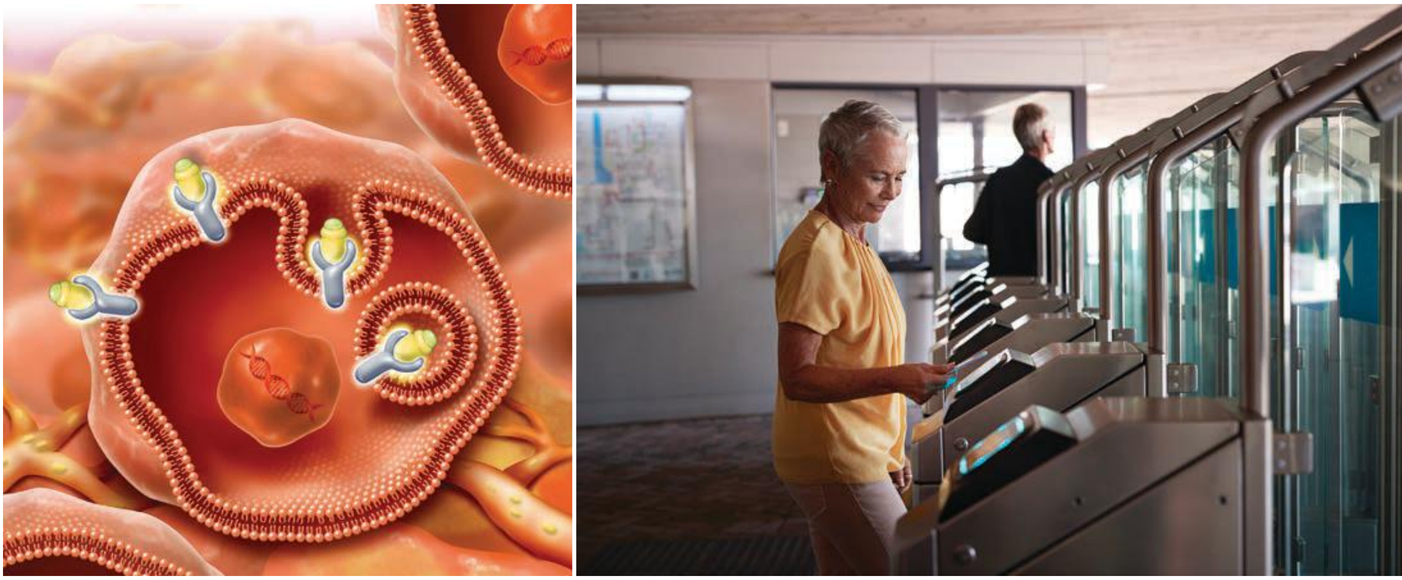


Figure 2.17 The cell membrane (shown at left) provides 'border security' for the cell.

ISBN 978-1-108-61069-8 Cambridge University Press

Practical 2.3

Modelling membrane activity

Aim

To model the movement of substances across a cell membrane

Materials

For the class:

- 2 litres of bubble solution (1800 mL water, 200 mL dishwashing liquid, 60 mL glycerol)

Per group:

- 4 straws for frame
- shallow tray
- 20 cm cotton thread
- clean straw
- 30 cm string

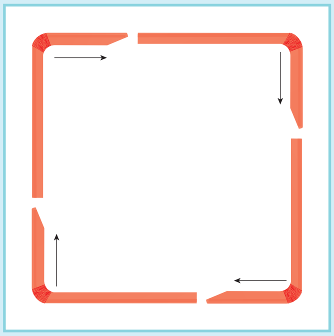


Figure 2.18 How to construct your square straw frame

Method

1 Create a square frame using four straws, as shown in Figure 2.18.
2 Pour bubble solution into the shallow tray.
3 Place the straw frame into the solution.
4 Lift the straw frame out of the solution gently, to create a bubble layer across the inside of the frame.
5 This bubble layer represents the cell membrane.

Dry hand

6 Have one of your group members place their dry hand through the bubble membrane.
7 Record your observations of this in the results table.

Hand covered in bubble solution

8 Form the bubble membrane again (repeat steps **2–5**).
9 Cover one hand with bubble solution and slowly pass the hand through the bubble membrane and back out.
10 Record your observations of this in the results table.

Cotton hole

11 Form the bubble membrane again (repeat steps **2–5**).
12 Create a small loop (2 cm diameter) in the cotton thread by knotting the thread.
13 Soak the cotton thread in the bubble liquid.
14 Carefully place the cotton loop into the membrane bubble.
15 Use a pencil or pen to pop the bubble membrane inside the cotton loop.
16 Record what you observe in your results table.
17 Pass the pencil through the bubble membrane hole you have created.

Double bubble

18 Using a clean straw, gently blow into the bubble solution.
19 Slowly lift the straw out of the solution, continuing to blow, to create a large single bubble.
20 Slowly return the straw to the bubble solution at the base of the bubble, and try to create a smaller bubble inside the bigger one.
21 Record what you observe in your results table.

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

String (dividing a membrane)

22 Knot together both ends of the string, to create a circle.
23 Place the string in the bubble solution and slowly remove it, to create a bubble membrane in the centre.
24 With a partner, hold both sides of the string circle and twist in opposite directions, to create a 'figure eight'.
25 Now you have created two isolated bubble membranes. Pop one of the membranes and record your observations.

Results

Record your observations in the following table.

	Observations
Dry hand	
Hand covered in bubble solution	
Cotton hole	
Double bubble	
String	

Evaluation

1 Explain your observations when your dry hand passed through the membrane bubble.
2 Membranes are self-repairing. Using your observations of the hand covered in bubble solution, describe how you modelled this ability.
3 Cell membranes have some large openings to allow bigger molecules to move into and out of the cell. Explain how you modelled this feature.
4 Some organelles use small membrane 'bubbles' to transport materials into and out of the cell. Using your observations, suggest why materials needing to be transported through a cell membrane must be packaged inside their own membrane.

Cytosol

Cytosol is a water-based mixture of small and large molecules that fills the cell. In eukaryote cells, it refers to the liquid outside the organelles. Although it appears mostly transparent in a light microscope, it has a very complex structure, with regions that vary greatly in concentration and viscosity, so parts of it may resemble jelly. Many of the chemical reactions that cells require to function take place between molecules dissolved in the water of the cytosol, controlled by enzymes that may form very complex structures. Many nutrients and other materials may be stored in the cytosol.

Using the city analogy, we would say the cytosol makes the city to be like Atlantis, or a coral reef – it is an underwater city. The water fulfills the same functions for the cell city that the air does for us.

Ribosomes

Ribosomes are very small structures that 'read' the codes sent to them in the genetic material and produce proteins that the cell needs to create structures and carry out different functions. Ribosomes would be the factories of the cell city, producing bricks, cars and different tools for the city to use.

ribosome
a structure in a cell that produces protein from amino acids

ISBN 978-1-108-61069-8

Cambridge University Press

Mitochondria

mitochondrion a structure in a cell that converts the energy from food into the form needed by the cell

Mitochondria are where sugars from food are turned into energy, in a process called *cellular respiration*. The output is a substance called ATP, the cell's fuel, that is then used to power its chemical reactions and movement. Cells use this energy for many tasks, such as moving things into and out of the cell, growth, repair and reproduction. The mitochondria can therefore be thought of as the power station of the cell.

Figure 2.19 Top: Graphical representation of a mitochondrion (left image) and an electron microscope image of mitochondria (right image). Bottom: The mitochondria 'burn' fuel (sugar) to generate power (as ATP molecules, not electricity) for the cell.

Endoplasmic reticulum

endoplasmic reticulum a network of tubes within a cell that transports substances inside the cell

The **endoplasmic reticulum** (ER) is a large folded membrane attached to the nucleus. Many ribosomes are located along the ER, and its main job is to transport the proteins made at the ribosomes around the cell. The name 'endoplasmic reticulum' might sound complicated but it is just a description of what it does: *endo* (inside), *plasmic* (cytoplasm), *reticulum* (network). The ER is basically a highway that connects and delivers proteins to different parts of the cell.

Figure 2.20 Left: Graphical representation of the endoplasmic reticulum around the outside of the nucleus. Right: The endoplasmic reticulum is the highway network of the cell city.

ISBN 978-1-108-61069-8

Golgi body

Golgi body
a structure in a cell involved in transport between the inside and outside of the cell

The role of the **Golgi body** is to fold and package the proteins made by the ribosomes, for export from the cell. Golgi bodies are like the post office of the cell. They place proteins into small sacks of membrane, called vesicles (postal vans), and send them out of the cell to other parts of the body.

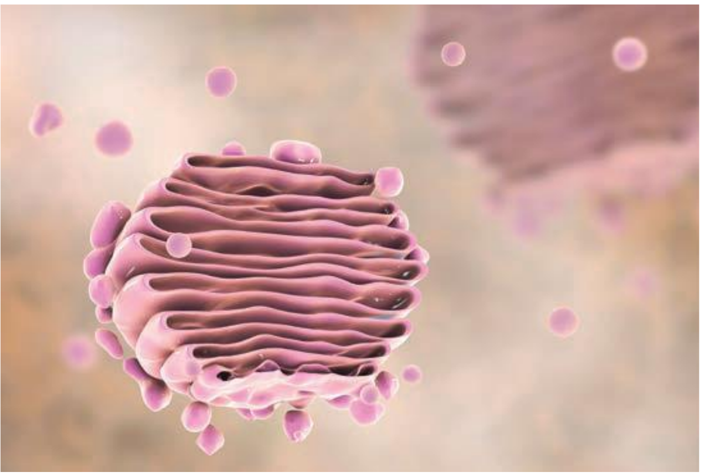


Figure 2.21 Left: Graphical representation of a Golgi body. Right: Golgi bodies act as the postal system of the cell city.

Try this 2.4

Organelles

Draw up a table with three columns. List all the organelles covered in this section in the left column. Give a description of their role in a cell in the middle column, and provide a simple picture or diagram in the right column.

Quick check 2.4

1 State the terms used for simple and complex cells.
2 Define the term 'organelle'.
3 Copy Figure 2.22 and label the following organelles: cell membrane, cytosol, nucleus (includes genetic material), ribosomes, endoplasmic reticulum, Golgi bodies, mitochondria.

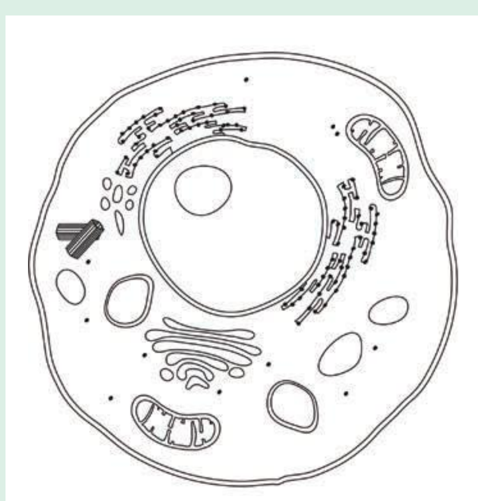


Figure 2.22 Diagram of a eukaryotic cell, ready for you to label it

VIDEO
What organelles do all eukaryotic cells contain?

ISBN 978-1-108-61069-8 Cambridge University Press

The cell's internal scaffolding

Explore! 2.3

Eukaryotic cells have a cytoskeleton.

A cytoskeleton is a structure that helps the cell maintain its shape and internal organisation.

It also provides mechanical support that enables things to move around inside the cell.

1 Research and summarise the roles of the following structures within cells: microtubules, intermediate filaments, microfilaments. These are tricky terms to understand and explain, so keep your answer simple.

Figure 2.23 A graphical representation of a microtubule

A new cell structure discovered

Science as a human endeavour 2.2

In 2015, scientists published their research about a cell structure that they had discovered. The brilliant thing about this discovery is that it could help scientists understand why some cancers develop. The structure is called 'the mesh' and it helps to hold cells together. This discovery has changed biologists' understanding of the cell's internal scaffolding.

QUIZ

Section 2.2 questions

Remembering

1 List three organelles found in all cells.

2 List three organelles found in all eukaryotic cells (not including the three from Question **1**).

Understanding

3 Explain the function of the nucleus.

4 Outline why the Golgi body can be thought of as the post office of the cell.

5 What am I?

- a I produce energy in the form of ATP for cells.
- b I am a barrier between the inside and the outside of cells, and I control who enters and leaves.
- c I am a water-based mixture that fills the cell, and many chemical processes happen within me.
- d I make proteins using the code in the genetic material of the cell.

Applying

6 Compare the function of the cell membrane with that of the nucleus.

7 Summarise the role of the ER and the Golgi body.

Analysing

8 Distinguish between unicellular and multicellular, using examples.

Evaluating

9 Different cells have different numbers of mitochondria. Suggest a reason why muscle cells contain more mitochondria than skin cells do.

10 Give a reason why cells would contain many ribosomes.

ISBN 978-1-108-61069-8

Cambridge University Press

2.3 Eukaryotic cells

All eukaryotic organisms have many of the same organelles as each other. Eukaryotes can be found in the kingdoms Animalia, Plantae, Fungi and Protista. In this section, you will look at the differences between the cells of animals, plants, fungi and protists.

Figure 2.24 Plants and fungi living together

Animal cells

Animal cells contain all the organelles you learned about in the previous section. However, the numbers of organelles in a cell may vary, depending on what type of animal cell it is. Multicellular organisms like yourself are made up of many different types of specialised cells. Each of these different cell types has a specific job that allows your body to function properly. All the cells in your body start off as one cell, the fertilised egg, and then this cell differentiates into all the specialised cells around your body.

Cells that have the potential to turn into any other type of cell are called **pluripotent stem cells**. Once a stem cell has differentiated into a specialised cell, such as a nerve cell, it can only ever replicate into another cell of the same type.

WORKSHEET

pluripotent stem cell
a cell that is able to develop into many different types of cell

Stem cells don't only exist in embryos. You still have some stem cells in your body today that are ready to turn into any type of cell you need. They can be found in different tissues around your body and are activated by certain triggers, such as an injury. For example, if you cut yourself, stem cells below the layers of your skin turn into skin cells to help replace the damaged cells. This replacement is not always perfect and, if the damage is too extreme, it can leave a scar.

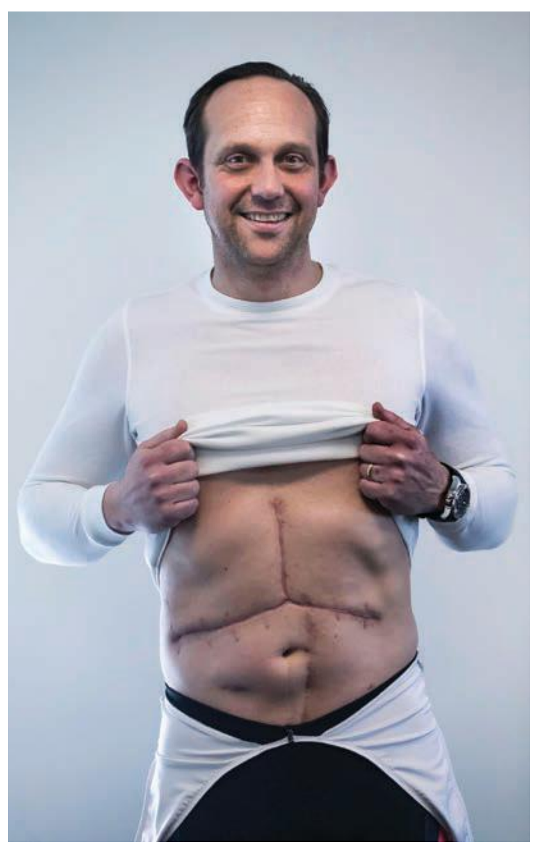


Figure 2.25 Olympic coach Justin Grace showing his scars following liver transplant surgery

ISBN 978-1-108-61069-8

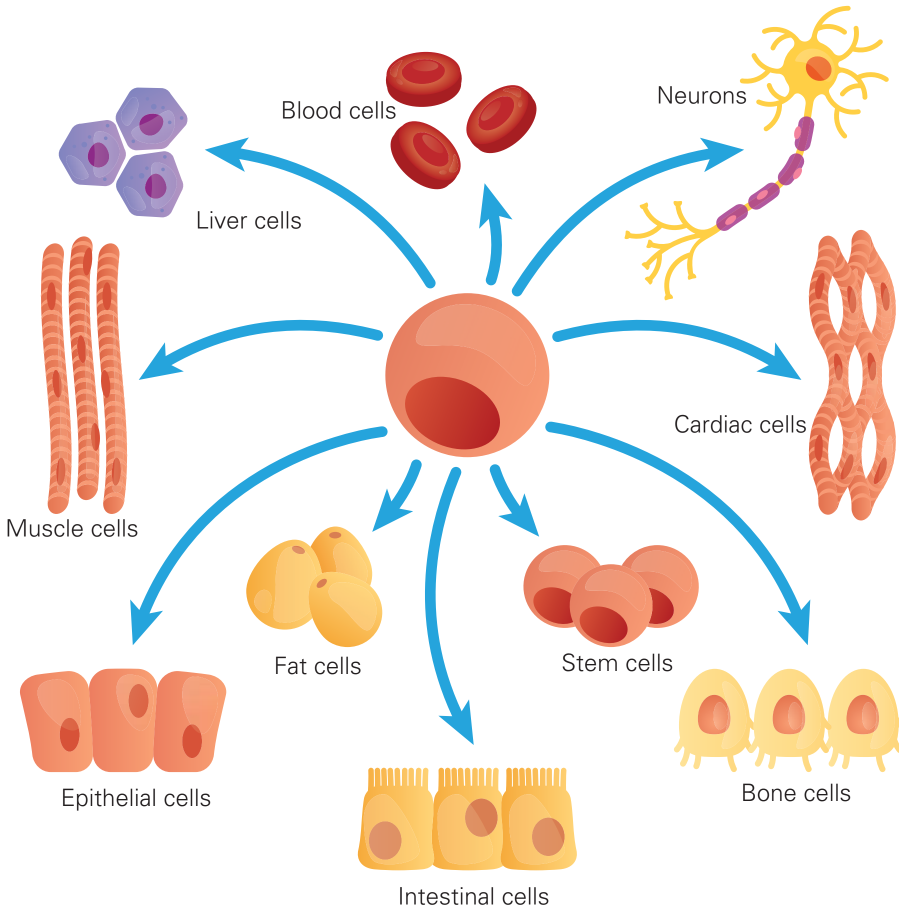


Figure 2.26 One cell becomes many types of cells, in a process known as cell differentiation.

Explore! 2.4

Stem cell therapy

Because stem cells are able to turn into any type of cell, they have the potential to be used in treating and curing many types of diseases and conditions. These treatments are known as stem cell therapy or regenerative medicine.

1 Find out about the blood cancer called leukaemia.
2 Investigate how stem cell therapy is used to treat leukaemia, and summarise your findings.

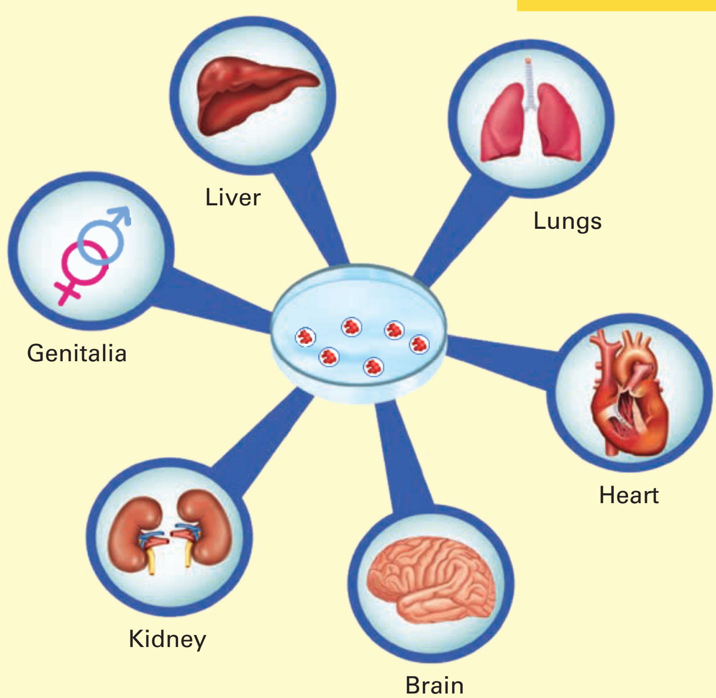


Figure 2.27 A stem cell can replicate and become any one of the 200+ types of cells in the body.

ISBN 978-1-108-61069-8 Cambridge University Press

Science as a human endeavour 2.3

Exciting uses of stem cells

Late in 2018, the results of two exciting research projects were published by scientists in Europe. First, in Germany, scientists succeeded in generating beating heart muscle cells from stem cells. Their work may provide a new approach for the treatment of heart attacks. Second, in Sweden, scientists developed a faster method of generating functioning brain cells from embryonic stem cells. The new method reduces the time required to produce the cells from months to two weeks, and may help in the treatment of neurodegenerative diseases such as dementia.

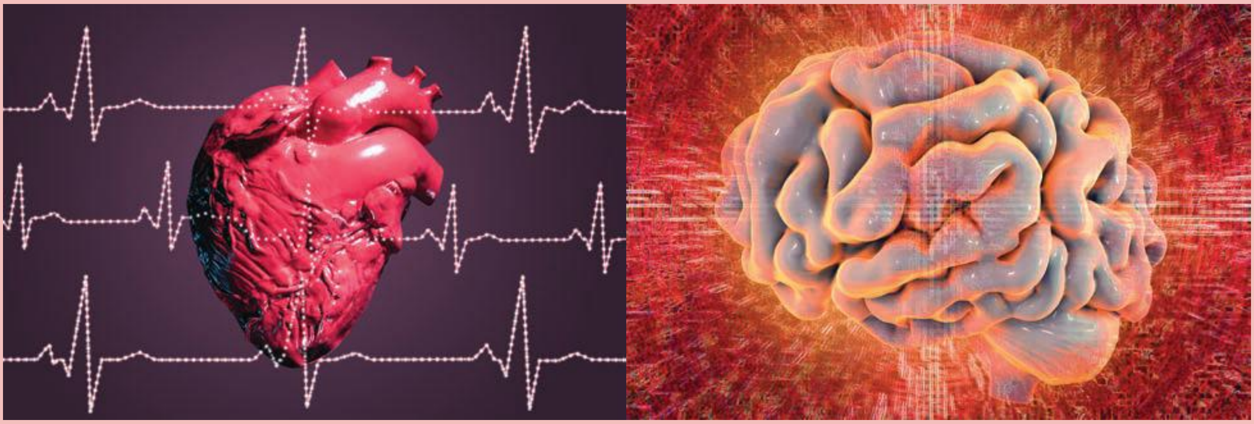


Figure 2.28 Stem cells may help in the treatment of heart and neurodegenerative diseases.

Quick check 2.5

1 List the organelles that are found in animal cells.
2 Multicellular organisms are often made up of specialised cells. What does the term 'specialised cells' mean?
3 Use the term 'differentiation' to explain how specialised cells form.
4 Describe what stem cells are and their use in medicine.

Plant cells

Plants are different from all other eukaryotic organisms in many ways. Most noticeably, they do not need to move in order to search for food, because they can make their own food in the process you met in Year 7 called *photosynthesis*. This difference means that plants have some organelles that animals and fungi lack. The special organelle in plants that carries out photosynthesis is called a **chloroplast**. Chloroplasts contain a green pigment called *chlorophyll*, and this pigment captures the Sun's light and makes plants green.

chloroplast
a structure in a plant cell that contains chlorophyll

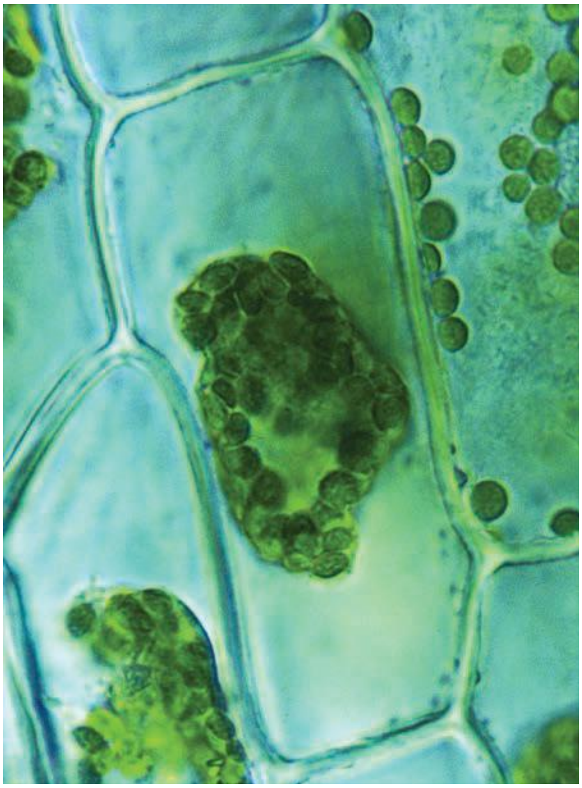


Figure 2.29 Plant cells: the green blobs are chloroplasts. Also note the thick cell wall that surrounds each cell.

Chloroplasts are found in plant cells that are exposed to light (e.g. leaf cells) but not in cells of the roots.

ISBN 978-1-108-61069-8 Cambridge University Press

Figure 2.30 Eucalyptus trees can only grow as tall as they do because of the rigid cell wall that surrounds each of their cells.

Because plants do not need to move, they lack a skeleton and muscles, but they still need to be able to support their weight so they can grow tall, towards the light from the Sun. This is why plant cells have a **cell wall**. The cell wall is a rigid structure that surrounds each cell (sitting outside the cell membrane) and provides shape and support for the plant. The cell wall is made of a substance called *cellulose*.

cell wall
a rigid structure that surrounds each plant cell, shaping and supporting the cell

Plant cells also contain an organelle called a **vacuole**. This organelle stores water and other nutrients for the plant. It also works with the cell wall to help support the plant and give it shape. If you have ever forgotten to water your plants at home, you might have noticed that they droop and wilt, becoming floppy, and if not watered will start to die. This is because the vacuoles in each cell are losing water, the cells become flaccid, and so the plant cannot hold its shape. Animal cells also contain vacuoles, but they are much smaller and are mainly used for storage of nutrients. The cells of some fungi, protists and bacteria may also have vacuoles.

vacuole
a structure in a plant cell that stores water and nutrients

Figure 2.31 A thirsty plant: the vacuoles are no longer full of water and so they cannot help to support the plant in standing upright.

Quick check 2.6

1 Name the organelles in a plant cell that an animal cell does not have.
2 Explain why plant cells have each of these 'extra' organelles.

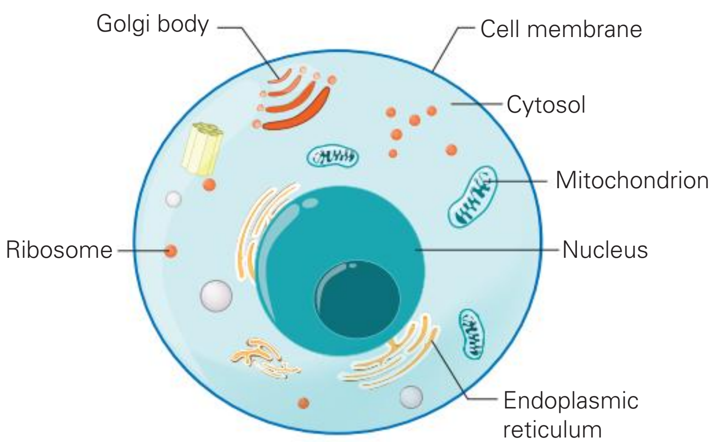
ISBN 978-1-108-61069-8 Cambridge University Press

Distinguishing animal cells from plant cells

You have seen that animal cells and plant cells have many organelles in common, as they are both eukaryotic cells that have many processes in common. However, you have also learned about the additional organelles that plant cells have, because these multicellular organisms have different structures and functions.

In addition, it is generally easy to identify plant cells under the microscope, because the cell wall usually gives them a shape with rigid straight lines and a thick outline, whereas animal cells have a less uniform shape and a much thinner outline.

WIDGET
Eukaryotic organelles



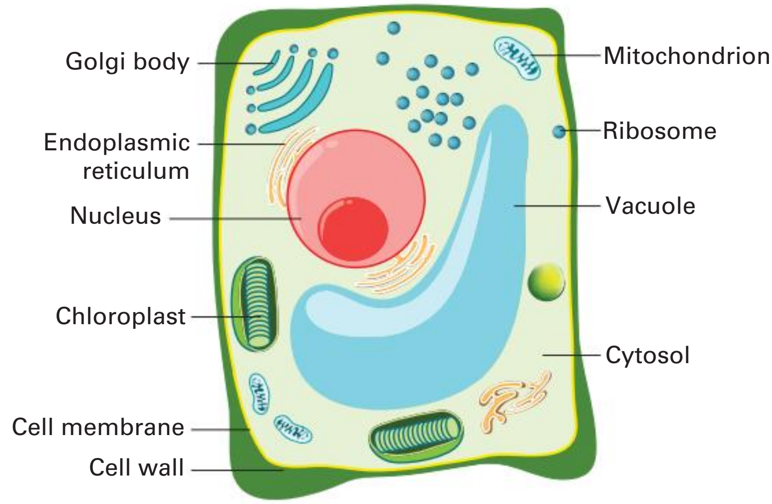


Figure 2.32 Animal cells and plant cells have many organelles in common, but because of their different structures and functions, there are also some different organelles.

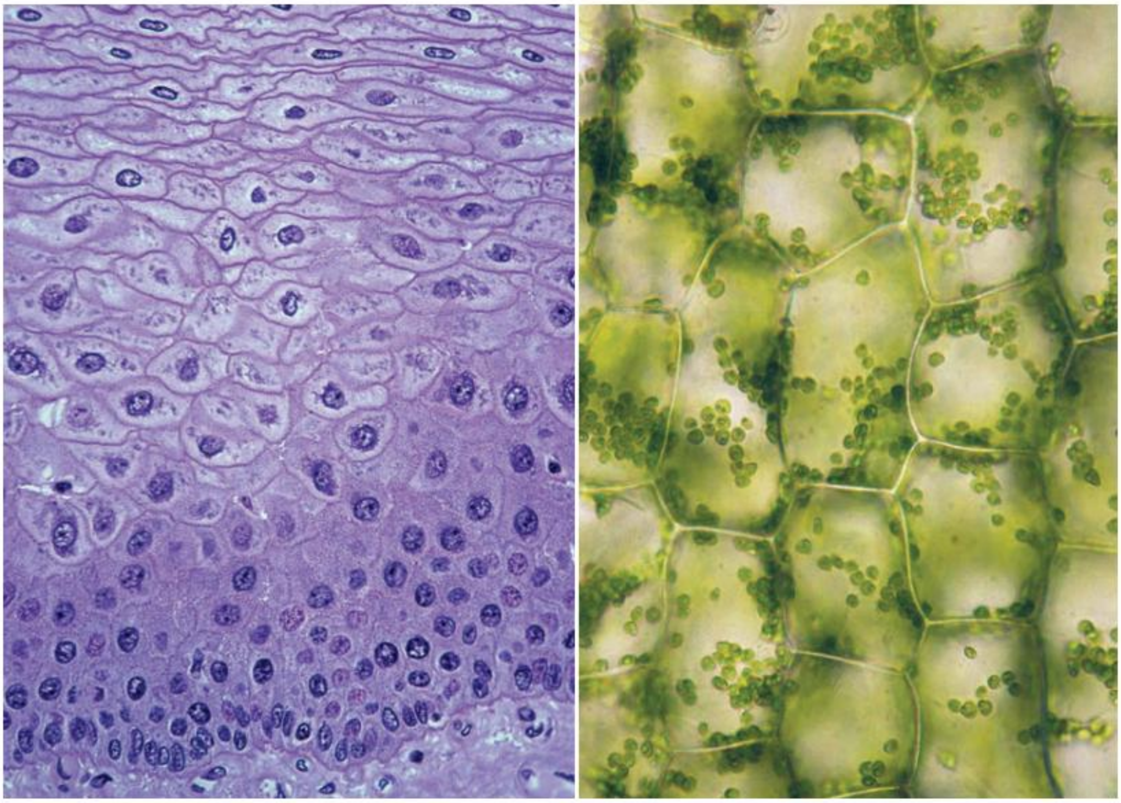


Figure 2.33 Left: Animal (oesophagus) cells at ×100 magnification. Right: Plant cells at ×100 magnification

ISBN 978-1-108-61069-8 Cambridge University Press

Try this 2.5

Making a wet mount

When you want to observe cells under a microscope, you need to prepare what is called a *wet mount*. Let's practise using pond water.

Use a pipette to place a drop of pond water in the centre of a glass slide. Then gently lower a cover slip onto the water, as shown in Figure 2.34. If the cover slip drops too quickly, it can trap air bubbles and then you won't be able to see your specimen as easily. Use a tissue or blotting paper on the edge of the cover slip to soak up any extra liquid.

Note: Some specimens may be dry and so you would need to add a drop of water. Some may be transparent, so you would need to add a stain instead of water.

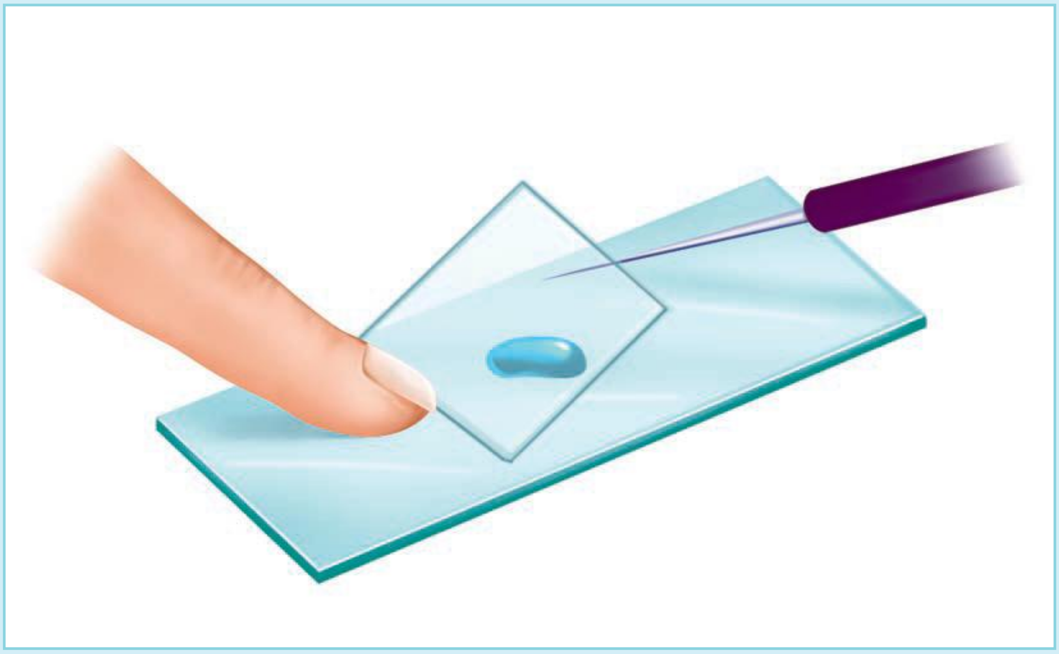


Figure 2.34 Lowering the cover slip slowly is very important when preparing a wet mount.

ISBN 978-1-108-61069-8

Practical 2.4

Observing cells under a microscope

Be careful

Ensure that the microscope is carried appropriately. Carry it with one hand holding the arm and one hand under the base. Do not use the coarse focus knob to cause the objective lens to touch the glass slide and damage it. No food items are to be consumed.

Aim

To observe the characteristics of plant and animal cells

Materials

- light microscope
- glass slides and cover slips
- toothpick
- onion and celery
- iodine solution
- ripe and unripe bananas
- prepared animal slides

Method

1. Prepare wet mounts:
   a. Peel a translucent (see-through) piece of tissue from the onion.
   b. Place the piece of onion tissue on a glass slide and add a drop of iodine solution.
   c. Cover the slide with a cover slip, using your wet mount technique.
   d. Repeat steps **a–c** for the celery.
   e. Use the toothpick to collect some ripe banana cells and smear them as thinly as you can across a glass slide.
   f. Add a drop of iodine solution and then cover with a cover slip.
   g. Repeat steps **e–f** for the unripe banana.
2. Observe the cells: starting with the microscope on the lowest magnification, turn the coarse focus knob until it is as close to the stage as it can go. Place on your first slide and focus using the coarse focus knob. Once focused, turn to the next objective lens. Use only the fine focus knob to focus now. Once focused, move to the highest magnification and again focus using the fine focus knob.
3. Draw a diagram: using a pencil, sketch diagrams of an onion cell, a celery cell, a ripe banana cell, an unripe banana cell, and four animal cells from the prepared slides. Label all the organelles you can see, using a ruler and labels at the side of the diagram. Record the name of the specimen, the magnification the drawing was drawn at, and determine the cell size.

Results

Your results will be in the form of four plant cell diagrams and four animal cell diagrams.

Evaluation

1. Explain why stains are needed.
2. Compare the onion and celery cells: what similarities and differences did you observe?
3. Compare the ripe and unripe banana cells: what similarities and differences did you observe? Can you explain the differences?
4. What characteristics did you observe in the plant cells? In the animal cells? What did they have in common? Explain why there are differences.
5. Were the plant and animal cells all the same size? If there are differences, can you explain why?

Conclusion

1. Make a claim regarding this experiment. Begin your statement with: ‘This experiment suggests that plant and animal cells … ’.
2. Support your claim by using the your observations. Begin your summary with: ‘It was observed that … ’.
3. Explain how the data supports your claim. Begin your sentence with: ‘This means that … ’.

ISBN 978-1-108-61069-8 Cambridge University Press

Practical 2.5

Making a model: 3D cell

Aim

To create a 3D model of a plant cell and an animal cell using the materials provided

Materials

- black beans
- white beans
- ping pong balls
- zip lock bags
- red food colouring
- green food colouring
- takeaway food container
- poppy seeds
- balloons
- glue and tape

Method

1. Look at the materials your teacher has provided for you and decide what you are going to use to represent each part of the plant cell and the animal cell.
2. Copy and complete the table below to indicate how each organelle is going to be represented in your model.
3. Construct your 3D model of the cell.
4. Explain to the class and your teacher how your model represents all the parts of a cell.

Results

Plants		Animals	
Cell	**Material used**	**Cell**	**Materials used**
Nucleus		Nucleus	
Cell membrane		Cell membrane	
Mitochondria		Mitochondria	
Ribosomes		Ribosomes	
Golgi body		Golgi body	
Endoplasmic reticulum		Endoplasmic reticulum	
Cytosol		Cytosol	
Large vacuole		Small vacuoles	
Chloroplast			
Cell wall			

Table summarising the materials you will use for constructing each of your model cells

Evaluation

1. Explain why models are used in science.
2. Assess two strengths and two limitations of your model.
3. Propose a way to make your model more accurate.

ISBN 978-1-108-61069-8

Fungi

Fungi are similar to both plants and animals, and most are multicellular, but they also have their own unique cell wall. Fungi are *heterotrophs*, like animals, which means they have to digest other organisms in order to gain nutrients. Fungal cells therefore don't have chloroplasts like plant cells do. They do have a cell wall, but it is made of *chitin*, not cellulose.

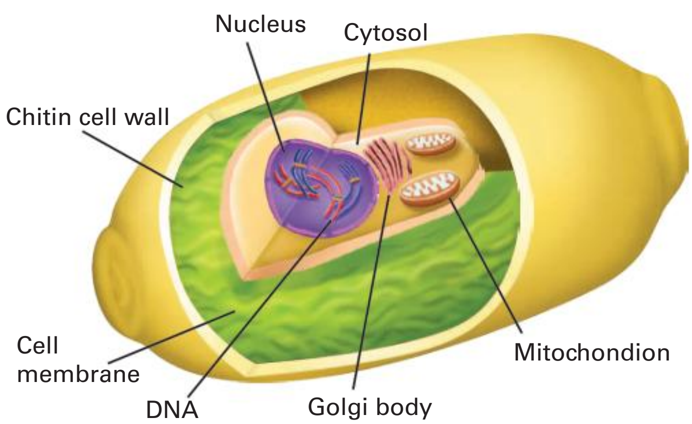


Figure 2.35 Diagram of a fungal cell

> **Fungi and beetles** — **Did you know? 2.4**
>
> The cell wall of fungal cells is made of chitin, and this is the same chitin that makes up the exoskeleton of insects such as beetles.
>
> 
>
> **Figure 2.36** Beetle exoskeletons and fungal cell walls are made of the same substance: chitin.

The main body of a fungus is called the *mycelium*; this is a large network of small filaments, called *hyphae*, that can stretch for over 10 kilometres! You don't often see hyphae, as they are very small, and you only really notice a fungus when it develops a fruiting body when conditions are perfect. This fruiting body can be seen as a mushroom or a toadstool, a truffle or a puffball. This is why you often see mushrooms appear soon after heavy rainfall. The fungus makes these fruiting bodies to produce spores in order to reproduce.

Figure 2.37 Fungi: (top) toadstool, (middle) chanterelle mushrooms, (bottom) puffball

ISBN 978-1-108-61069-8 Cambridge University Press

Practical 2.6

Observing mould

Aim
To observe the structure of citrus mould under a light microscope

Materials
- prepared slides of a mould sample (preferably citrus)
- microscope

Be careful

Ensure that the microscope is carried appropriately. Carry it with one hand holding the arm and one hand under the base. Do not use the coarse focus knob to cause the objective lens to touch the glass slide and damage it.

Method
1 Focus the microscope onto the mould, starting on the lowest power.
2 Draw the observed specimen, remembering to estimate size and record the magnification.

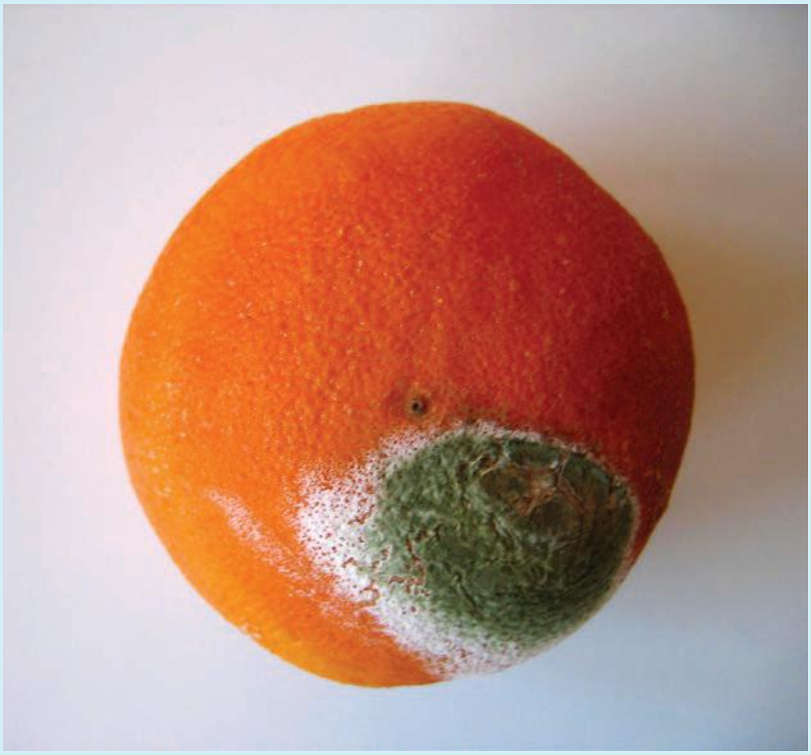


Figure 2.38 Citrus mould, a type of fungus

Results
Drawing of your specimen, including magnification and an estimate of size.

Evaluation
1 Describe the structure of the mould.
2 Identify whether the mould is unicellular or multicellular.
3 Are all the cells you are observing identical? What does this suggest?
4 Often some fruit in a fruit bowl can go mouldy while other fruit is not affected. Suggest a reason for this.

ISBN 978-1-108-61069-8 Cambridge University Press

Quick check 2.7

1. State whether fungi are prokaryotic or eukaryotic.
2. Name the organelle that fungal cells have that animal cells do not.
3. Contrast the cell wall of a plant with the cell wall of a fungus.
4. Explain the function of the cell wall.

Protists

Protista is a kingdom that consists solely of unicellular organisms that are eukaryotic. This means they contain the organelles that you learned about in the previous section. However, scientists have changed the classification of many of these organisms several times, because they display characteristics of both plants and animals. All **protists** need to live in a moist environment and so are very common in most aquatic environments. If you look at a sample of pond water under the microscope in the warmer months of the year, you will likely see many types of protists, such as euglena, rotifers, amoebas and paramecia. Each of these types of protists is slightly different in structure, depending on their function.

protist
a unicellular, eukaryotic organism that is part of the kingdom Protista

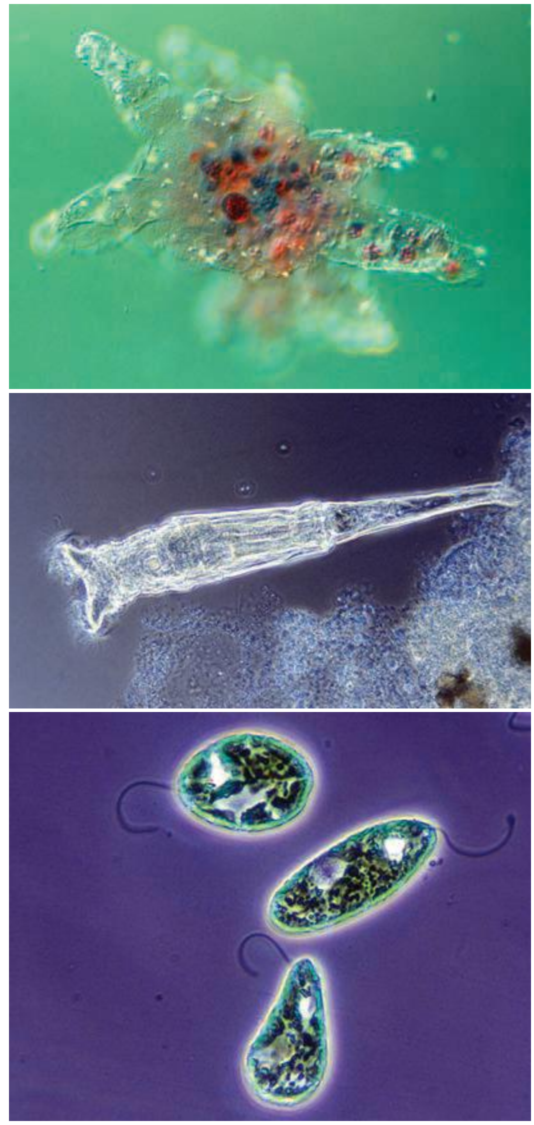


Figure 2.39 Protists: (top) amoeba, (middle) rotifer, (bottom) Euglena

Section 2.3 questions

QUIZ

Remembering

1. State the organelle involved in photosynthesis.
2. Name the three key differences between plant cells and animal cells in terms of their organelles.
3. List three examples of protists.
4. Define the term 'specialised cells' and provide examples.

Understanding

5. Outline the two parts of a plant cell that provide support and explain how they work together.
6. Explain why fungi are known as heterotrophs.
7. Summarise the steps you need to take when preparing a wet mount.
8. Stem cells are currently of massive interest to scientists. Research why this is the case, using what you have learned about their use in therapy and other medicinal applications.

continued…

ISBN 978-1-108-61069-8 © Roberts et al. 2019 Cambridge University Press

...continued

Applying

9 a Name the organelles labelled A to E in the eukaryotic cell shown in Figure 2.40.

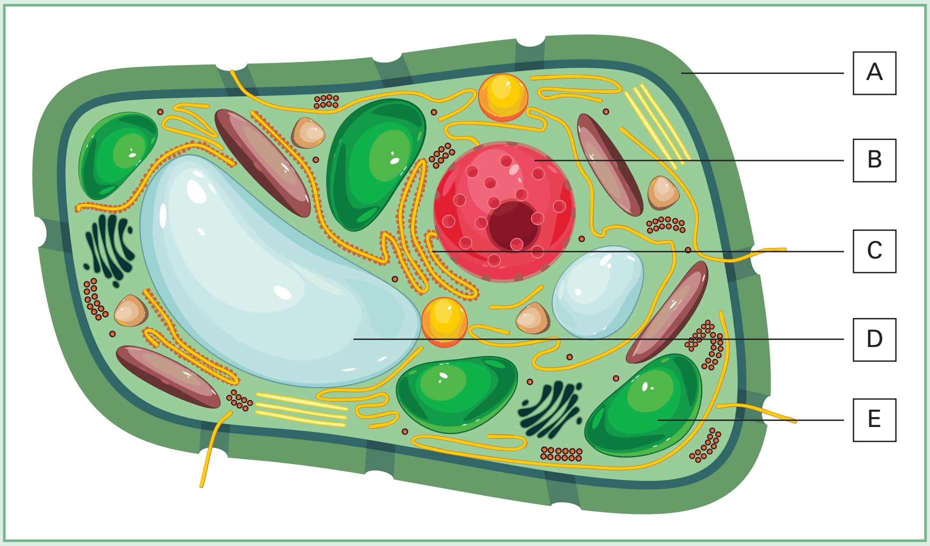


Figure 2.40 Eukaryotic cell

b What type of cell is shown in Figure 2.40? Explain your answer.

10 Identify where you are most likely to find protists.

11 Explain how the shapes of various cells help them to carry out their function within the body. You may like to refer to red blood cells, sperm cells and muscle cells.

Analysing

12 a Draw a Venn diagram to compare an animal cell to a fungal cell in terms of the cell's structure and organelles.

b Draw a Venn diagram to compare a plant cell to a fungal cell in terms of the cell's structure and organelles.

13 Yeast are unicellular eukaryotic cells, and belong to the Fungi kingdom. A student conducted an experiment to test the effect of temperature on the activity of yeast, which will produce a gas when added to a solution of sugar in water. The student placed 2 g of yeast and 10 g of sugar into a glass apparatus full of water, designed to trap any gas produced in a narrow closed vertical tube at the top. The amount of gas can be measured by the height of the column of gas that collects in the tube. They did the experiment three times with the apparatus containing water at three different temperatures, and measured the height of the column of gas produced after 1 minute.

Temperature (°C)	Height of column of gas produced in the tube (mm)			
	Trial 1	Trial 2	Trial 3	Average
10	60	64	62	62
30	102	98	100	100
60	20	14	17	17

a Using the student's results, assess the effect of temperature on yeast function.

b Identify the optimum temperature for yeast.

c Suggest the effect that an even higher temperature, such as 100°C, would have on the yeast being tested.

Evaluating

14 Justify this statement: 'Fungi are all around us but you can't always see them.'

15 Propose reasons why humans need muscles and a skeleton, whereas plants do not.

ISBN 978-1-108-61069-8 Cambridge University Press

2.4 Function and malfunction

Cell division

WORKSHEET

At the start of this chapter you learned about cell theory. The development of cell theory was made possible by the invention of the microscope, which allowed scientists to observe and prove certain characteristics that all cells display. One of the most easily observable parts of cell theory is that 'all cells come from pre-existing cells'. This is referring to cell division, when one cell splits to form two new identical cells, called *daughter cells*. The scientific term for this process in eukaryotes is **mitosis**. In prokaryotes, it is known as **binary fission**.

mitosis
the type of cell division in which one cell divides into two cells that are exactly the same

binary fission
a mode of asexual reproduction by bacteria, where genetic information is copied and the cell splits in half

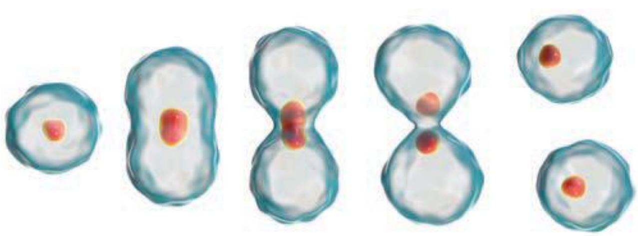


Figure 2.41 A simplified representation of mitosis: one cell forms two new daughter cells

Figure 2.42 A cut heals because mitosis occurs, creating new cells to replace the damaged ones.

Did you know? 2.5

Skin

You lose about 40 000 skin cells every minute of every day. This means that, over a lifetime, you will lose at least half of your body weight in skin cells. Have you ever wondered where dust comes from? Most of the dust in your house is made up of your dead skin cells. No wonder mitosis happens a lot!

Why do cells divide?

Mitosis happens for a number of reasons: repair, growth and reproduction.

Repair

If you cut your skin or break a bone, your body can close the wound or set the bone over time. This happens because millions of new cells are produced to replace the damaged cells. Some cells in your body, such as your red blood cells and skin cells, need to be replaced regularly.

Growth

In order to grow, your body needs to make more cells. You first started out as a single cell, which was a fertilised egg. By the time you become an adult, you will be made of around 37.2 trillion cells. A massive amount of cell growth occurs before you are born and in your first few years of life, but you will still be growing until your late teens. This means your bone cells need to reproduce in order for you to get taller, your muscle cells need to keep up with your bone cells, and your nerve cells need to grow in order to extend throughout your body.

ISBN 978-1-108-61069-8 Cambridge University Press

Figure 2.43 Plants need to grow too, and so their cells also undergo mitosis.

Reproduction

Unicellular organisms such as bacteria remain one cell their entire life. They don't undergo cell division for growth and repair, because their whole body is just one cell. The only reason bacteria divide is for reproduction. This form of reproduction is known as *binary fission* and involves the bacterium splitting in half to produce an identical copy of itself. Because this process does not require a mate and is fairly simple, bacteria can reproduce around every 30 minutes. This means that, in one day, a single bacterial cell could become 140 737 488 355 328 cells.

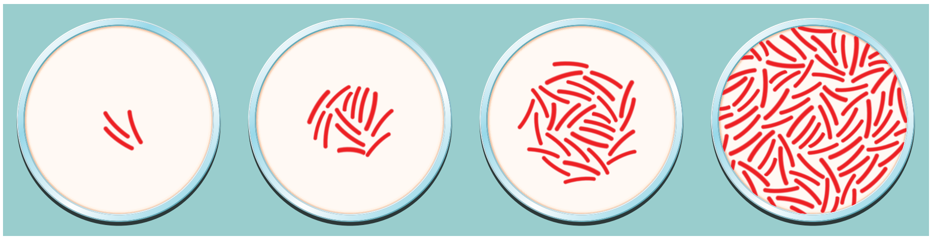


Figure 2.44 Bacteria, under the right conditions, can reproduce very quickly by binary fission.

Explore! 2.5

Cancer

Cancer is a disease of the body's cells. Cells normally grow and multiply in a controlled way, but if there is a change in someone's genetic material, this control can be lost. *Cancer* is the term used to describe uncontrolled cell division. Because cancerous cells can arise from almost any type of cell, there are about 100 different types of cancers.

1 Research and define the terms 'benign' and 'malignant'.
2 Select a type of cancer to investigate – for example, prostate, breast, bowel, skin, lung. Summarise the cause, prevention and treatment of the chosen cancer.

Figure 2.45 Doctor checking a mole for signs of skin cancer

Science as a human endeavour 2.4

Cervical cancer

You may have seen in the news in late 2018 that Australia is on track to be the first country in the world to eliminate cervical cancer. This prediction has been credited to the introduction, a decade ago, of the human papillomavirus (HPV) vaccination program for schoolchildren. The Cancer Council NSW has shown that, if vaccination and screening levels are continued, rates of diagnosed cervical cancer will drop.

Figure 2.46 HPV vaccination

ISBN 978-1-108-61069-8

Cambridge University Press

Quick check 2.8

1. Cell division is a normal process that occurs in your body. List the three reasons it occurs.
2. Explain why skin cells need to divide regularly.
3. What is the name of the process that bacteria undergo to reproduce?
4. Describe a disease that results from a malfunction of the normal process of cell division.

Micro-organisms

Micro-organisms are organisms that are so small they can only be viewed using a microscope. Bacteria, some fungi and some protists are examples of such small organisms. As you know, most bacteria (such as those in your intestines) and fungi (such as the yeast used to make bread) are harmless and can actually benefit us in some way. However, some are dangerous. 'Germ' or 'pathogen' is the general term used to refer to a micro-organism that can cause a disease or infection. When you go to the toilet you probably wash your hands straight away. This is because you were taught from an early age that washing your hands kills germs. This might seem like common sense, but until about 150 years ago, people didn't know that diseases came from micro-organisms and that the air is full of micro-organisms. Before this time, people believed that mould on bread appeared spontaneously – this theory is known as *spontaneous generation*.

A scientist known as Louis Pasteur was a microbiologist who used microscopes to study the microscopic world. He conducted a series of experiments proving that food went off because it was contaminated by micro-organisms in the air. His experiments led him to invent *pasteurisation*, which is the process of heating food or drink to a high enough temperature to kill any micro-organisms, before sealing it. This drastically increases the shelf life of foods and prevents the spread of disease.

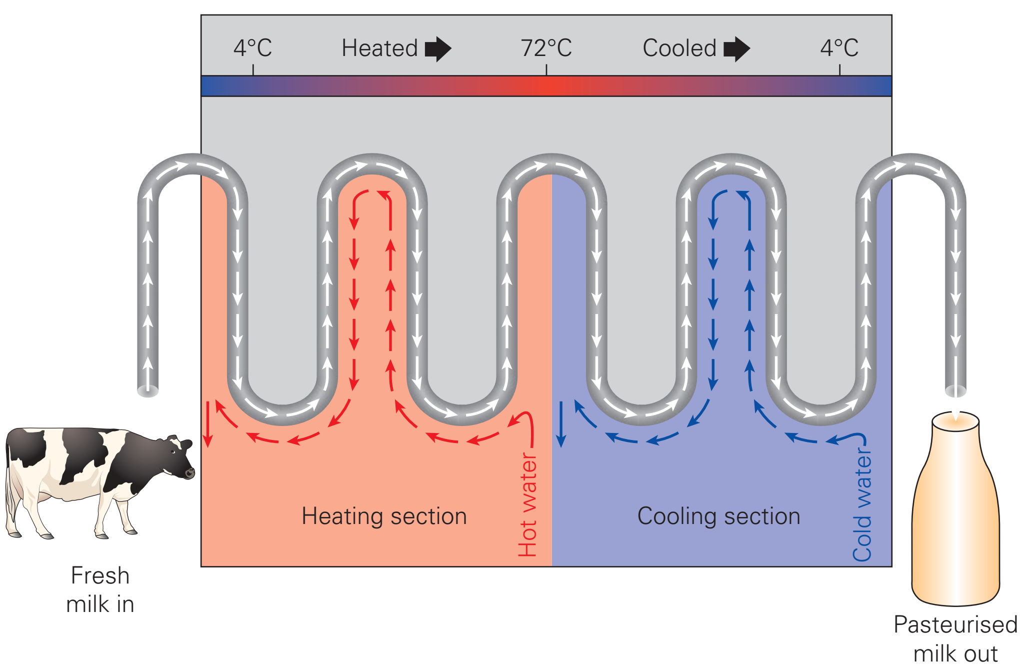


Figure 2.47 The process of pasteurisation

ISBN 978-1-108-61069-8

Cambridge University Press

Try this 2.6

Observing 'friendly' bacteria under the microscope

Using your microscope and wet mount preparation skills, look at some bacteria under the microscope. You will need the stain called methylene blue, and a sample of yoghurt or probiotic drink containing live bacteria strains. Look at the size and structure of the bacterial cells, and consider how similar/different they are to eukaryotic cells like plant and animal cells.

Practical 2.7

Modelling pasteurisation

Be careful

Ensure benches are cleaned and hands are washed before leaving the laboratory.

Aim

To test the effect of temperature on the growth of bacteria

Materials

- probiotic drink
- 4 agar plates
- sterile swabs
- evaporation dish
- Bunsen burner
- tripod, heatproof mat, pipe clay triangle
- sticky tape
- disposable gloves

Method

Part 1: Boiled probiotic

1 Place 10 mL of probiotic drink into the evaporation dish.
2 Heat to boiling point using a Bunsen burner.
3 When the mixture starts to boil, turn off the heat.
4 Dip the sterile swab into the heated mixture and spread the mixture over the agar sheet, as shown in Figure 2.48 and explained below.
Swabbing technique
When you use the sterile swab, gently rub the swab over the agar in tight lines to start with, and then slowly spread the lines apart as you move down the agar plate.

Figure 2.48 How to rub the swab over the agar

5 Place the lid on the plate and, with 2 to 4 pieces of sticky tape, tape down opposite edges of the plate.
6 Label the agar plate. Write your group name, date, and the independent variable. Keep your writing small, and write around the outside edge of the agar plate.
7 Place the agar plate in the incubator with the agar side up, at 30 degrees, for two days.

Part 2: 30 degree probiotic

8 Dip a new sterile swab into the original probiotic mixture (unboiled).
9 Swab an agar plate as you did previously.
10 Seal the agar plate with sticky tape around the outside and label the agar plate underneath.
11 Place the agar plate in the incubator with the agar side up, at 30 degrees, for two days.

Part 3: Refrigerated probiotic

12 Repeat steps **8–10** and place the agar plate in the refrigerator for two days.
13 Identify the following variables in your experiment: independent variable, dependent variable and controlled variables.
14 Write a hypothesis or prediction about how each condition will affect the growth of bacteria.
15 After two days, remove the agar plates from the incubator and refrigerator, and count the number of colonies that you can see on the agar plates. A colony should look like a slightly raised round dot on the agar plate.

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Results

Copy and complete the table, to record your results.

Probiotic treatment	Number of bacterial colonies
Boiled	
Kept at 30°C	
Refrigerated	

Summary of the experimental results

Evaluation

1 Did your results support or disprove your hypothesis? Explain your results for each treatment.
2 Suggest two ways that your results could be useful for controlling bacterial growth.
3 Propose another independent variable that could have been tested, to expand on your results.
4 Consider whether you had a control in this experiment. If so, which treatment was the control? Explain your answer.
5 Describe three possible sources of error and suggested improvements for this experiment.

Conclusion

1 Make a claim regarding this experiment. Begin your statement with: 'This experiment suggests that temperature … '.
2 Support your claim by using the data you gathered and include potential sources of error. Begin your summary with: 'The results show that … '. Also include: 'Possible sources of error were … '.
3 Explain how the data supports your claim. Begin your sentence with: 'This means that … '.

Following on from Pasteur's experiments, other scientists used microscopes to help them link micro-organisms to disease. This led to the realisation that washing our hands, cleaning our homes and cooking food properly can limit the spread of disease.

Figure 2.49 Washing hands can prevent the spread of micro-organisms.

By following simple hygiene practices, humans are living much longer and healthier lives. Some ways in which you can prevent the spread of micro-organisms and prevent diseases from passing from one person to another are:

1 Cover your mouth and nose with a tissue or your elbow pit when you sneeze.
2 Wash your hands regularly, especially if you cough or sneeze into your hands.
3 Avoid touching your eyes, nose or mouth after touching contaminated surfaces such as hand rails or door handles.
4 Do not share drink bottles or cutlery with other people unless the bottles or cutlery are clean.
5 Quarantine – this is when a sick person is kept away from the healthy population, to prevent the illness from spreading. If your doctor has ever told you to stay home from school, that is a form of quarantine.

ISBN 978-1-108-61069-8

Cambridge University Press

Figure 2.50 Always sneeze into a tissue.

Did you know? 2.6

Touching your face is one of the easiest ways to allow micro-organisms into your body. On average people touch their face around 2000 times per day. See how many times you touch your face in the next 20 minutes – it may shock you!

Figure 2.51 How many times do you touch your face?

Quick check 2.9

1 Define the following terms: pathogen, micro-organisms, pasteurisation.
2 Explain the link between the three terms in Question **1**.
3 Why is it better to sneeze into your elbow and not into your hands?

Disease

When someone says 'disease' it might seem obvious what they mean. However, a disease can be many things: it can be a viral, bacterial or fungal infection, it can be inherited from your parents, or it can be a condition that develops over time due to your environment. That is why we say that a disease is any condition that negatively affects the normal functioning of any part of a living thing. Because this definition is very broad, we classify diseases into two categories: infectious and non-infectious.

Having a deeper understanding of cells allows us to understand and treat many diseases.

In the past, if you were very sick and had to go to the doctor, you many have been given **antibiotics**. Antibiotics kill most of the bacteria they come into contact with, but do not harm the cells of your body.

antibiotic
a medicine or chemical that can destroy harmful bacteria in the body or limit their growth

Figure 2.52 Antibiotics kill most of the bacteria they come into contact with.

Before the invention of modern antibiotics, there were limited ways to treat bacterial infections, so if you had a cut that was infected, you had two choices. You could either try the limited treatments, wait and hope that the infection got better and did

ISBN 978-1-108-61069-8 Cambridge University Press

Figure 2.53 Infected mouth ulcer

not spread, or you could cut that part of your body off, to prevent the infection from spreading to the rest of your body.

Alexander Fleming accidentally discovered the first antibiotic effective against a wide range of bacteria in 1928, when he was growing some bacteria in a laboratory. The bacteria became contaminated with a mould from some fruit, and he noticed that the mould was killing the bacteria. This led to the discovery of the first antibiotic, called *penicillin*. Penicillin works by breaking down the cell wall of bacteria, which causes the cells to burst and die. For his work on developing penicillin and being the first to use it to treat an infection, the Australian

Figure 2.54 Testing antibiotics

scientist Howard Florey shared the Nobel Prize with Alexander Fleming and one other.

Today we have developed many other types of antibiotics. Some work in the same way as penicillin, and others slow or prevent the reproduction of bacteria, which gives the body's immune system a better chance to deal with the infection itself.

Figure 2.55 Sometimes rest is all your body needs, to help heal itself.

It is important to remember that antibiotics only work on bacteria. If you are infected by a virus or some other type of micro-organism, taking antibiotics will not cure you. In fact, taking antibiotics when you don't need them can kill all the good bacteria in your digestive system, and in the long term can help to create bacteria that are resistant to antibiotics.

Figure 2.56 Antibiotic-resistant bacteria are a very real threat.

ISBN 978-1-108-61069-8 Cambridge University Press

Fighting antibiotic-resistant bacteria

Science as a human endeavour 2.5

According to the World Health Organization, around 700 000 people die every year as a result of antibiotic resistance. Antibiotic-resistant bacteria cannot be killed using antibiotics. In 2017, scientists in the UK and Germany published the findings of their discovery: a new way of targeting the processes that bacteria carry out. This discovery could lead to the development of new antibiotics and help overcome antibiotic resistance.

Quick check 2.10

1. State the definition of 'disease'.
2. State the categories of disease.
3. Name a type of antibiotic.
4. Describe how antibiotics work.

Practical 2.8

Fungi-fighting bacteria

Background information

Some bacteria produce an antifungal substance – this is a substance that can kill fungi. Soil is a good source of antifungal bacteria, and so your aim in this experiment is to test the effectiveness of different soil dilutions on the growth of fungi.

Aim

To test the effectiveness of different soil dilutions on the growth of fungi

Be careful

Ensure benches are cleaned and hands are washed before leaving the laboratory.

Materials

- 4 dilutions of soil: 10% (1 g soil), 20% (2 g soil), 30% (3 g soil) and 40% (4 g soil) with water added up until the 10 mL mark for each dilution
- yeast solution (1 tablespoon yeast in 250 mL warm water)
- 1 agar plate per group
- sterile swab
- 4 plastic pipettes
- sticky tape
- disposable gloves

Method

1. Identify the independent and dependent variables for this experiment.
2. Using the variables you identified in step **1**, write an experimental hypothesis or prediction to be tested.
3. Draw a cross on the bottom of the agar plate, creating four quadrants.
4. Thoroughly swab the agar plate with the yeast solution, horizontally and then vertically, to get full coverage.
5. Using a pipette, place a few drops of each soil dilution in each quadrant and label the agar plate lid.
6. Allow time for the drops to be fully absorbed into the agar.
7. Cover the agar plate with the lid and with 2 to 4 pieces of sticky tape, tape down opposite edges of the plate. Label the outside edge of the plate on the agar side.
8. Place in an incubator at 30°C for two days.
9. Observe the growth of the yeast in each quadrant and record the results.

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Results

Record your results in the table below.

Soil dilution (%)	Amount of yeast growth as a % of the quadrant

Evaluation

1 Did your results support or disprove your hypothesis? Explain.
2 Suggest an application in real life for your findings.
3 Identify three variables you controlled in this experiment. Explain the importance of each of these controlled variables.
4 Identify sources of error in this experiment, and suggest ways in which the experiment could be improved.

Conclusion

1 Make a claim regarding this experiment. Begin your statement with: 'This experiment suggests that soil … '.
2 Support your claim by using the data you gathered and include potential sources of error. Begin your summary with: 'The results show that … '. Also include: 'Possible sources of error were … '.
3 Explain how the data supports your claim. Begin with: 'This means that … '.

Section 2.4 questions

QUIZ

Remembering

1 Define the term 'mitosis'.
2 State the three reasons that cells divide.
3 Why are antibiotics only useful in treating bacterial infections?

Understanding

4 Explain how bacteria reproduce.
5 Sometimes cells are described as clones. Explain what this means.
6 Demonstrate the difference between infectious and non-infectious diseases, using examples.

Applying

7 Summarise the process of pasteurisation, illustrating how it is beneficial to humans.
8 Identify the reasons why you should never remove the sticky tape from your agar plates after carrying out an experiment investigating bacteria and its antifungal properties.
9 Explain in what way cancer relates to the control of cell division.

Analysing

10 Distinguish between malignant and benign cancer.
11 Compare how the development of different microscopes has led to our current understanding of cells.

Evaluating

12 'Pasteurisation has led to improved human health.' Assess the truth of this statement.
13 Design an experiment that investigates hand washing. Your aim is to determine the effectiveness of washing hands on preventing bacterial growth. You may like to begin by identifying your independent and dependent variables, and consider using agar plates for this task.

ISBN 978-1-108-61069-8 Cambridge University Press

Review questions

SCORCHER

Remembering

1 Of the four kingdoms – Animal, Plant, Fungi, Protist – which consist of unicellular organisms and which consist of multicellular organisms?
2 Name two examples of protists.
3 Name three types of specialised cells.
4 Name the common components of the monocular light microscope.

Understanding

5 a What is the role of the following organelles in the cell?

Organelle	Role in the cell
Nucleus	
Cytosol	
Golgi body	
Ribosomes	

b Copy the cell diagram below, and label the organelles listed in part **a**.

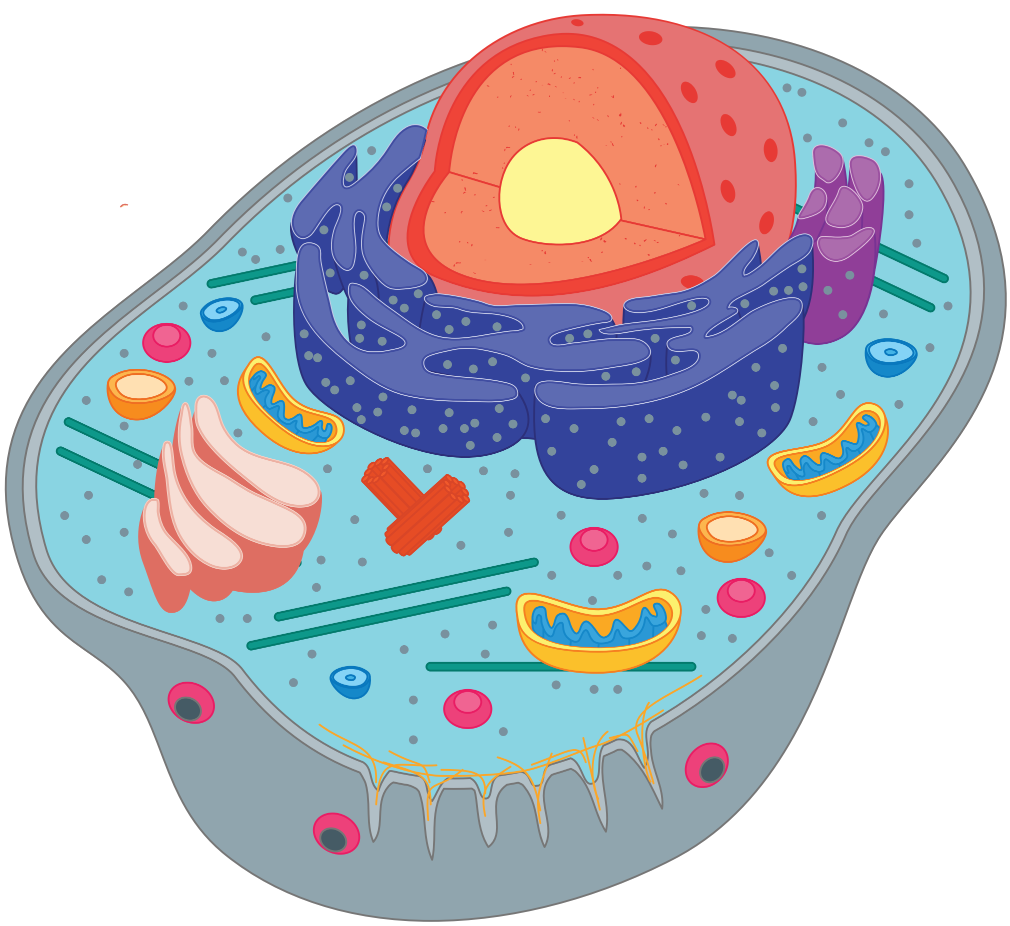


Figure 2.57 Eukaryotic cell

c Is the cell shown in part **b** a plant cell or an animal cell? Explain how you know.
6 Identify the role of the mitochondria in cells and why they are so important.
7 Identify the type of cell that can turn into any other type of cell.

ISBN 978-1-108-61069-8

Cambridge University Press

8 Place the following microscope instructions in order by numbering the steps in the left column. Step 1 has been done for you.

Step	Description
	Check that the iris adjustment is open
	Draw a diagram
	Return to low magnification objective lens
	Centre your specimen slide on the stage
	Rotate the objective lenses until the low magnification lens is in place
	Turn on the power
1	Carry microscope with two hands to the bench
	Carry microscope with two hands back to the cupboard
	Turn off the power and let the lamp cool
	Using coarse focus knob, focus away from the slide
	Lower the lowest magnification objective lens until it is close to the stage
	Swing a higher magnification objective lens into place
	Remove cover and plug in the microscope
	Unplug the microscope, pack up and place on cover
	Use only the fine focus knob

Applying

9 After going on holiday, you come home to find that all your plants are wilted. Explain why this has occurred, referring to parts of the cell.

10 Identify two disadvantages of the electron microscope.

11 Identify the type of microscope that needs to be used to view objects smaller than a cell.

12 a Use 'yes' or 'no' to complete the table below, which summarises the organelles that are found in each cell type.

	Animals	Plants	Fungi
Nucleus			
Cell wall			
Large vacuole			
Cytosol			
Cell membrane			
Chloroplast			

b Classify animals, plants and fungi as unicellular, multicellular or both.

Analysing

13 Peroxisomes are small organelles found in eukaryotic cells. Their job is to break down waste in the cell. Using the 'cell as a city' model, suggest an appropriate analogy for peroxisomes.

14 Contrast the terms 'resolution' and 'magnification'.

15 Draw a Venn diagram that compares prokaryote cells (such as bacteria) to eukaryotic cells (such as plant and animal cells).

Evaluating

16 Create a flow diagram to describe the process involved in a stem cell transplant for leukaemia.

17 Evaluate the use of models when explaining the structure of the cell.

ISBN 978-1-108-61069-8 Cambridge University Press

STEM activity: Design a city

VCSSU092 VCDSTC048 VCDSCD049 VCDSCD051 VCSIS113

Background information

All living things, from humans to dogs, trees and bacteria, are made up of cells. Cells are the smallest unit of life and are so small that you cannot see most of them without a microscope. While some organisms, such as bacteria, are made up of only one cell, multicellular organisms can be made up of trillions of cells. Cells work together to form organs, which work together to form body systems (e.g. respiratory, circulatory), which are vital in working together to form complex multicellular organisms.

Although cells are small, they are complex. For example, today we use microscopes to see inside a cell and observe even smaller components of the cell, called organelles. These organelles all have different functions and work together to keep the cell alive. Cells also reproduce via a process called mitosis, in which each cell divides and produces two identical cells. Unicellular organisms reproduce by mitosis, and multicellular organisms use mitosis for growth and repair.

Analogies are often used in science to explain, in simple terms, how processes work. An *analogy* is a comparison with something familiar. The way in which organelles in a cell function together can be compared with the way in which the components of a city work together to make the city function well. Cities all need to have structures and processes in place, to manage functions such as transport, sanitation, utilities, housing, construction and food production. There also needs to be a governing body that oversees all these activities.

Figure 2.58 A cell can be compared to a city.

ISBN 978-1-108-61069-8

Design brief: Design a city using cells as a model

Activity instructions

Your task is to design a city, based on the structure and functions of a cell. Your model should address some of the challenges that we face in modern cities (e.g. transportation, overcrowding). You will first need to think about all the major organelles and their functions, and then try to relate them to a feature of a city. For example, the mitochondria are often described as being like the power plant of a cell.

Once you have determined all the analogies, brainstorm some of the major challenges faced by people living in modern cities. Research the ways in which a cell might solve the various challenges you have come up with, and put together a presentation illustrating your solutions.

This is an opportunity to be creative. Your presentation could include sketches or diagrams, and should it propose solutions to a number of problems encountered in modern cities.

Suggested materials/presentation format

- Poster
- PowerPoint
- Video

Evaluate and modify

1. Analyse the solutions you have come up with, and comment on how achievable they would be in the real world today.
2. Explain any problems that might be encountered when implementing your solutions in the real world today. What types of technologies could be incorporated into your solutions (e.g. artificial intelligence, renewable energy)?
3. Evaluate the effectiveness of your analogies by examining what features of how a city works are different from how a cell works. For example, if you have mentioned that chloroplasts are like solar panels, explain how the process of photosynthesis is different from the process of converting light energy into electricity.

ISBN 978-1-108-61069-8

Chapter 3 **Organ systems**

Chapter introduction

You are a large and complex multicellular organism. You eat, move, sleep, think, breathe and fight disease every day, and you can only do this because of all the different types of cells and tissues in your body. Throughout this chapter, you will learn about how the cells, tissues and organs in your body work together to allow you to function effectively. You will also explore how scientific advances have allowed humans to repair and replace parts of the body.

Curriculum

Multicellular organisms contain systems of organs that carry out specialised functions that enable them to survive and reproduce (VCSSU094)	
• examining the specialised cells and tissues involved in structure and function of particular organs	3.1
• describing the structure of each organ in a system and relating its function to the overall function of the system	3.2, 3.4, 3.5
• identifying the organs and overall function of a system of a multicellular organism in supporting life processes	3.2, 3.4, 3.5
• comparing similar systems in different organisms, for example, digestive systems in herbivores and carnivores, respiratory systems in fish and mammals	3.3, 3.6

Victorian Curriculum F–10 © VCAA (2016)

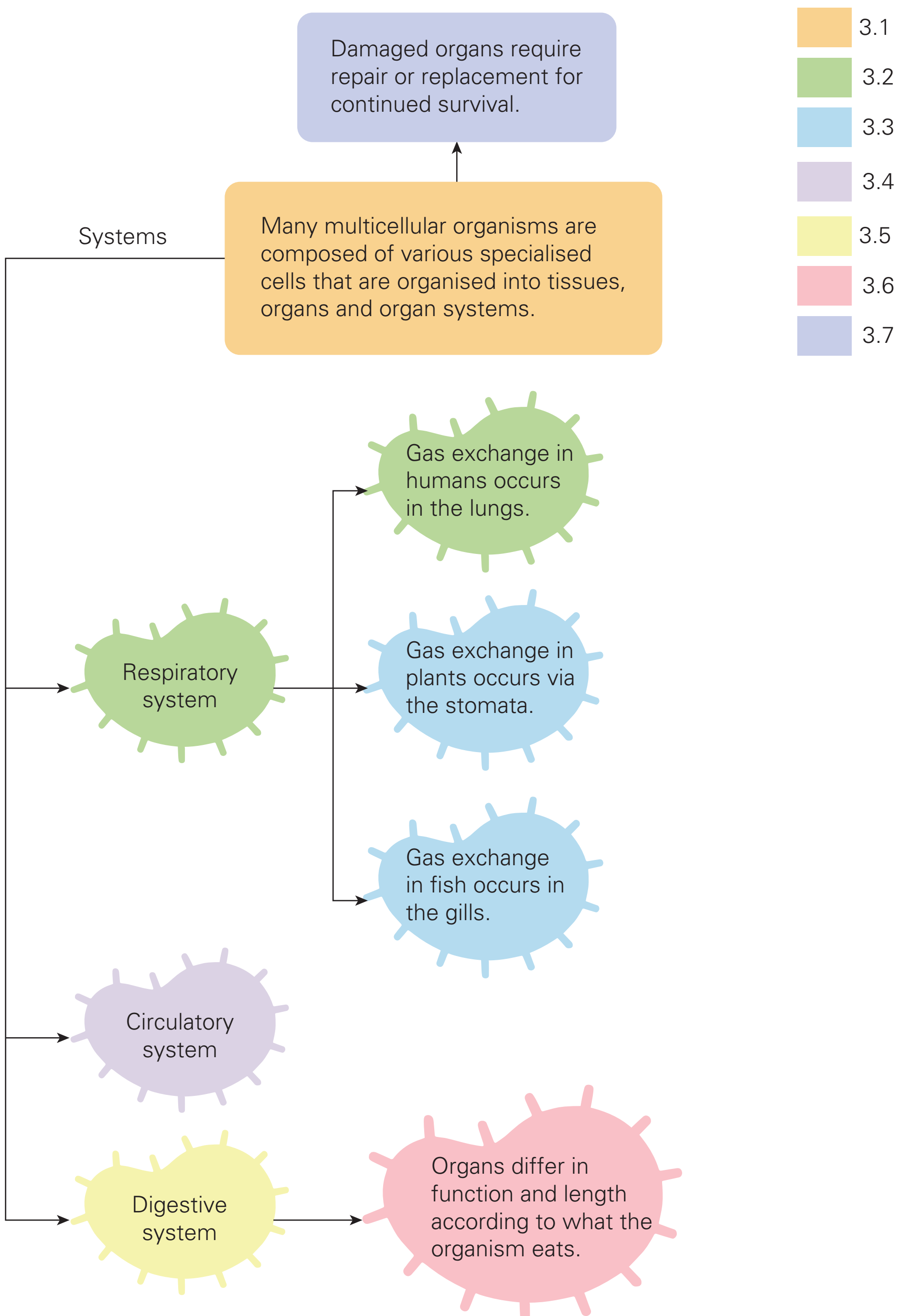
ISBN 978-1-108-61069-8

Glossary terms

alveoli
anus
aorta
artery
atrium
bile
bolus
bronchi
bronchioles
capillaries
carnivore
cellular respiration
chemical digestion
chyme
diaphragm
duodenum
enzyme
ethical
function
gall bladder
guard cells
haemoglobin
herbivore
ileum
jejunum
lenticels
mechanical digestion
neuron
organ
organ rejection
organ transplantation
pancreas
pharynx
plasma
platelets
rectum
saliva
sinoatrial node
sphincter
stomata
structure
tissue
trachea
vein
vena cava
ventricle
villi
xenotransplantation

ISBN 978-1-108-61069-8 Cambridge University Press

Concept map



ISBN 978-1-108-61069-8

Cambridge University Press

3.1 Cells to systems

Specialised cells

WORKSHEET

Humans are animals, and our cells contain a nucleus, cell membrane, cytoplasm, mitochondria and all the other organelles discussed in the previous chapter. Even though most of our cells contain the same basic components, the different types of specialised cells within our bodies all have certain features or **structures** that allow them to perform a specific **function**. A structure is any physical part of an object, and a function is an activity that the structure helps the object to complete.

structure
the shape of an object

function
the job that an object does

All the cell types in your body begin as unspecialised stem cells. As the cells grow and develop, they differentiate, forming over 200 different types of cells that are you. These cells then replicate to produce more copies of each type of specific cell.

Neurons

Nerve cells or **neurons** allow all the parts of your body to work together, by transferring signals to and from your brain to each part of your body via the nervous system. Nerves are important because they allow us to interact with the world around us via our senses. Neurons are long, thin cells that connect to each other via their highly branched ends. They have long axons, which are specialised to carry electrical signals over long distances, at very fast speeds. The longest nerve cell in your body stretches from the bottom of your spine to your big toe.

neuron
a nerve cell

Figure 3.1 Neurons are shown on the left, and on the right is the main organ of the nervous system, the brain.

Red blood cells

Red blood cells transport oxygen to all the cells in your body. These blood cells have to pass along tiny blood vessels and so they are flat and have a bi-concave shape, like a flexible disc or a donut.

Figure 3.2 Red blood cells travelling through a blood vessel

ISBN 978-1-108-61069-8 Cambridge University Press

When they reach maturity they do not have a nucleus, which gives them extra room to carry oxygen around the body. As they do not have a nucleus, they cannot undergo cell division, and so all red blood cells are produced in the bone marrow. Your red blood cells are replaced every 120 days.

Sperm cells

Sperm cells carry half the genetic information of a normal human cell. Their purpose is to combine with an egg cell in a process known as fertilisation, which is the first step of reproduction. This means that the sperm cells have to be able to move. That is why they have a specialised tail, called a flagellum, which beats in a corkscrew motion and allows the sperm cell to swim. Sperm cells also have many mitochondria at the top of the tail, to provide energy for fast movement.

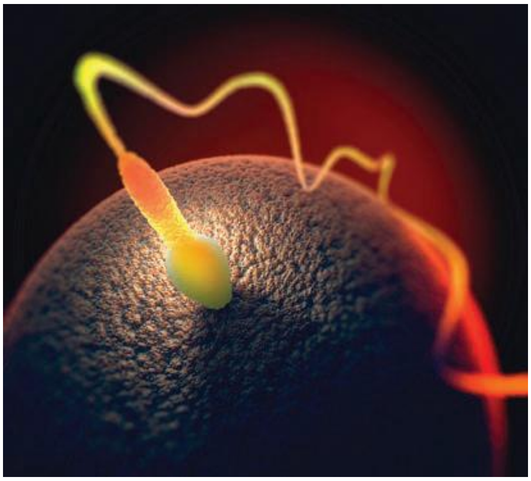


Figure 3.3 A sperm tries to penetrate an egg. Note its long whip-like tail.

Quick check 3.1

1 How many different types of cells are there in the human body?
2 What are unspecialised cells called?
3 List one structural feature of each of the following cell types:
   a Neuron
   b Red blood cell
   c Sperm.

Practical 3.1

Specialised cells

Be careful
Ensure that you carry the microscope appropriately. Carry it with one hand holding the arm and one hand under the base. Do not make big changes in magnification, so the glass slide does not get damaged.

Aim

To observe specialised cells under the microscope

Materials

- compound microscope
- transparent ruler
- prepared slides of blood
- prepared slides of neurons
- prepared slides of blood vessels

Method

Estimating the field of view

1 Place the transparent ruler on the stage of the microscope.
2 Starting on the lowest magnification, focus on the ruler.

continued…

...continued

3 Measure the diameter of the area you can see under the microscope (field of view) using the ruler.
4 Record this measurement in the field of view (FOV) table.
5 Calculate the FOV size in micrometres (μm) by multiplying by 1000.
6 Calculate the FOV for each of the higher magnifications by repeating steps **2–5**.

Estimating the size of the object

7 Place your first prepared slide on the stage of the microscope.
8 Focus on the object using the lowest-power lens.
9 Estimate how many of the cells will fit in a straight line across the middle of the FOV.
10 Divide the total FOV size that you have already calculated by the estimated number that will fit across the FOV.
11 Record your estimated size for the object in the results table.
12 Draw a scientific drawing of the cell you are observing.
13 Repeat steps **8–12** for each slide.

Results

Copy the following tables and use them to record your observations and measurements.

Magnification (ocular lens × objective lens)	FOV size (mm)	FOV size (μm) (mm × 1000)

FOV table

Cell	Scientific drawing and magnification	Number of times cell would fit across the FOV	FOV diameter	Estimated size of object (FOV/number of times object fits across)
Blood				
Neuron				
Blood vessel				

Results table

Evaluation

1 Describe how the size of each of the cells you observed benefits its function.
2 Assess the accuracy of your estimated sizes.
3 Suggest a way of improving your size estimates.

Conclusion

1 What claim can be made from this activity regarding the size of cells and how this relates to their function? Begin your sentence with: 'This activity suggests that .... '.
2 What evidence did you gather? Begin your brief summary with: 'The observations reveal that ... ' and remember to include possible sources of error.
3 Explain how the data supports your claim. Begin your sentence with: 'This means that .... '.

ISBN 978-1-108-61069-8 Cambridge University Press

Levels of organisation

Cells are organised into tissues, tissues into organs, organs into organ systems. An example is shown in Figure 3.4.

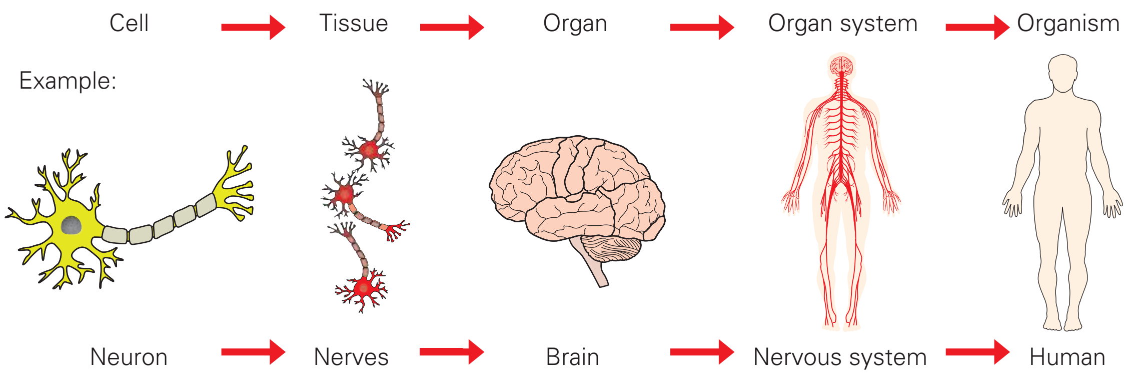


Figure 3.4 The nervous system is an example of cells being organised into an organ system.

Cells

A cell is the basic unit of life. Every living organism is made up of at least one cell. Unicellular organisms are made up of only one cell and this cell interacts directly with its environment. This means that the cell can absorb nutrients from the substance it is on or in, and excrete waste directly into its surroundings. Humans are multicellular, and are composed of many specialised types of individual cells that carry out specific functions. Because of this, the cells inside your body cannot gain nutrients and get rid of wastes without the help of other cells. This is where tissues, organs and organ systems come into play.

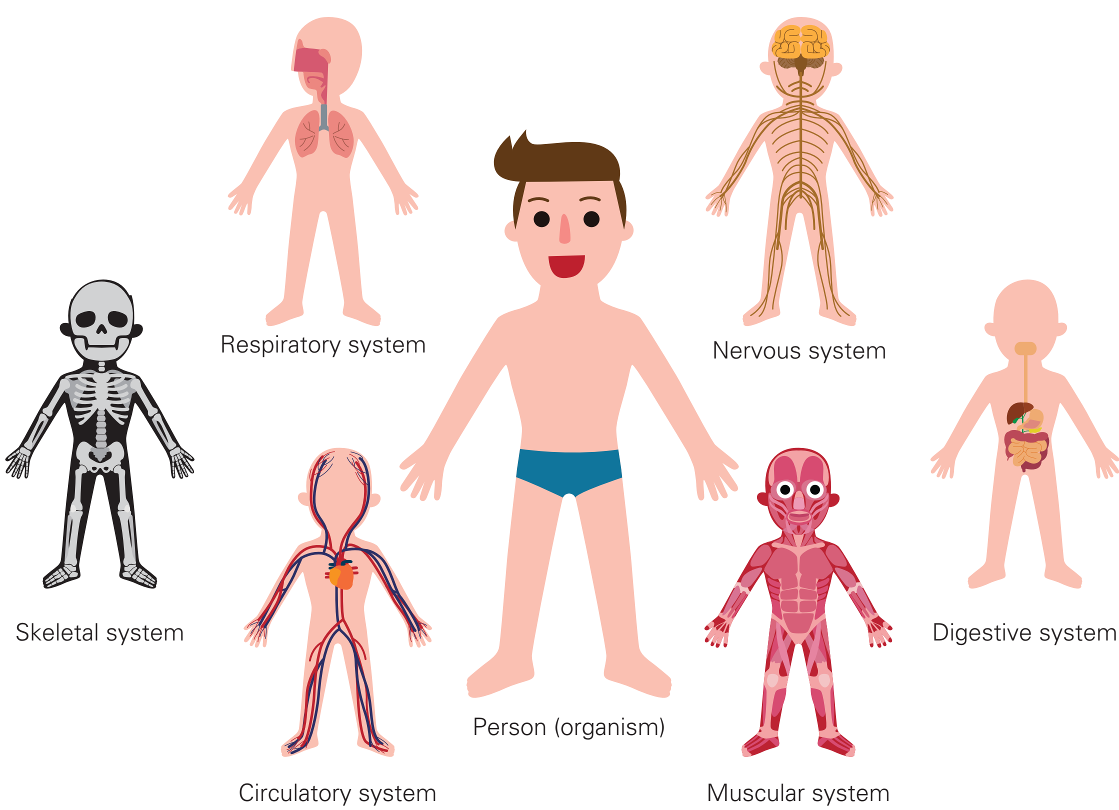


Figure 3.5 A multicellular organism such as a human is composed of many specialised cells, which are organised into tissues, organs and organ systems.

ISBN 978-1-108-61069-8 Cambridge University Press

Tissues

When a group of cells of the same type work together in a body, we call them a **tissue**. One of the most obvious tissues in animals is muscle tissue. These groups of cells contract and relax in order to generate movement by the animal. Muscle tissues require lots of energy, and so each cell has many mitochondria to carry out cellular respiration and provide that energy. Muscle cells also have a good supply of blood, to deliver oxygen and glucose for cellular respiration and to remove waste products such as carbon dioxide. Other types of tissue include lung tissue, liver tissue, and connective tissues such as tendons and ligaments. Even blood is considered a tissue.

tissue
a group of cells performing the same function

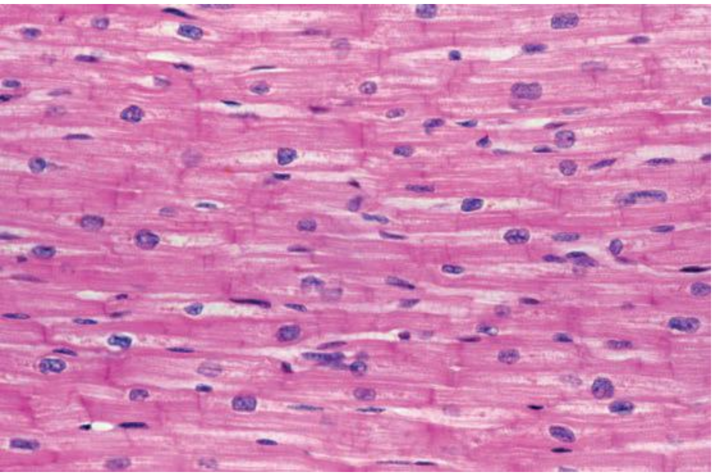


Figure 3.6 A high-magnification photograph of human cardiac (heart) muscle, seen through a light microscope. Note that each of the long, thin muscle cells has a purple nucleus.

Organs

A group of different tissues working together to perform a specific function is called an **organ**. The brain is one of the most important organs in the body and is made up of different nerve tissues that make up the grey and white matter. There are also many blood vessels that flow through the brain.

organ
a group of tissues working together to perform a function

Figure 3.7 The human brain is a complex organ composed of neurons, blood vessels and other cells.

Did you know? 3.1

The largest organ in the human body is actually our skin. On average, skin weighs around 2.7 kg and, if stretched out, would cover over 1.5 square metres. If you look closely at a small area of skin – say, the palm of your hand – you will see tiny holes, called pores. What you can't see is that there are over 6 metres of blood vessels, thousands of nerve endings and hundreds of tiny glands secreting oil onto your skin. The skin cells themselves are replaced every 10–30 days, which means that, on average, we each get through around 900 complete skins in a lifetime.

Science as a human endeavour 3.1

Practice makes perfect

In late 2017, a research team from the University of Minnesota used 3D printers to produce lifelike artificial organs for training surgeons to practise on. While the use of models and computer simulations in surgical training is not new, these fake organs are much more realistic, as they perfectly mimic the anatomical structure, look and feel of a patient's organ. It is even possible to embed soft sensors in them, to give the surgeons feedback about their technique, with the aim of minimising surgical errors and improving patient outcomes.

ISBN 978-1-108-61069-8

Organ systems

A group of different organs working together is called an organ system (or body system). The structures of the system each perform distinct processes or functions. Your digestive system is one of the most diverse organ systems in your body, with around twelve main organs, such as the mouth, stomach, liver, pancreas and intestines, along with many other smaller organs and glands that help to break down food and absorb nutrients into your body.

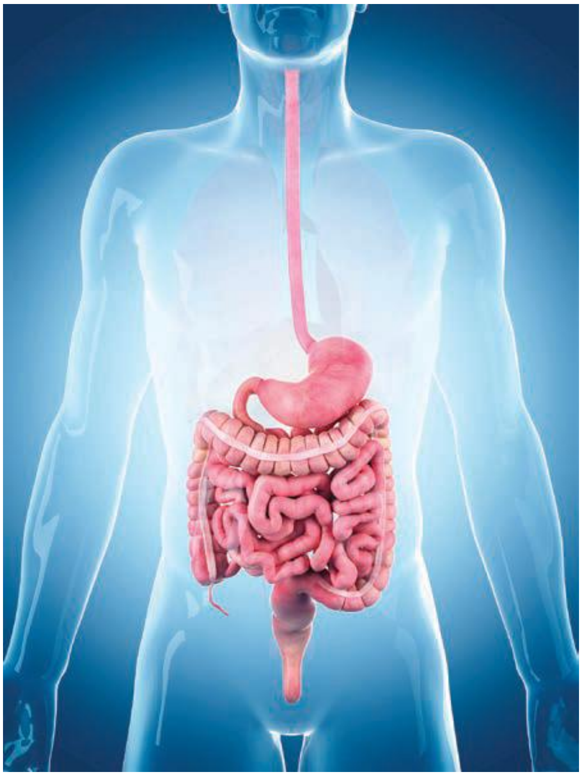


Figure 3.8 The human digestive system is essentially a long tube from the mouth to the anus. Many accessory glands assist in the digestive process.

Try this 3.1

How many human organ systems can you name? Brainstorm with a partner and make a list. A helpful starting point might be to think of organs in the body and then classify them according to what organ system they belong to.

Organisms

A group of organ systems working together supports a living being, called an *organism*. Each day, we eat food, breathe air and excrete waste products from our bodies. The many organ systems in our bodies work together in integrated ways to detect and respond to changes and complete the processes required to keep us alive.

Figure 3.9 A couple show an ultrasound image of their unborn baby. It is amazing to think that inside this tiny organism (within another organism!) all the body's essential organ systems are developing.

Quick check 3.2

1 Place the following structures into the correct level of organisation, from largest to smallest.
cell, organ system, organism, organ, tissue
2 Why don't unicellular organism have organs?
3 Name five components of the human digestive system.
4 What is a tissue?

ISBN 978-1-108-61069-8

Cambridge University Press

Explore! 3.1

Plants are people too!

Well, not exactly, but they are eukaryotic organisms, just like us. This means their cells have complex membrane-bound organelles, such as the nucleus. We tend to think that, because plants are usually sessile (stationary), they are less complicated than animals, but plants also have specialised cells that are organised into tissues, organs and organ systems.

Research one plant of your choice and list one example of each of the levels of organisation:

Cell: Tissue: Organ: Organ system: Organism:

Try this 3.2

Levels of organisation study mate

Step 1 Hold a piece of A4 paper in 'portrait' (upright) orientation.

Step 2 Fold it in half vertically – from left to right.

Step 3 Cut the front page only into six horizontal sections, and label the front of these six flaps 'organelle, cell, tissue, organ, organ system, organism' from the top down.

Step 4 On the back of each flap, add the definition of each of the six levels of organisation.

Step 5 On the back page of the brochure, add some examples of each of the six levels of organisation.

When you look at the front of the brochure, you should see the names of the levels of organisation.

As you open each flap, you should see the definition and examples.

Section 3.1 questions

QUIZ

Remembering

1 State the function of red blood cells.

2 State one structure of a nerve cell that allows it to complete its function.

3 Define the term 'tissue'.

Understanding

4 Explain how the sperm cell's tail relates to its function.

5 Explain why multicellular organisms need multiple specialised cell types working together to function properly.

Applying

6 Sketch some simple diagrams that model the difference between a cell, a tissue, an organ and an organ system.

7 Choose which of the following statements are correct.

A An organ is composed of different types of tissue.

B A tissue is composed of only one type of cell.

C If you look at a tissue under the microscope, you will see many different organs.

Analysing

8 Compare and contrast a sperm cell and a red blood cell.

9 Categorise the following terms as either cells, tissues, organs, organ systems or organisms: liver, neuron, sperm, dog, digestive, human, eucalyptus, brain, muscle, blood.

Evaluating

10 A new organism is discovered, and a study of its internal anatomy reveals that nutrients enter via a hole and are transported through a long tube into a storage area, before being excreted through a sphincter. Justify whether this is evidence of a tissue, an organ or an organ system.

ISBN 978-1-108-61069-8

3.2 The human respiratory system

Breathing vs respiration

WORKSHEET

You can probably hold your breath for about a minute, maybe two, but after that your body forces you to take a huge gulp of air. This is because the cells in our bodies need a constant supply of fresh oxygen, in order to produce energy and function efficiently. **Cellular respiration** is the process that happens inside the mitochondria in our cells, which turns glucose and oxygen into useable energy. The process also produces the waste products of carbon dioxide and water. If you stop breathing, you are preventing oxygen entering your body and therefore depriving your cells of oxygen.

cellular respiration
a process that occurs inside the mitochondria, where oxygen and glucose react to form carbon dioxide and water, producing useable energy

Key idea
To summarise: breathing is a physical process, respiration is a chemical process.

Figure 3.10 When you breathe out on a cold day, you can see your warm breath start to condense in the cold air.

Did you know? 3.2

Freedivers

While you or I might be able to hold our breath under water for about 30 seconds, people who practise freediving can hold their breath for more than 20 minutes! Freedivers do not use equipment like scuba gear. Instead, they have developed techniques such as hyperventilation, which allows them to reduce the concentration of carbon dioxide in their blood. Special breathing exercises aim to increase their lung capacity, and their bodies are adapted to dealing with prolonged periods of low oxygen. In 2012, German freediver Tom Sietas held his breath under water for 22 minutes and 22 seconds, breaking the Guinness World Record by 22 seconds.

Figure 3.11 Freediving in the ocean

ISBN 978-1-108-61069-8

Cambridge University Press

The respiratory system

The main job of the organs in the respiratory system is to get oxygen into your body cells and release the waste product carbon dioxide into the air. The respiratory system works very closely with the circulatory system, which transports the oxygen you breathe in and removes the carbon dioxide you breathe out.

Big breath in!

When you breathe in (inhale), a large muscle at the base of your ribs, called the **diaphragm**, contracts and pulls down. At the same time, the intercostal muscles between your ribs contract, moving the ribs upwards and outwards. This reduces the pressure in your lungs and draws air in through your mouth and nose as the pressure outside is higher than in the lungs. As you breathe out (exhale), the diaphragm relaxes and air is passively released through your nose and mouth because the pressure has increased in the lungs.

diaphragm
a dome-shaped muscle that separates the chest and abdominal cavities; it contracts to cause us to inhale

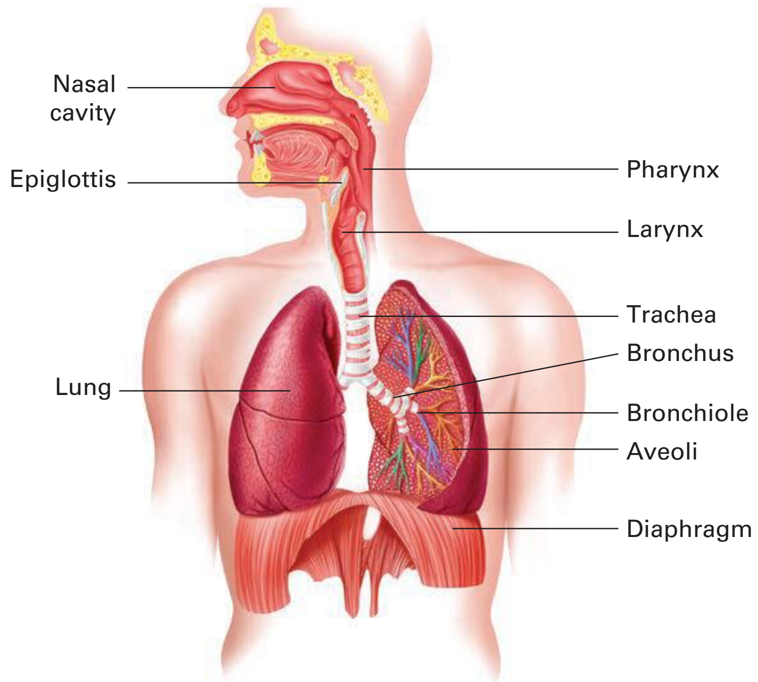


Figure 3.12 Structure of the human respiratory system

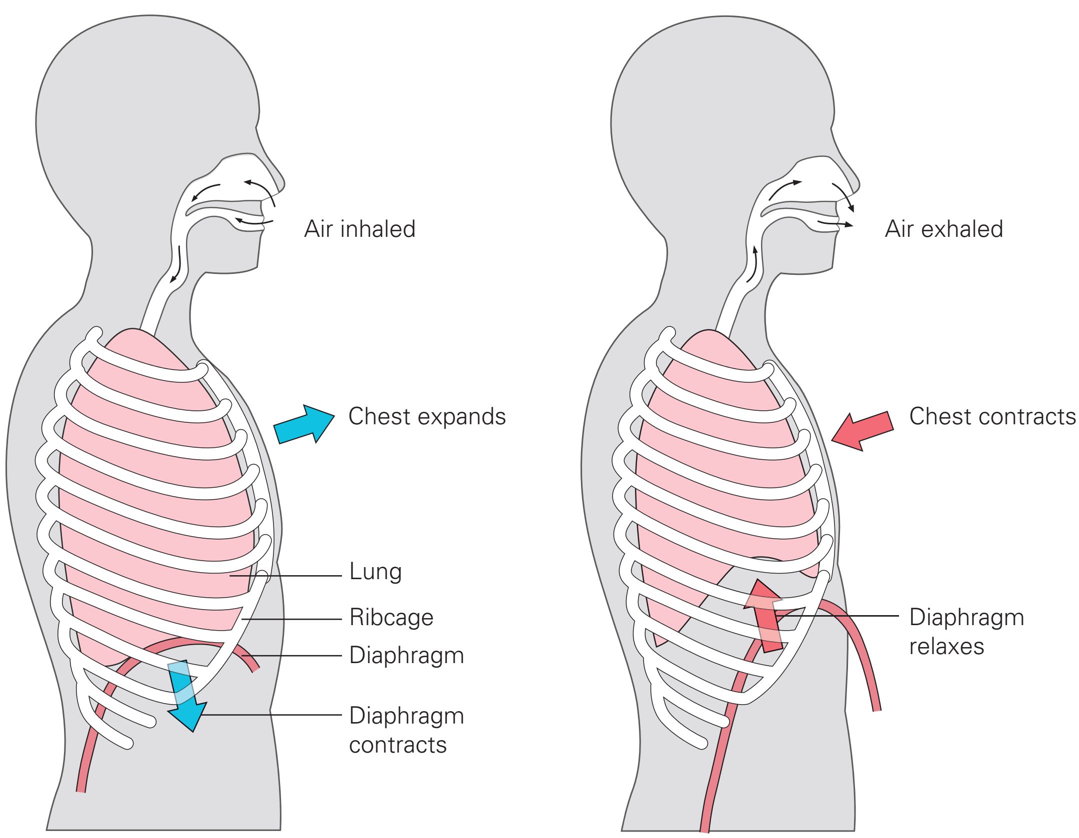


Figure 3.13 The movements of the chest during inhalation and exhalation

ISBN 978-1-108-61069-8 Cambridge University Press

Try this 3.3

Diaphragmatic breathing

Diaphragmatic breathing involves paying close attention as you breathe, in a slow and controlled way. It is commonly used during mindfulness activities and meditation. Let's have a try!

Step 1 Find a comfortable position where you are standing up straight against a wall, or seated in a chair with your feet flat on the floor. Close your eyes.

Step 2 Relax your shoulders. Place your hands over your stomach, around the level of the base of your ribs.

Step 3 Close your mouth and begin to breathe in and out slowly through your nose. Notice how, when you breathe in, your stomach seems to swell under your hands and your rib cage expands upwards and outwards. As you breathe out, you can feel the diaphragm relax and your ribs sink back in.

Step 4 Practise breathing in and out through your nose, in a slow and controlled way. Pay attention to the noise of your breath, and try to notice the sensation as the air enters and exits your nose. If you are aware of any tension you are holding in your body, for example in your shoulders, try and relax, and breathe out the tension with each exhalation.

Practising diaphragmatic breathing is a great way to refocus and allow yourself to be present in the moment. It can slow your heart rate, boost oxygen levels and even reduce blood pressure.

Mouth and nose

The two main openings to your respiratory system are your mouth and your nose. It is best to breathe through your nose, as the function of your nose is to warm up and moisten the air coming into your body, filter out any particles via the hairs in your nasal cavity and also stimulate your sense of smell. If you close your mouth and exhale, the air will be directed out through your nose. This is because the nose and the mouth are connected in a region called the **pharynx**, which leads to the **trachea** or windpipe.

pharynx
the throat region where the nasal cavity and oral cavity meet, leading into the trachea

trachea
the tube that carries air down to the lungs; also known as the windpipe

Explore! 3.2

Snoring

Snoring can be an annoying habit and can prevent people from getting a good night's rest. You snore because parts of your throat relax and vibrate as you breathe once you're asleep. However snoring can also be a symptom of bigger medical problems. Do some research into why snoring occurs and what can be done to stop it. Your research should answer the following questions.

1 What are some risk factors for snoring (things that increase your likelihood of snoring)?
2 Which structures in the respiratory system are involved in snoring?
3 Snoring can be a warning sign of a medical condition called sleep apnoea. Describe this condition.
4 What treatments are available to reduce snoring?

Trachea and bronchi

The trachea is a wide tube with thick protective rings of cartilage that keep it open. You can feel the rings if you feel your throat. Warm, moist air from the nose and mouth enters the lungs by travelling down the trachea. The structure of your lungs is very similar to a tree. The trunk of the tree is the trachea, and this large tube splits into two smaller tubes called **bronchi**,

bronchi
the two branches of the airways that split off the trachea, one main left bronchus to the left lung and one main right bronchus to the right lung

Figure 3.14 This drawing of the lungs shows the blue central trachea dividing into the left and right bronchi. The orange bronchi then branch into bronchioles.

ISBN 978-1-108-61069-8 Cambridge University Press

which are similar to branches and lead into the left and right lungs. The bronchi then branch into smaller and smaller tubes called **bronchioles**, which are similar to small twigs.

bronchioles
smaller branching tubes that branch off the two large bronchi and lead to the alveoli

Alveoli

When the air gets to the end of the smallest bronchiole, it enters small sac-like structures called **alveoli**. The alveoli are only one cell thick and are surrounded by a net of very small blood vessels, called **capillaries**. This is where gas exchange occurs: oxygen diffuses out of the alveoli and into the capillary (into the bloodstream). Carbon dioxide moves in the opposite direction, from the capillary into the alveoli. As the diaphragm and intercostal muscles relax, the carbon dioxide-rich air is released back out through your nose and mouth.

alveoli
the tiny sacs at the end of bronchioles in the lungs; the site of gas exchange with capillaries

capillaries
the smallest blood vessels, one cell thick, and the site of gas exchange with cells

VIDEO
Describe what happens in an alveolus

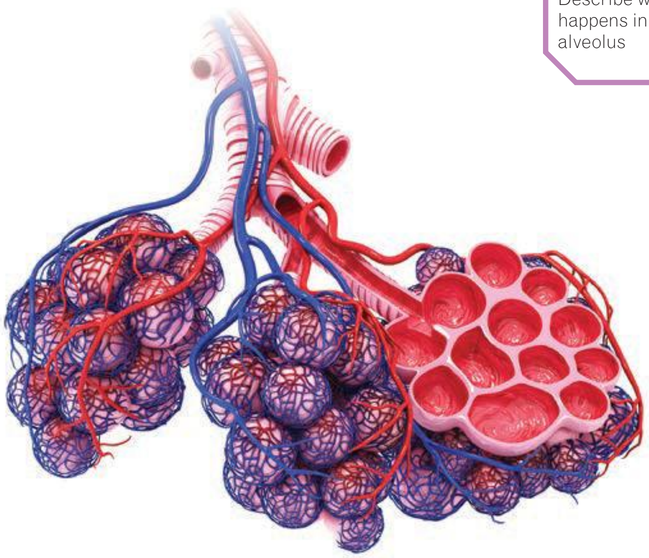


Figure 3.15 Gas exchange occurs between the alveoli and the capillaries. The oxygenated blood is returned to the heart, and the carbon dioxide-rich air is exhaled.

Practical 3.2

Modelling the pressure changes in the lungs

Aim

To model how contraction of the diaphragm creates negative pressure inside the lungs

Materials

- plastic bottle, 500 mL or 1 L
- straw
- 2 rubber bands
- 2 balloons
- putty
- scissors
- sticky tape

Method

1. Tie a knot in one of the balloons and then cut off about a quarter of the other end.
2. Cut the bottle in half and only use the top half.
3. Put sticky tape around the cut edge of the bottle.
4. Stretch the cut balloon over the cut bottle opening, and secure in place with an elastic band and sticky tape.
5. Put a straw into the second balloon and use an elastic band to hold them together.
6. Place the straw with balloon attached through the neck of the bottle and seal the hole with putty.
7. Pull down on the bottom balloon covering and describe what you observe.

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

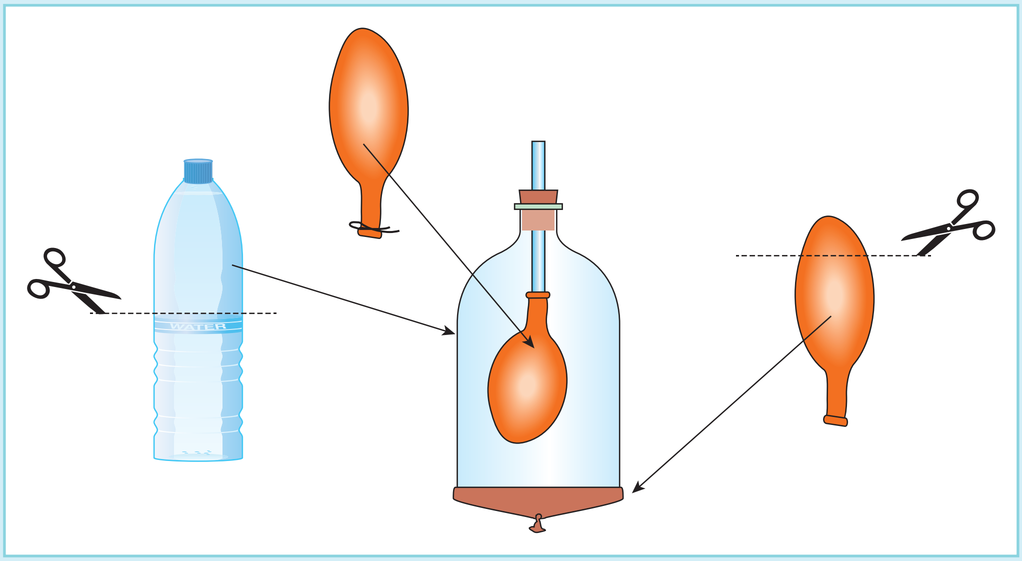


Figure 3.16 Experiment set-up. Breathing in: pressure in the lungs is lower than the atmosphere, so air flows in. Breathing out: pressure in the lungs is greater than the atmosphere, so air flows out.

Results

Draw your model of the lung in your book and label each of the parts that represents the following structures: lungs, ribs, diaphragm, trachea, mouth.

Evaluation

1. Describe the flow of air when you pull down on the balloon at the bottom of your model.
2. Explain what happens to the balloon lung when you push the balloon at the bottom of your model upwards.
3. Create a story board that explains how your model reflects the function of the respiratory system.

Conclusion

What similarities can you draw between your model and the actual human respiratory system? Begin your sentence with: 'This activity demonstrates that ... '.

Science as a human endeavour 3.2

Asthma

Asthma is a chronic lung condition that involves inflammation of the airways, tightening of the bronchioles in response to certain triggers, and hypersecretion of mucus in the airways. People who suffer from mild asthma might feel slightly tight in the chest when they exercise or breathe in cold air, but some severe sufferers must take medications such as steroids every day to treat the inflammation.

A recent development has seen asthma patients benefitting from using an antibody that has previously been used to treat eczema (an inflammatory skin condition that causes dry, itchy rashes). The antibody appears to block a protein that causes some of the inflammation in the airways, and results in improved lung function in the participants and less reliance on steroid medications.

Figure 3.17 An asthma sufferer uses a reliever medication (an inhaler or puffer) to open up their airways.

ISBN 978-1-108-61069-8 Cambridge University Press

Quick check 3.3

1 Define the main function of the respiratory system.
2 Describe what happens to air as it passes through the nose.
3 Arrange these terms in order so that they represent the direction of airflow during inhalation: alveoli, pharynx, nose/mouth, bronchus, trachea, bronchiole.
4 Explain how the diaphragm is involved in breathing in and out.

Did you know? 3.3

Your lungs float!
Each of your lungs contains around 300 million alveoli, which you can imagine as tiny balloons. When 'inflated', the lungs are the only organ in the human body that can float on water.

Gas exchange in animals

Deep in the lungs, the alveoli are the site of gas exchange in humans and other species that have lungs. But some members of the animal kingdom have developed very different specialised structures for gas exchange, such as gills in fish, skin in frogs and tracheoles in insects. All these structures share common features to allow for efficient function. These features are:

- a very large surface area. This is usually achieved by folding or layering many small cells together, which increases the amount of gas that comes into contact with the animal's blood.
- a moist surface that gases dissolve into before they enter or leave the body. This makes the process of diffusion much easier for gases.
- a thin surface and small barrier between the inside and the outside of the body. This means that the gas has to travel a smaller distance.
- a transport system near these structures, such as blood vessels, to transport the gases to all parts of the body.

The alveoli in our lungs have all the features listed above, which makes them an extremely efficient gas exchange surface. Their surface area is so large that if you were to pop your alveoli open and spread them out flat, they would cover 18 table tennis tables. That is a lot of surface area for gas exchange, squeezed into your chest.

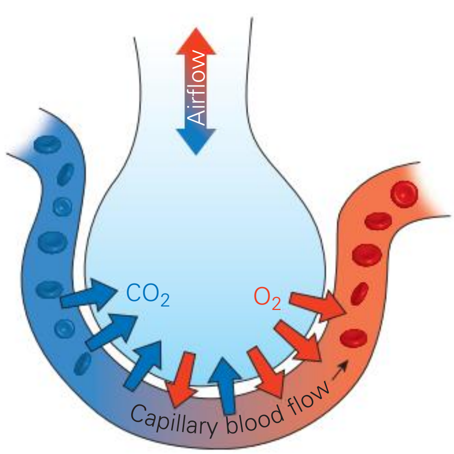


Figure 3.18 Gas exchange between the alveolus and the capillary. Note the direction of diffusion as oxygen enters the bloodstream and carbon dioxide leaves the bloodstream.

Quick check 3.4

1 Recall the site of gas exchange in the lungs.
2 State three gas exchange structures found in the animal kingdom.
3 What is the advantage of having a moist surface for gas exchange?

ISBN 978-1-108-61069-8 Cambridge University Press

Practical 3.3

The products of breathing

Aim

To demonstrate the products found in exhaled air

Materials

- air pump
- straw
- conical flask
- glass Petri dish
- bromothymol blue
- water

Method

Bromothymol solution

1. Add 50 mL of water to a conical flask.
2. Add a few drops of bromothymol blue and record the colour in the 'Observations before' column of your results table.
3. Using a pump and a straw, blow air slowly through the solution for 30 seconds.
4. Record your observations in the 'Observations after' column.
5. Using your breath and the same straw, blow air slowly through the bromothymol solution for 30 seconds, being careful not to suck up any of the solution.
6. Record your results in the 'Observations after' column.

Petri dish

7. Using a pump, blow air directly over the Petri dish.
8. Record any changes in the results table.

Air source	Bromothymol solution		Petri dish	
	Observations before	Observations after	Observations before	Observations after
Pump				
Exhaled				

9. Using your breath, exhale directly over the Petri dish.
10. Record any changes in the results table.

Results

Evaluation

When carbon dioxide is dissolved in water, it becomes acidic. Bromothymol blue turns from blue to green/yellow when it is exposed to acid.

1. Using the information above and the results you collected, explain your bromothymol blue before and after results.
2. State the independent variable (the one you changed and tested) in this experiment.
3. Discuss your observations of the Petri dish portion of the practical, and relate your findings to the products of respiration.
4. Identify two potential sources of error in this experiment.
5. Limewater turns from translucent to opaque when exposed to carbon dioxide. Using this information, explain one way you could improve the experiment if you repeated it in the future.

ISBN 978-1-108-61069-8

Cambridge University Press

Explore! 3.3

Frog business

Life began in the oceans, and gills were the first form of respiratory organ. As animals began to move onto land, a new gas exchange surface was needed. Evidence of this gradual change from aquatic life to terrestrial (land) life is present in amphibians today. In amphibians such as frogs, newts and salamanders, there are several ways in which gas can be exchanged. Unlike mammals and birds, amphibians are cold blooded. This means that their level of respiration can be lower, compared with a warm-blooded animal, and so their cells need less oxygen to function properly.

1 Tadpoles spend all their time in water. Find out how they get oxygen, and explain how the features of gas exchange (thin, moist surface etc.) relate to this process.
2 As tadpoles transition into adults, the process they use to gain oxygen changes. Explain how it changes.
3 Find out what 'cutaneous respiration' is and how it relates to a frog getting oxygen. Link this information to the features that gas exchange surfaces exhibit.

Figure 3.19 A frog keeping its nostrils above water to breathe

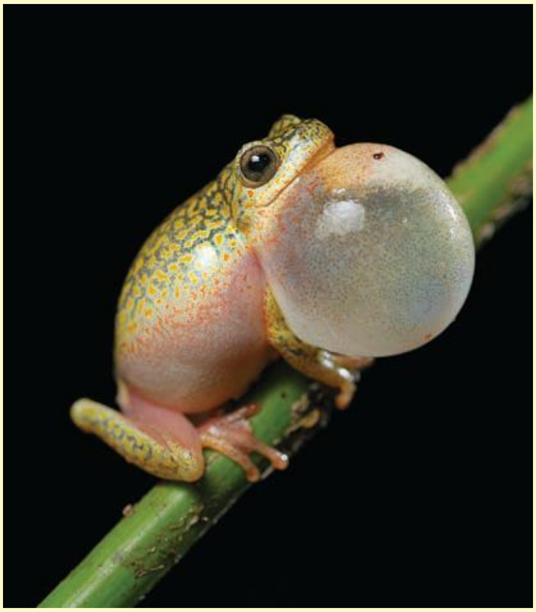


Figure 3.20 A frog with an extended buccal cavity

Try this 3.4

Modelling an animal respiratory system

Using whatever materials you can find (suggestions: plastic bags, string, sawdust, bucket, rubber tubing), construct a model of an animal's respiratory system.

ISBN 978-1-108-61069-8

QUIZ

Section 3.2 questions

Remembering

1 Name the gas that is absorbed into the body by the respiratory system.
2 Name the gas that is removed from the body by the respiratory system.
3 State the correct name for the 'windpipe'.

Understanding

4 Describe the features necessary for effective gas exchange.
5 Explain how the parts of the respiratory system are similar to a tree.
6 Outline the functions of each of the following parts of the respiratory system:

Structure	Function
Alveolus	
Trachea	
Nose	
Bronchiole	

Applying

7 Summarise the movement of the diaphragm during inhalation and exhalation.
8 Identify how the structure of the alveoli facilitates gas exchange.
9 A person suffers a spinal cord injury at a level that paralyses their diaphragm. What effect would this have on their ability to breathe?
10 Construct a flow chart showing the route taken by an oxygen molecule, starting from the air in your classroom and finishing in a body cell.

Analysing

11 Contrast the term 'breathing' with the term 'respiration'.
12 The graph In Figure 3.21 shows a person's respiration rate when resting and when exercising.
  a What was the person's respiration rate at rest?
  b What was their respiration rate at the maximum treadmill speed?
  c Infer why their respiration rate increased during exercise.

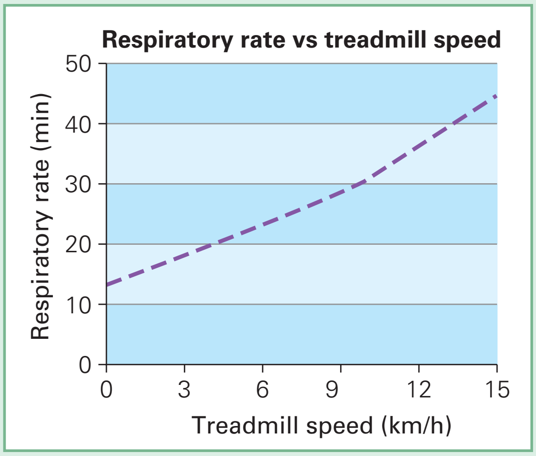


Figure 3.21

Evaluating

13 Suggest why it is better to breathe through your nose than through your mouth.
14 Cystic fibrosis is a disease that causes over-production of mucus in the airways and can be life-threatening if the person catches a cold or the flu, resulting in a chest infection. Suggest a reason why a build-up of fluid in the lungs can be harmful, and why the person may experience shortness of breath.

ISBN 978-1-108-61069-8 Cambridge University Press

3.3 Other respiratory systems

Respiratory systems in plants

Gas exchange is important for all living organisms, including plants. Plants carry out cellular respiration as well as photosynthesis, and so they need organs that allow their internal structures to exchange gases with the environment. The main gas exchange organ in plants is the leaf. It is in the leaf that plants take up carbon dioxide (one of the reactants in photosynthesis) and release oxygen (a waste product of photosynthesis).

Each plant has many leaves, in the same way that your lungs have many alveoli. Leaves are usually flat, which increases the surface area not just for light absorption but also for gas exchange. Each leaf has tiny mouth-like structures, called **stomata**. The stomata are mainly on the underside of the leaf, and they control the entry and exit of gases from the plant. **Guard cells** in the stomata enable them to open and close.

stomata
tiny pores (holes) in leaves that allow entry/exit of gases such as oxygen and carbon dioxide

WORKSHEET

guard cells
cells on either side of a plant stoma that control gas exchange by opening and closing the stoma

The guard cells of stomata contain large vacuoles that, when filled with water, hold the stomata pores open. However, when the plant begins to dry out in periods without rain, or in high temperatures or low humidity, the vacuoles inside the guard cells empty out and the cells become floppy or flaccid. This closes the stomata pores and reduces the amount of water vapour lost through the leaf. Plants need to allow gases to move in and out, but they also need to minimise the loss of water vapour through the stomata. It is a balancing act, and plants do an amazing job (especially those that live in the desert).

Figure 3.22 Leaves are like lungs for a plant.

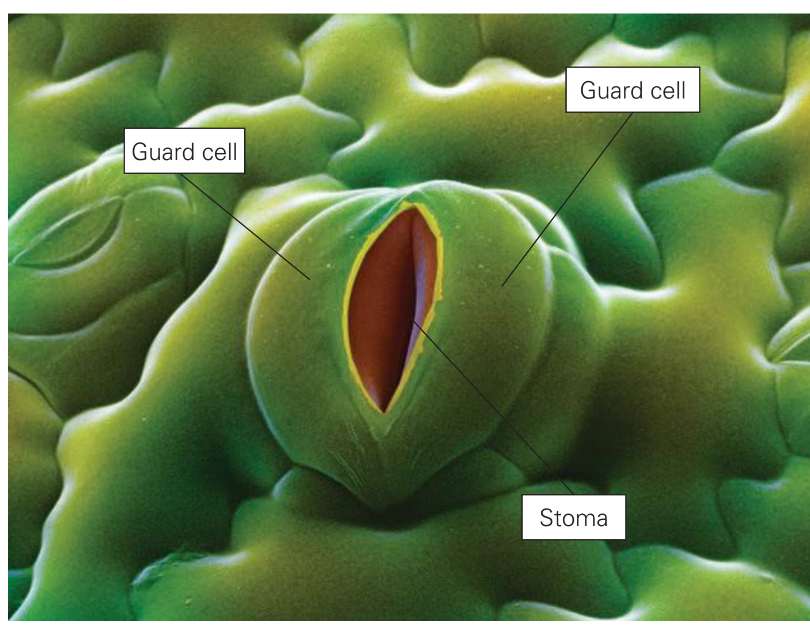


Figure 3.23 Swollen guard cells have forced open this stoma, allowing gases to enter and exit the leaf.

ISBN 978-1-108-61069-8

Practical 3.4

Stomata lab

Aim
To observe plant stomata using a compound microscope, and estimate their size

Materials
- leaves
- compound microscope
- transparent ruler
- sticky tape
- glass slide
- transparent nail polish

Be careful
Carry the microscope appropriately, with one hand holding the arm and one hand under the base. Do not make big changes in magnification, so that the glass slide is not damaged.

Method

Calculating FOV and estimating the size of the object

Refer to *Practical 3.1* for the methods of calculating the size of the field of view and estimating the size of the object.

Creating a stomata slide

1. Either pick three leaves from a walk around your school grounds or choose from leaves provided by your teacher.
2. Identify the top and bottom of the leaf.
3. Use the nail polish to paint a thin layer of varnish on a small section of the bottom side of the leaf.
4. Allow the polish to dry completely.
5. Place the sticky tape over the dry polish and pull off.
6. Place the sticky tape with the polish impression onto a microscope slide, and use the compound microscope to focus on the stomata impression.
7. Focus on the highest possible magnification and sketch an image of the stomata. Use the FOV calculations to estimate the size of the stomata.
8. Repeat for each leaf.

Results

Magnification (ocular lens × objective lens)	FOV size (mm)	FOV size (μm) (mm × 1000)

FOV table

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

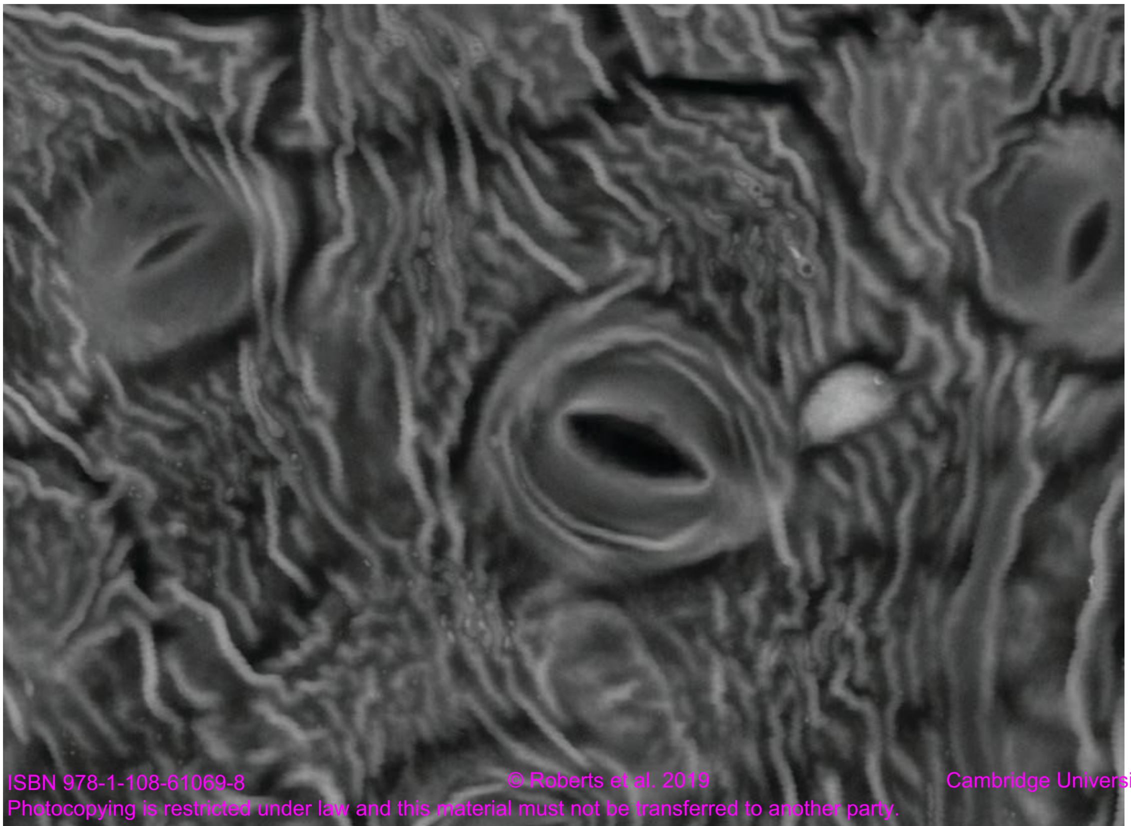
...continued

Plant	Sketch, magnification and size estimate

Evaluation

1 State the estimated size of a stoma.
2 Outline how you could improve the reliability of your estimate.
3 Explain why different plants are likely to have a different number of stomata.
4 Suggest a reason why some stomata are open while others are closed.
5 Suggest one possible source of error in this experiment.
6 Suggest one way to improve this experiment if you were to repeat it in the future.

Figure 3.24 One stoma open and two stomata closed



ISBN 978-1-108-61069-8

Try this 3.5

Modelling stomata with a balloon

1. Using a twist balloon, blow it up and fold it in half but do not tie a knot in the end.
2. Keeping the balloon folded, allow some air to escape slowly from the balloon.
3. Notice how the two sides of the balloon begin to come together.

This is similar to what happens in the stomata as they lose water. By closing the stomata, the plant is able to limit water evaporation and save water.

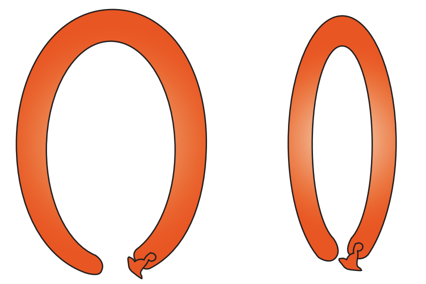


Figure 3.25

Science as a human endeavour 3.3

Thirsty plants

At present, agriculture consumes 90% of the world's fresh water, in order to irrigate (water) crops. Scientists have found a way to genetically alter crops so that they are only able to partially open their stomata. This means the plants lose less water vapour when they open their stomata to gain the carbon dioxide they need to carry out photosynthesis. In a study conducted on tobacco plants, the modification improved crop water use by 25% but did not affect the yield of the crops – that is, the same amount was produced. Tobacco plants are easier to genetically modify, but now the research team hope to apply their discoveries to food crops.

Although the stomata on leaves do a great job of providing gases for the leaves, other parts of the plant need to respire, using oxygen. The thick woody parts of trees, such as the branches, stems and trunks have structures called **lenticels**. You can often see these in the bark – they look like small dots or stripes. Lenticels allow the thick woody parts of the plant to exchange gases with the air.

lenticels
small slits on trunks or branches of trees that allow gas exchange

Quick check 3.5

1. Name the structures in leaves that allow gas exchange.
2. List three environmental factors that could cause stomata to close.
3. Explain the process involved in closing the stomata.
4. Identify how plants conduct gas exchange through their trunks.

Figure 3.26 The small horizontal slits in this tree trunk are lenticels. You may have seen these on trees but not known what they are.

ISBN 978-1-108-61069-8 Cambridge University Press

Respiratory systems in fish

Lungs cannot function under water, and gills do not function on land. However, both these structures take in oxygen from the surroundings and excrete carbon dioxide from the body.

It might seem strange to think of water containing gases such as oxygen and carbon dioxide, but it does. These gases are dissolved in the water, just like sugar can dissolve in water. Interestingly, colder water can contain more dissolved oxygen than warmer water does.

Most fish respire through their gills, which are on either side of their head, near the mouth. The sections of gills look very similar to feathers and are called *filaments*. Filaments are like the alveoli in your lungs. They provide a large surface area, to maximise the amount of gas that can be exchanged between the fish and the water around it. Each filament also contains individual capillaries that increase the blood's exposure to the water around the fish, and this increases the amount of oxygen that the fish can absorb.

Figure 3.27 The highly folded inside of fish gills maximises the surface area available for gas exchange.

Because the gills are very delicate, they are protected by a hard shield known as the *gill cover*, which has an opening at one end to allow water to flow out.

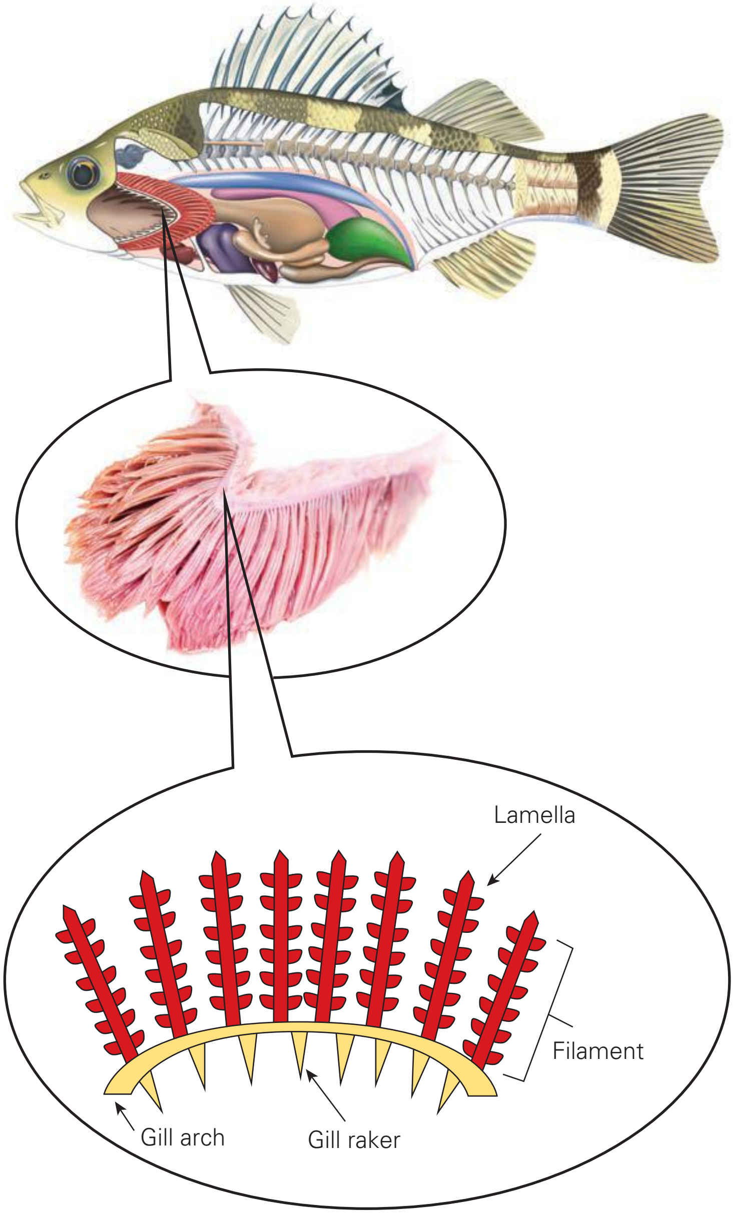


Figure 3.28 The complex structure of fish gills

ISBN 978-1-108-61069-8

Cambridge University Press

Explore! 3.4

Counter-current flow

Fish also have another way of increasing the level of diffusion in their gills, known as *counter-current flow*. This process maximises the exchange of gases, because a guiding rule for diffusion is: the bigger the difference between the concentration of a gas in two areas, the faster diffusion occurs.

1 Research what counter-current flow is and explain how it works.
2 Draw a picture to demonstrate counter-current flow in a fish gill.

Did you know? 3.4

Axolotls

You may think axolotls have a super stylish headdress, but it actually has a very important job. It is their gills!

Figure 3.29 The gills of an axolotl stick out from the side of its head to maximise gas exchange with the surrounding water.

Quick check 3.6

1 True or false: warm water holds more dissolved oxygen than cold water.
2 State the gases that fish need to exchange with their environment.
3 Outline the features of gills that allow efficient gas exchange.
4 List three ways in which gills speed up the diffusion of gases into and out of a fish.

Practical 3.5

Fish dissection

Aim

To observe a fish dissection and view gills under a microscope

Materials

- dissection microscope
- Petri dish
- $\frac{1}{2}$ fish per class
- dissecting scissors
- probe
- small knife
- disposable gloves

Be careful

Carry the microscope appropriately, with one hand holding the arm and one hand under the base. Do not make big changes in magnification, so the glass slide does not get damaged.

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Method

Retrieving the gills

1 Your teacher will make incisions with dissecting scissors, as shown in Figure 3.30.

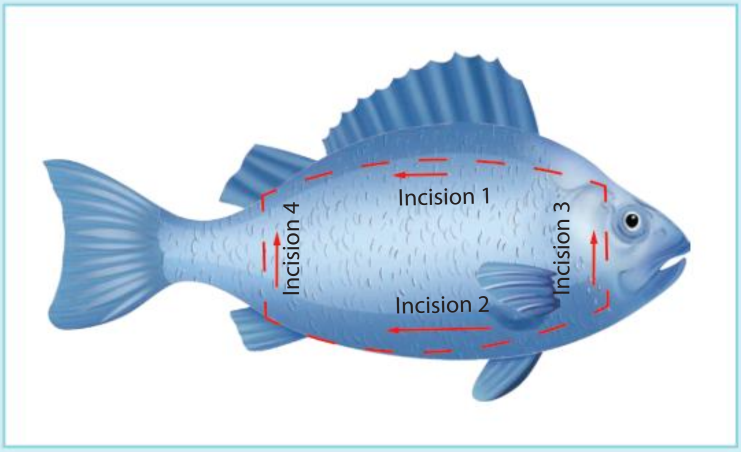


Figure 3.30 External incisions

This will expose the internal anatomy of the fish.

2 Your teacher will identify the structures shown in Figure 3.31.

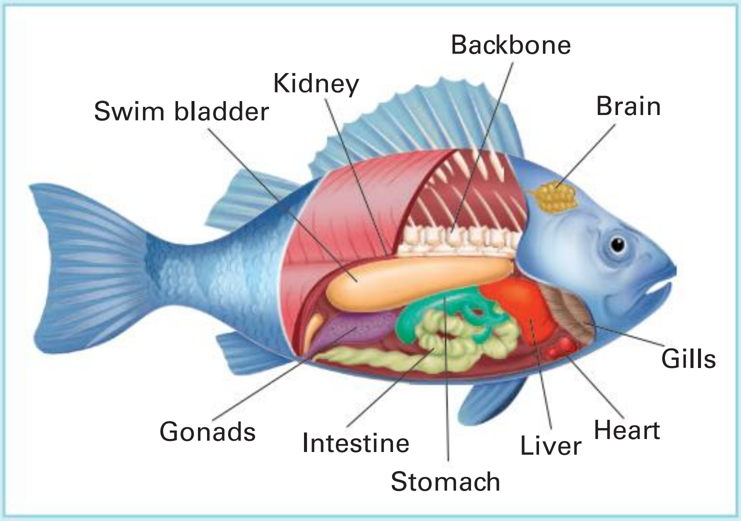


Figure 3.31 Internal organs of the fish

Organ	Feature
Heart	The heart of a slow-moving fish is small, the heart of a fast-moving fish is large.
Liver	A large organ located near the heart. Produces many digestive liquids and stores some vitamins and nutrients.
Gonads	Sex organs, male or female. Some species have both types of gonads in one fish.
Kidneys	Two kidneys, located near the spine, regulate water levels in the body.
Gills	The aquatic version of lungs. Each gill arch holds many hundreds of filaments, which are feather-like structures with a large surface area.

Structural features of each organ

continued...

ISBN 978-1-108-61069-8

Cambridge University Press

...continued

3 Your teacher will cut open the gill arch to expose the gills. You will be able to see that the gills are stacked on top of each other.

4 Your teacher will cut the gill arches and pass one to each group.

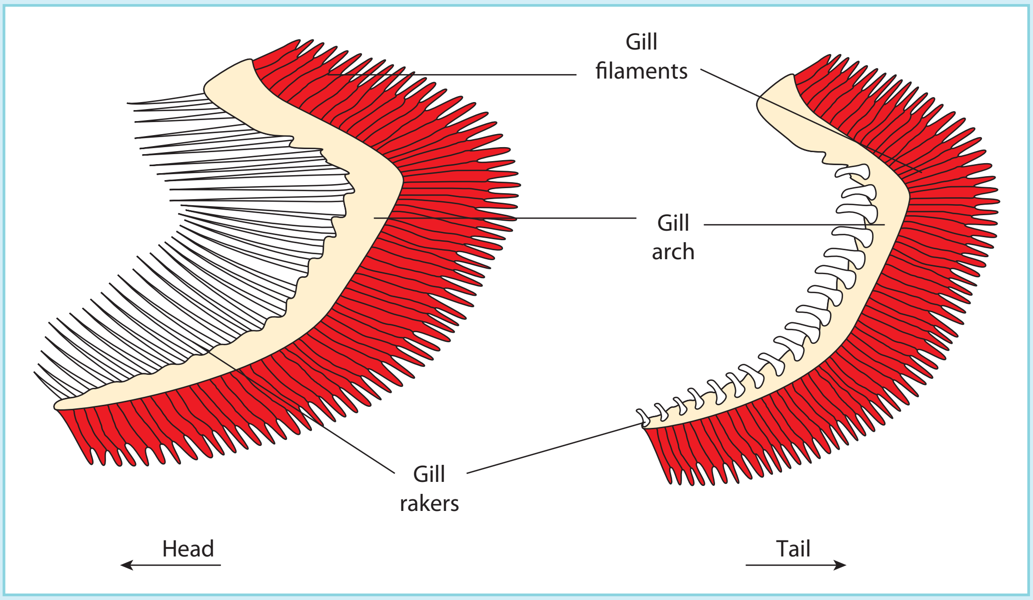


Figure 3.32 Observe the structures: *gill filaments* are the site of gas exchange; *gill rakers* are appendages along the front edge of the gill arch; *gill arches* support the gills.

Observing the gills

5 Take one of the gill filaments that your teacher has cut from the fish and place it in a Petri dish. Observe the structure of the gill filaments – each filament has many plates, called *lamellae*.

6 Add a small amount of water to the Petri dish and observe how the gill filaments and lamellae separate when they are in water.

7 Use a dissecting microscope to focus on the structure and draw a sketch.

8 Notice that there is a yellow/red sticky substance on the gills. This is a protective mucus similar to the mucus in your lungs.

Evaluation

1 Name the organ involved in water regulation in fish.

2 The insides of humans are protected by skin. What structure do fish have?

3 Explain what you observed when you added water to the gill arch.

4 Using your observations, suggest why fish cannot 'breathe' out of water.

5 Identify how you might improve this practical if you were to repeat it in the future.

Conclusion

1 What conclusion can be made from this activity regarding the structure of fish gills and how this relates to their function? Begin your sentence with: 'This activity suggests that … '.

2 What evidence did you gather to support the conclusions you have drawn? Begin your brief summary with: 'We observed … . Therefore … '.

ISBN 978-1-108-61069-8

Cambridge University Press

Science as a human endeavour 3.4

Super crab!

The invasive green shore crab has surprised researchers by demonstrating that it uses its gills not only for obtaining oxygen, but also for getting nutrients. Because crabs have a hard shell, it was assumed that they obtained their nutrition by eating food and digesting it. However, crabs have been observed to absorb amino acids (which make up proteins) through their nine sets of specialised gills. This might explain why crabs are able to thrive in tough environmental conditions.

Figure 3.33 The green shore crab

Section 3.3 questions

QUIZ

Remembering

1 Define the term 'gas exchange'.
2 List three gas exchange structures found in nature.
3 State the location of stomata.

Understanding

4 Explain how stomata open and close.
5 Outline the reason for lenticels on a tree.
6 Summarise how surface area is maximised in gills.

Applying

7 Identify the conditions likely to promote high levels of dissolved oxygen in water.
8 Graph the following data to produce a line graph showing the amount of dissolved oxygen (in milligrams/litre) in fresh water and sea water at different temperatures. Use temperature as the independent variable (on the *x*-axis of the graph) and dissolved oxygen (mg/L) as the dependent variable (on the *y*-axis of the graph). Use different coloured lines for fresh water and sea water.

Water temperature (°C)	0	10	20	30	40	50
Dissolved oxygen in fresh water (mg/L)	14	11	9	8	7	6
Dissolved oxygen in sea water (mg/L)	12	9	7	6	5	5

Analysing

9 Compare the structure of the lungs to the structure of a tree.
10 Contrast the structure of human lungs with the structure of frog lungs.

Evaluating

11 Imagine a world where plants ceased to exist. Outline the impact this would have on humans in terms of the gases that we each require and produce when breathing.

ISBN 978-1-108-61069-8

Cambridge University Press

3.4 The human circulatory system

WORKSHEET

The partner of most of the organ systems in the body is the circulatory system. This is a transport system that moves oxygen, nutrients, hormones, immune cells, waste and heat throughout the body, in one continuous loop, for your entire life. Without the circulatory system, none of the other organ systems would be able to function.

Figure 3.34 The heart is the main organ of the circulatory system.

Heart

The heart is a powerful muscular pump. It has one job: to maintain pressure in your circulatory system, which moves the blood around your body. It generates high pressure, which pushes blood out of your heart into the arteries. Blood continues moving because of muscles around the veins putting pressure on the veins. Blood is pushed towards the heart because valves in the veins prevent back-flow.

Once in your heart, blood is ready for recirculation. Your heart does this by contracting and relaxing about 60–90 times per minute.

Testing your heart rate

Try this 3.6

Your heart rate responds to the oxygen requirements of your body. For each of the following test conditions, follow the procedure below and record your heart rate (in beats per minute) in the table. You will need a stopwatch.

Find your pulse by gently pressing two fingers over your radial artery (on the soft side of your wrist, slightly off centre towards the thumb). Count the number of beats you feel in 15 seconds, using the stopwatch, and then multiply by 4 to find your heart rate in beats per minute (bpm).

Test your pulse under the following conditions, then copy and complete the table.

Test condition	Heart rate (bpm)
Lying down	
Sitting	
After jogging for 3 minutes	

Figure 3.35 Feeling for the radial pulse

Graph your data as a bar chart, and answer the following questions.

1 During which test condition was your heart rate:
   a at its highest
   b at its lowest?

2 For each answer you gave to Question **1**, propose a reason why this was the case.

ISBN 978-1-108-61069-8 Cambridge University Press

Your heart is located near the centre of your chest, and it is about the same size as when you form a fist with your hand. It is made up of four main sections: the right **atrium** and left atrium (top parts of the heart), and the right and left **ventricles** (v-shaped bottom part of the heart).

atrium
one of the two upper chambers of the heart, the left atrium and right atrium

ventricle
one of the lower two chambers of the heart, the left and right ventricles

Unlike other muscles in your body, the heart contracts (beats) without having to receive instructions from the brain. This is because it has a natural pacemaker, called the **sinoatrial node**, in the wall of the right atrium. The sinoatrial node sends an electrical signal throughout the heart, causing it to contract.

sinoatrial node
a natural pacemaker that controls the heartbeat and is located in the wall of the right atrium

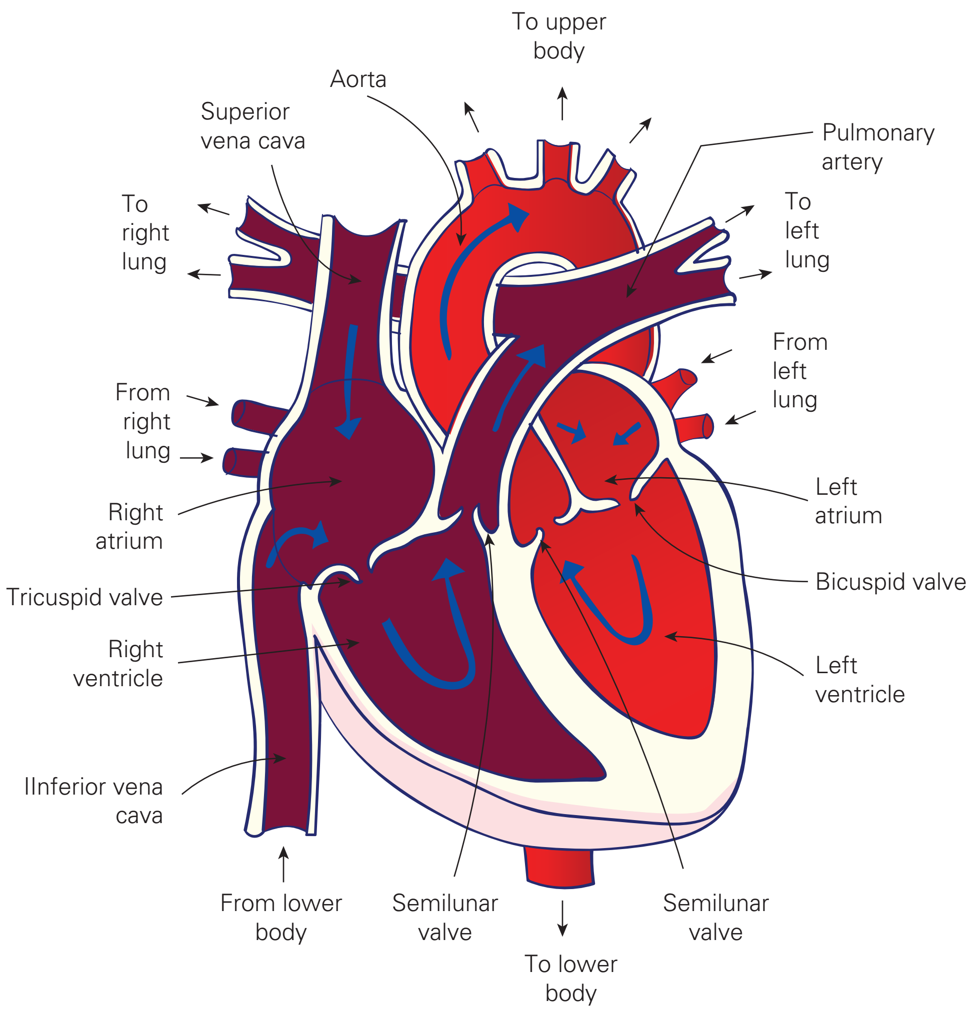


Figure 3.36 The human heart and its major vessels, chambers and valves. The heart is labelled as it sits in your chest, but it is drawn as if it were visible to someone facing you. This is why the left ventricle is located on the right-hand side of the diagram.

VIDEO
Describe how the heart chambers contract

The human circulatory system is like a double pump: the left side sends blood out to the body, and the right side sends blood to the lungs. Let's follow the path of a red blood cell through the circulatory system, using Figure 3.37 on the following page.

Did you know? 3.5

Red or blue?

When you look at your wrist, you might be tempted to think that your veins are blue. The light passing through our skin makes our veins look blue, but this is just an illusion!

Your veins contain deoxygenated blood (lower levels of oxygen) which is actually still red, just a darker shade. Some diagrams use blue to indicate areas of the circulatory system containing deoxygenated blood, but this is just a colour choice. Your blood is always red.

ISBN 978-1-108-61069-8 Cambridge University Press

Blood returning to the heart from the body enters the heart though the superior **vena cava** and goes into the right atrium. This blood has low levels of oxygen and high levels of carbon dioxide, and so in the diagram it is coloured dark red.

vena cava
the large vessel that returns deoxygenated blood to the heart, emptying into the right atrium

The blood then passes into the right ventricle, and is prevented from travelling backwards by a valve between the atrium and the ventricle. Once in the ventricle, the blood is then pumped out of the heart and travels via the pulmonary artery to the lungs.

As the blood passes through the lungs, it releases the carbon dioxide it has stored within it and gains oxygen from the alveoli of the lungs. Notice that, in Figure 3.37, the blood coming from the lungs is now coloured bright red.

The oxygenated blood then returns from the lungs through the pulmonary veins into the left atrium, where it passes into the left ventricle and is then pumped out via the **aorta** to all the different parts of the body, delivering oxygen to the cells and picking up the waste carbon dioxide.

aorta
the largest vessel leaving the heart, from the left ventricle, carrying oxygenated blood to the body

Quick check 3.7

1 Name the four chambers of the heart.
2 Which structure is the heart's natural pacemaker?
3 For each of the vessels listed below, state whether it carries oxygenated or deoxygenated blood.
   a Vena cava
   b Pulmonary artery
   c Pulmonary vein
   d Aorta

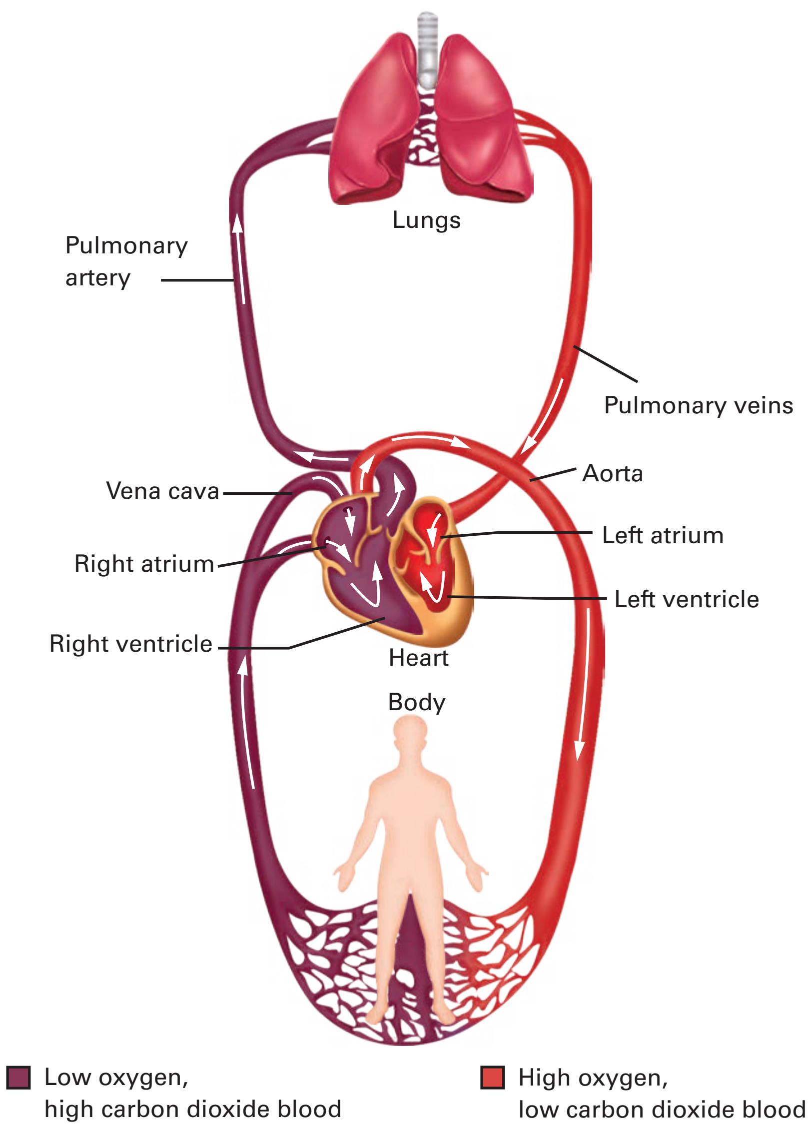


Figure 3.37 Blood flows in the following loop: right atrium ➔ right ventricle ➔ pulmonary artery ➔ lungs ➔ pulmonary vein ➔ left atrium ➔ left ventricle ➔ aorta ➔ body tissues ➔ vena cava ➔ right atrium … and the loop starts again.

ISBN 978-1-108-61069-8

Practical 3.6

Sheep heart dissection

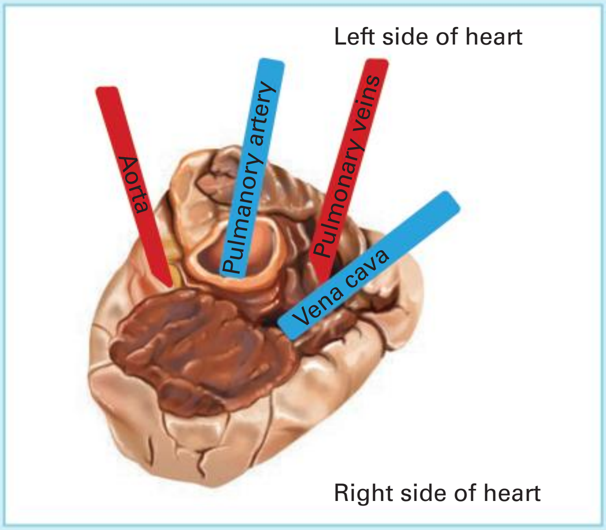
Aim

To identify the path of blood flow through the heart and become familiar with the structures

Materials

- lamb heart, preferably with aorta and vena cava attached
- dissecting scissors
- disposable gloves
- two blue and two red pipe cleaners (or straws)
- wash bottle
- dissecting tray

Method



1 Place the heart on the dissecting tray, and identify the front (anterior) and back (posterior).
2 Before cutting into the heart, identify:
   - the vena cava – place a blue pipe cleaner into the vena cava (representing deoxygenated blood)
   - aorta – place a red pipe cleaner into the aorta (representing oxygenated blood)
   - pulmonary artery – place a blue pipe cleaner here (representing deoxygenated blood, note that this connects to the same chamber as the vena cava)
   - pulmanory vein – place a red pipe cleaner here (representing oxygenated blood, note that this connects to the same chamber as the aorta)
   - right/left side (remember, these will be opposite your left and right).
3 Place your finger into the vena cava and then into the aorta. Notice the difference in strength and thickness of the walls of the blood vessels.

Right atrium

4 To open the right side of the heart, place the dissecting scissors into the vena cava and cut down the wall of the heart, stopping about a quarter of the way down the heart.
5 Open the atrium chamber and locate the valve joining the right atrium to the right ventricle.
6 Using water from a wash bottle, fill the right ventricle through the valve.
7 Gently squeeze the heart and observe as the water moves up and tries to re-enter the atrium.

Right ventricle

8 Continue to cut down the same line you made earlier, to expose the right atrium.
9 Locate the 'heart strings' within the ventricle.

Left side of the heart

10 Repeat the process above to expose the left side of the heart.
11 Compare the thickness of the walls of the heart on the left and right sides.

Evaluation

12 Identify which chambers of the heart receive the blood and which pump the blood.
13 Describe the action of the valves in the heart.
14 Compare the wall thickness of the right and left sides of the heart. Suggest a reason why they differ.
15 Describe how the vena cava and aorta felt on your finger.

ISBN 978-1-108-61069-8 Cambridge University Press

Science as a human endeavour 3.5

Mapping the heart

The electrical signals generated in your heart usually keep it beating in a way that allows the atria to fill, then the ventricles to fill, and then the blood to exit via the major vessels. But occasionally, the electrical signals go haywire. In some cases, the heart can go into a rapid, dangerous arrhythmia. In a recent study, scientists created 3D simulations of a patient's heart, to allow them to tailor medical treatment. A 3D simulation can allow cardiac surgeons to identify the exact location of the electrical problem, and destroy the tiny areas of heart muscle that are causing the problem, to prevent the heart from going into a fatal arrhythmia.

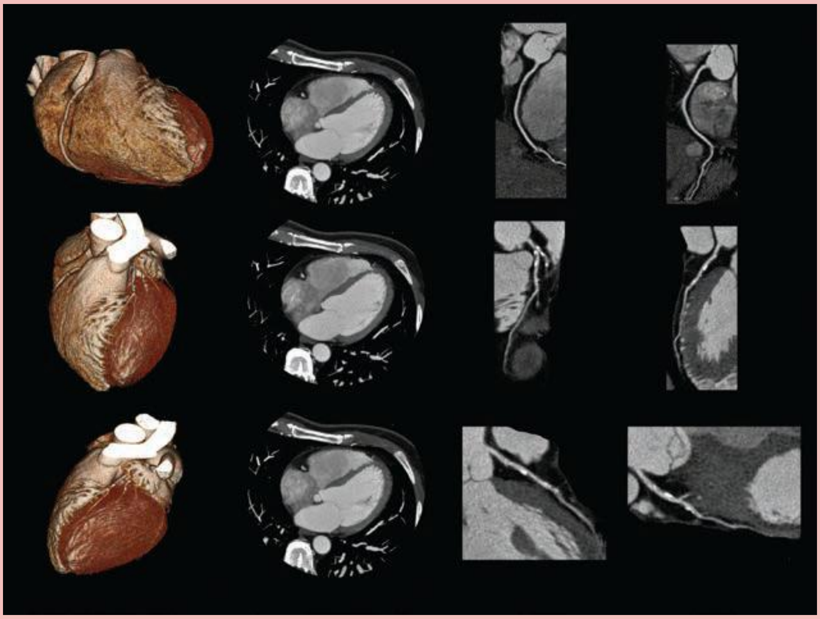


Figure 3.38 A CT scan of a patient's heart

Vessels of the circulatory system

There are three main types of blood vessels in the body: arteries, veins and capillaries.

artery
a thick, muscular elastic vessel that carries blood away from the heart

Arteries

Arteries take blood away from the heart. They usually carry oxygenated blood to all the cells of the body, with one exception: the pulmonary artery, which carries deoxygenated blood to the lungs. The blood in arteries is pumped out of the heart with a lot of force and this means that the artery walls have to be thick, muscular and strong to withstand the great pressure being pushed upon them.

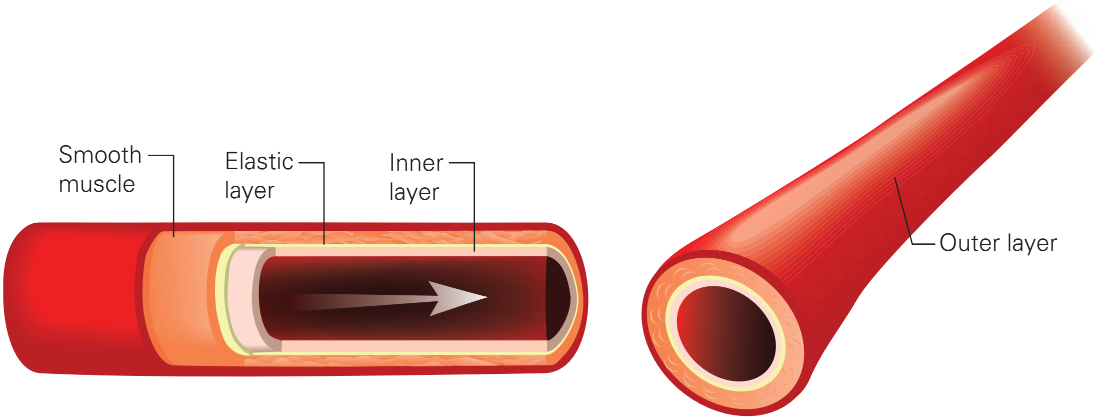


Figure 3.39 The structure of an artery

ISBN 978-1-108-61069-8 Cambridge University Press

Capillaries

As the blood travels away from the heart, it enters smaller and smaller blood vessels, eventually leading to the capillaries. Just like the alveoli in the lungs, all other tissues in the body are surrounded by a network of tiny capillaries that allow nutrients and gases to be delivered to cells while removing waste. The walls of capillaries are extremely thin, only one cell thick, to allow nutrients and gases to pass into the tissues.

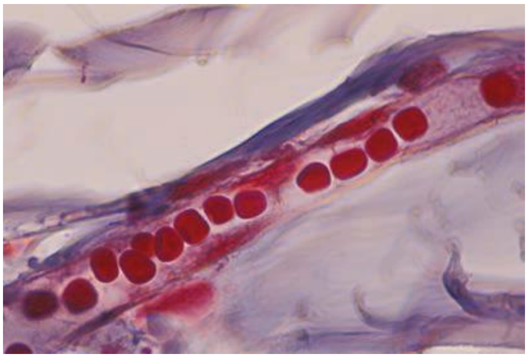


Figure 3.40 A capillary is only slightly wider in diameter than a red blood cell.

Veins

As the blood travels away from the body tissues and back towards the heart, it moves from the capillaries into the **veins**. At this point in the cycle, the blood is under much less pressure and so the vein walls do not need to be as thick and muscular as artery walls. However, the veins need to prevent blood from flowing backwards, and so they have special valves that prevent blood from flowing backwards.

vein
a thin-walled vessel with valves that carries blood back to the heart

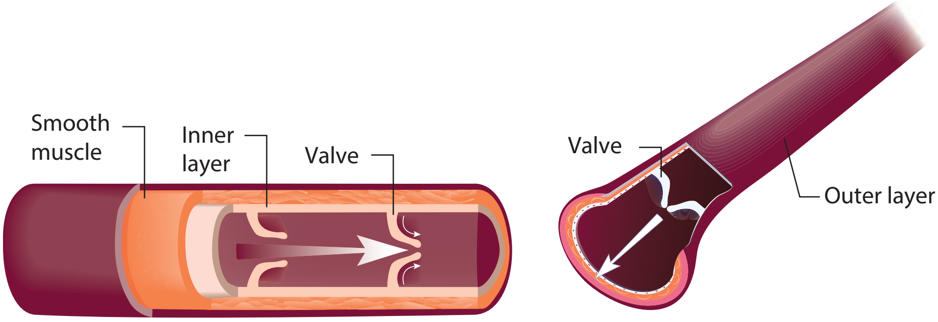


Figure 3.41 The structure of a vein

Quick check 3.8

1. State the vessel type that matches each feature listed below.
   a. thick, muscular walls
   b. diameter one cell wide
   c. valves to prevent backflow of blood
   d. carry oxygenated blood (except for the pulmonary vessel)
2. Why do arteries carry blood at high pressure?

Explore! 3.5

Circulatory system technologies

There are a number of surgical procedures and devices that can assist people who have malfunctioning hearts. Choose one or more of the following to research, and answer the questions below.

- coronary artery stents
- automatic external defibrillators
- implanted pacemakers
- mitral valve replacements

1. How does this device or technique work?
2. What problems of the heart does it assist with?

ISBN 978-1-108-61069-8 Cambridge University Press

Examining vessel types — Try this 3.7

Your teacher can provide some prepared slides showing cross-sections of arteries, veins and capillaries. Observe these vessel types under the microscope, and try to identify all the features discussed in this section.

Blood

The human circulatory system is structured around a pumping heart and connected vessels, but the third part is the tissue that is actually circulated: blood.

You have around five litres of blood circulating around your body all the time. This blood contains dissolved nutrients, gases and several types of cells.

Most of your blood is made up of a liquid called **plasma**. Plasma is a yellowish liquid, made up mainly of water, that contains all the dissolved nutrients and hormones that are travelling to the tissues around your body.

plasma
the yellow liquid component that makes up 55% of blood; carries water, dissolved gases and hormones

haemoglobin
the red pigment in blood that binds to oxygen, allowing red blood cells to carry oxygen

The second-largest component of blood is the red blood cells. These cells contain a molecule called **haemoglobin**, which gives blood its red colour. Haemoglobin allows red blood cells to hold many more oxygen particles than they could without it. Red blood cells are unusual, as they do not have a nucleus. This gives them more space to carry oxygen molecules. They are shaped like a doughnut without a hole in the centre. We call this shape a *bi-concave disk*. This shape provides a greater surface area for gas exchange, and also allows them to be extremely flexible and fit through small capillaries easily.

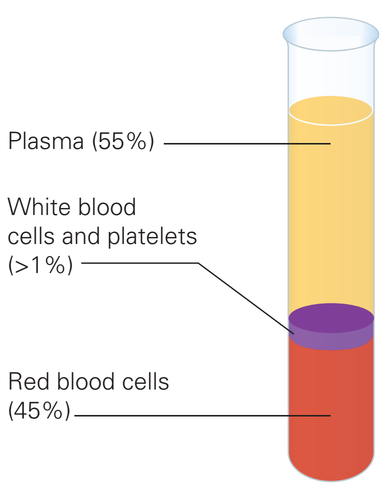


Figure 3.42 The components of blood, separated into layers

Figure 3.43 Red blood cells

White blood cells make up about 1% of the overall volume of blood. This varies depending on whether you are sick, because white blood cells are part of the immune system. White blood cells are generally much bigger than red blood cells. They help the body fight infection by foreign organisms, by eating these organisms and breaking them down, or by using special chemicals known as antibodies to destroy the invaders.

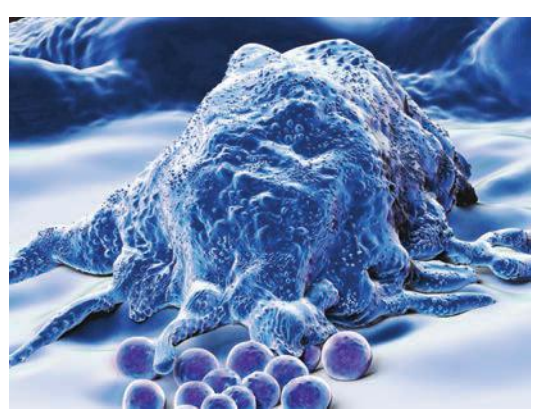


Figure 3.44 A large white blood cell (called a macrophage) eating and destroying bacteria

ISBN 978-1-108-61069-8 Cambridge University Press

The third component of your blood is the **platelets**. These tiny fragments of cells help blood to clot and help scabs form. Platelets are much smaller than red blood cells. They help to seal any punctures along the blood vessels. If your body had too few platelets, then you wouldn't be able to stop bleeding if you had an injury. On the other hand, if you have too many platelets, clots can form inside the blood vessels and stop the blood from flowing properly. These internal clots can lead to heart attacks or strokes.

platelets
tiny fragments of cells that assist with blood clotting

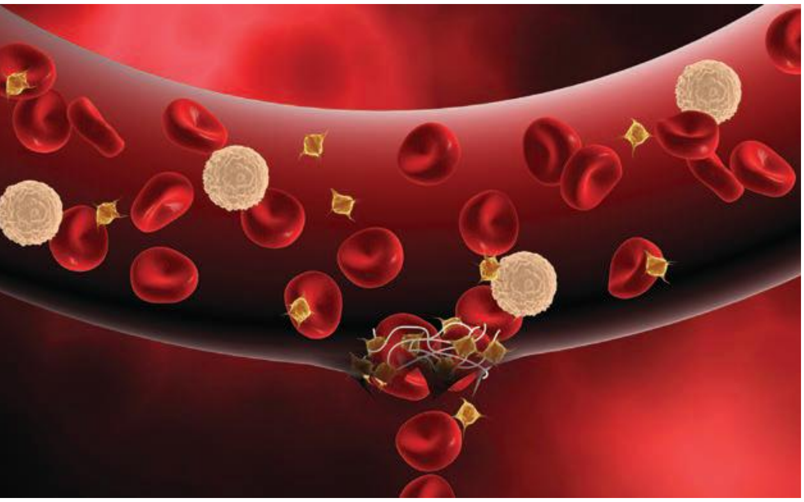


Figure 3.45 Platelets in the blood, sealing a hole in a blood vessel

Figure 3.46 Platelets help a scab to form over a wound

Did you know? 3.6

Changing blood composition

The composition of your blood can change, depending on many environmental factors.

At higher altitudes there is less air, and so there is less available oxygen. People who live at higher altitudes have more red blood cells to cope with this. If you were to go and live on the top of a mountain, after about a week your blood would have adjusted too.

Quick check 3.9

1 On average, how much blood is in your body?
2 What are the three components of the human circulatory system?
3 Name three types of cells found in the blood, and state their approximate % composition of blood.
4 What is contained in the plasma?

Section 3.4 questions

QUIZ

Remembering

1 State the function of the heart.
2 Recall how many times a healthy human heart beats per minute.
3 State the components of blood.
4 Name the smallest type of blood vessel.

continued…

ISBN 978-1-108-61069-8

...continued

Understanding

5 Explain how heart muscle is different from a muscle in your arm.
6 Explain the function of a platelet.
7 Explain how the structure of a capillary allows it to exchange nutrients and gases with cells.

Applying

8 Identify the point in your circulatory system where your blood pressure would be highest.
9 Identify the point in your circulatory system where your blood pressure would be lowest.
10 The image below is an ECG readout of a person's heartbeat. The ECG machine captures the electrical signals of the heart. The section between the arrows represents one full cardiac cycle (heart beat + refilling stage). If the person's heart rate is 120 beats per minute, how much time does this full cycle take?

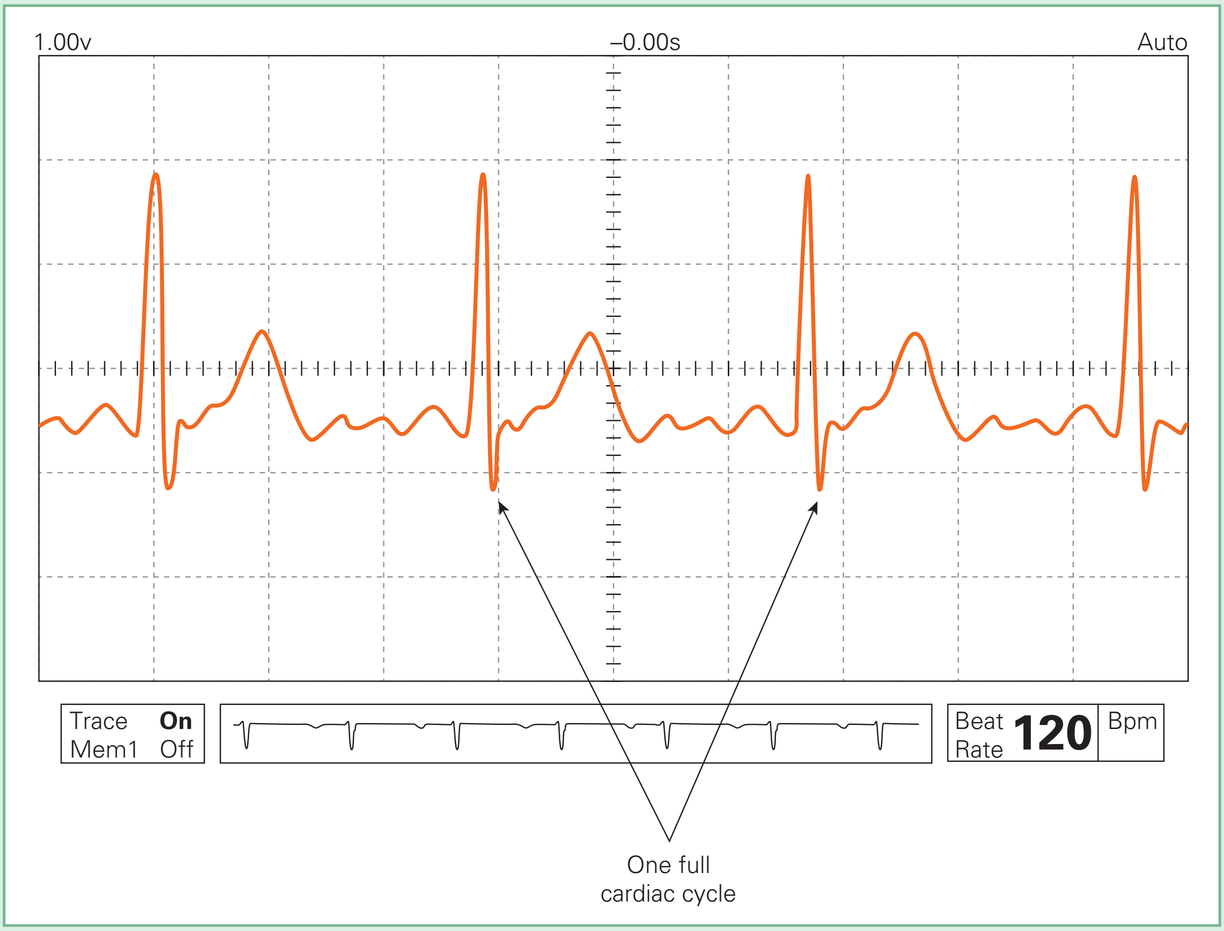


Figure 3.47 ECG printout of a person's heartbeat

Analysing

11 A baby is diagnosed with 'patent foramen ovale', a condition distinguished by a hole in the wall of the heart, between the left and right atria. Identify what effect this hole would have on the blood that is being pumped out the aorta.
12 Construct a flow chart showing the path of an oxygen molecule, from when it diffuses from the alveoli into the capillary, until it reaches a muscle cell in your leg.

Evaluating

13 Suggest a problem that would be faced by someone who has too few platelets in their blood.

ISBN 978-1-108-61069-8 Cambridge University Press

3.5 The human digestive system

The nutrients we need

WORKSHEET

Humans are heterotrophs, which means we cannot produce our own food, as plants can. We need to obtain nutrients from the environment around us by eating other living organisms. The main types of nutrients that humans need can be grouped into four main categories:

- carbohydrates – the main source of energy in the human diet. Bread, pasta, rice and oats are all great sources of carbohydrates. The simplest carbohydrate is glucose.
- proteins – the building blocks of life and the main structural component of most of the living parts of your body. Meat, cheese, eggs, seeds, nuts and legumes are great sources of protein.
- lipids – also called fats and oils. Fats transport vitamins around our bodies, are a good energy source, and also help protect the delicate organs inside our bodies.
- vitamins and minerals – essential for the efficient functioning of our body. There are many vitamins and minerals that we can't make ourselves, so we have to consume them in the food we eat.

Did you know? 3.7

Where does vitamin C come from?

Vitamin C helps the body to hold on to iron in the blood, which increases the amount of oxygen the blood can carry. It also aids in the production of collagen, which helps heal cuts in your skin.

You would get most of your vitamin C from red, yellow and orange fruits and vegetables. But where do carnivores get their vitamin C from? Dogs and many other animals can actually synthesise their own vitamin C inside their bodies. This adaptation could come in handy if you do not like eating your vegetables!

Figure 3.48 All citrus fruits have a high level of vitamin C.

Quick check 3.10

1. What is the simplest carbohydrate?
2. What might you know lipids as?
3. What are some sources of protein?

ISBN 978-1-108-61069-8 Cambridge University Press

Parts of the human digestive system

The role of the digestive system is to acquire all the nutrients the body needs. Food is broken down into its smallest components by chemical and mechanical digestion, and the nutrients are absorbed into your bloodstream and transported to the cells that need them.

mechanical digestion
a series of mechanical processes that breaks food down, such as chewing with teeth, mixing in the stomach and emulsification with bile

chemical digestion
a series of chemical reactions that breaks food into simpler chemical substances that can be used by the body

Mechanical digestion involves physical changes – that is, breaking food into smaller components but not changing the chemical structure of the food. Examples include breaking food apart with your teeth and tongue, and bile acting to emulsify (break up) fats.

Chemical digestion involves chemical changes that occur when acids, enzymes and other chemicals break the food down into its most basic chemical components.

The human digestive system is essentially a long tube from your mouth to your anus! Let us take a closer look at the structure and function of this vital organ system.

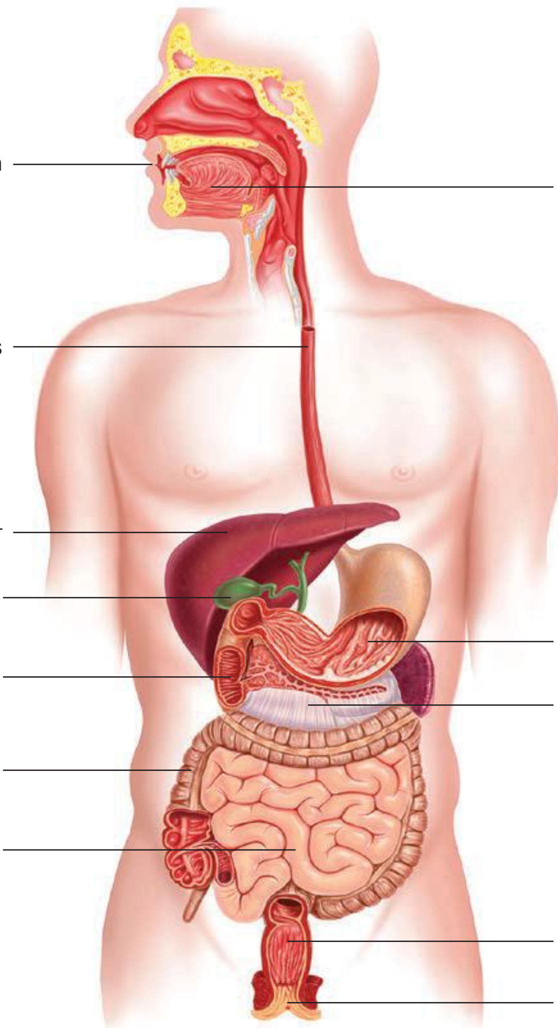


Figure 3.49 The human digestive system

ISBN 978-1-108-61069-8 Cambridge University Press

Mouth and tongue

The mouth has many specialised structures that start the digestive process. First, your teeth snip, tear, chomp and grind the food, breaking it down into smaller pieces. This increases the surface area of the food, which helps with chemical digestion later. The tongue moves the chewed food around the mouth and coats it in saliva. It forms a lump of partially broken-down food, called a **bolus**.

bolus
a lump of partially digested food

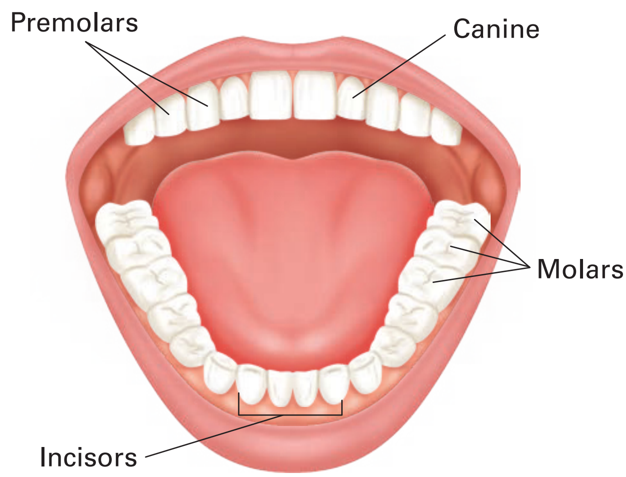


Figure 3.50 The different kinds of adult teeth: incisors for cutting, canines for tearing, and molars for grinding

Did you know? 3.8

The average person's tongue is around 8.5 cm long and has 2000–4000 taste buds on it. A quarter of the population have 4000 taste buds and have a superior sense of taste. Your taste for certain foods can change throughout your life, because as you age you lose some taste buds and your sense of smell decreases, meaning that you become less sensitive to food. As a teenager, your sense of smell and taste are much stronger than an adult's.

Figure 3.51 An average human tongue (left); an average sun bear tongue (right)

ISBN 978-1-108-61069-8 Cambridge University Press

saliva
liquid secreted by the digestive system to lubricate a bolus of food; also contains enzymes to assist chemical digestion

enzyme
a protein that can help speed up chemical reactions

Saliva lubricates the food to make its movement through your body smoother. It also contains special chemicals, called **enzymes**, that begin to break down the food at a molecular level.

The main enzyme found in your saliva is called *amylase* and it begins to break down carbohydrates, such as starch, into glucose in your mouth. Many more enzymes are found along the digestive tract, and each is designed to break down a particular food type.

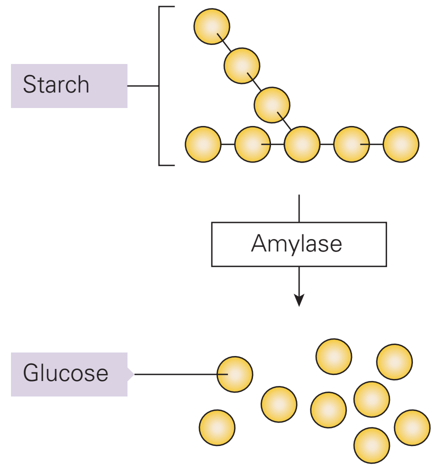


Figure 3.52 Amylase breaks the bonds in starch to form smaller glucose molecules.

Try this 3.8

Thanks, enzymes!

Ask your parent/guardian if you can try this at home. Place a small piece of bread or a dry savoury cracker on your tongue and leave it to sit there for a while. As the amylase in your saliva begins to break down the carbohydrates, you should be able to taste the sweeter glucose sub-units.

Practical 3.7

Testing enzymes

Aim

To test the function of amylase in the digestion of carbohydrates

Materials

- 3 test tubes
- starch solution
- Benedict's solution
- amylase powder
- hot water bath set to 60°C
- stopwatch

Method

1. Construct an appropriate hypothesis for this experiment. The independent variable (the one you will change and test) is the presence of amylase enzyme. The dependent variable (the one you will measure the effect on) is whether or not glucose is present, as indicated by the colour change.
2. Label the test tubes 1, 2 and 3.
3. In tube 1, add 10 mL water.
4. In tubes 2 and 3, add 10 mL of starch solution.
5. Add ¼ tsp of amylase powder to test tubes 1 and 3.
6. Place a stopper on test tubes 1 and 3, and shake.
7. Leave for 2 minutes.
8. Add 3 mL of Benedict's solution to each test tube and place in the hot water bath at 60°C for 5 minutes.
9. Note any colour changes in the Results table. If sugar is present, the solution will turn yellow or brick-red, depending on the amount of sugar.

continued…

ISBN 978-1-108-61069-8

Cambridge University Press

...continued

Results

Test tube	Colour after heating	Glucose present?
1: Water, amylase, Benedict's		
2: Starch solution, Benedict's		
3: Starch solution, amylase, Benedict's		

Evaluation

1 Explain whether your results support or disprove your hypothesis.
2 Suggest the reason that water was used in test tube 1.
3 Suggest a way that the reliability of this experiment could be improved.
4 Amylase is found in saliva. Explain why food may become sweeter if you chew it for longer.
5 State at least three variables you needed to control during this experiment, to ensure that it was a fair and valid test of the independent variable.
6 Suggest two potential sources of error in this experiment.
7 Suggest one way you could improve the experiment, if you were to repeat it in the future.

Conclusion

1 What claim can be made from this experiment regarding amylase and the chemical digestion of carbohydrates? Begin your sentence with: 'This experiment suggests that ... '.
2 What evidence did you gather? Begin your brief summary with: 'The results show that ... ' and remember to include possible sources of error.
3 Explain how the data supports your claim. Begin your sentence with: 'This means that ... '.

Oesophagus

When you swallow food, a wave-like contraction of your oesophagus pushes the food down towards your stomach. This movement is known as *peristalsis*, and it continues all the way along your digestive tract to constantly keep the food moving along. Peristalsis is so effective that you could actually eat upside down and the food would still be pushed against gravity, up your oesophagus!

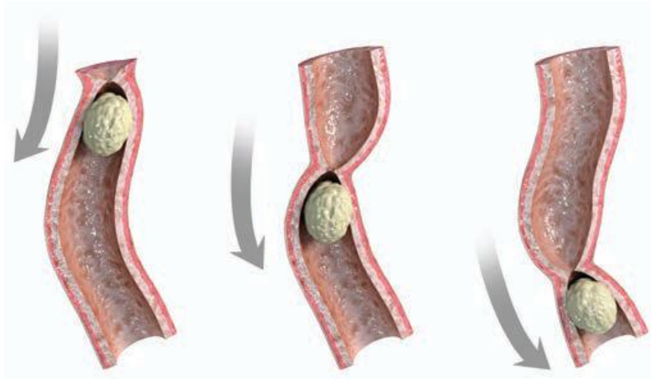


Figure 3.53 Peristalsis moves food down the oesophagus.

VIDEO
Describe peristalsis

Modelling peristalsis **Try this 3.9**

Find a nylon stocking and cut off the toe end of the leg. Place a tennis ball at the toe end and gently squeeze behind the tennis ball, to move it along the length of the stocking. This is how the muscles of the oesophagus push a bolus of food along.

Quick check 3.11

1 Describe the function of saliva.
2 Name the enzyme found in saliva.
3 How many taste buds does the average person have?
4 Is chewing food an example of mechanical or chemical digestion?
5 Define 'peristalsis'.

ISBN 978-1-108-61069-8

Stomach

At the bottom of your oesophagus is a **sphincter** that opens to allow food to enter your stomach. The stomach contains many types of enzymes, along with very strong hydrochloric acid – these are known as the gastric juices. The sphincter at the opening of the stomach is very important, as it prevents these enzymes and acids from entering the oesophagus and burning the tube, causing a symptom called indigestion or 'heartburn'.

sphincter
a muscle that surrounds an opening in the body and can tighten to close it, e.g. at the bottom of the oesophagus, leading into the stomach

Food stays in your stomach for 2–6 hours, depending on the size, amount and type of food. During this time, the stomach contracts and churns the food (mechanical digestion), helping to further break up the large particles, while mixing the bolus with the gastric juices (chemical digestion). The acid in your stomach also performs another important function: it kills many of the harmful bacteria that might be found on the food you eat. The stomach wall is a mucosal membrane, which produces mucus to protect the stomach tissue from the strong acids.

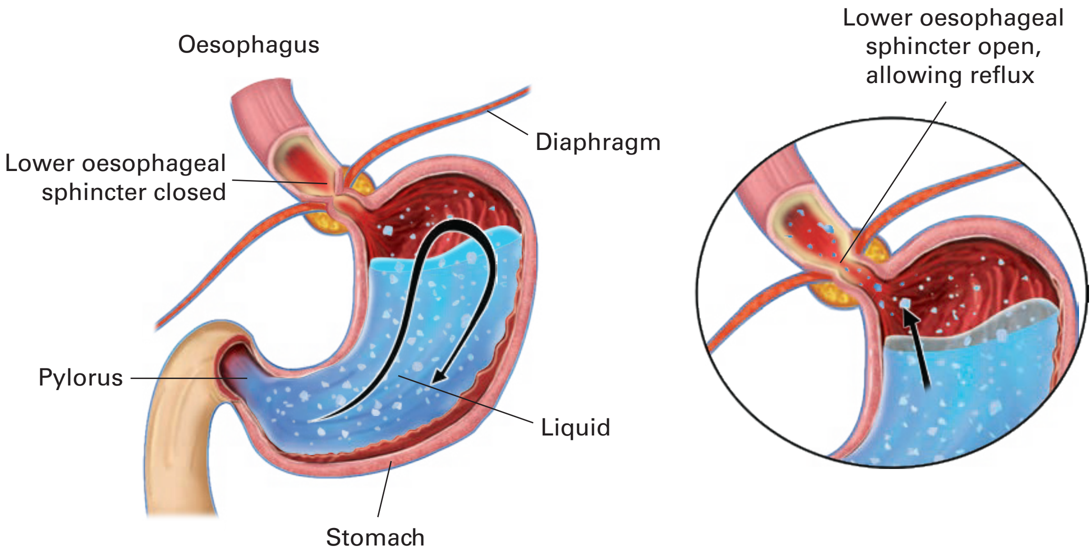


Figure 3.54 When the oesophageal sphincter fails to close, gastric juices can irritate the bottom of the oesophagus.

Try this 3.10

How do antacids work?

Antacid tablets are taken during episodes of heartburn, to try and neutralise some of the acid in the stomach. Let's observe how they work.

You will need the following: pH data logger and probe, 1 M hydrochloric acid, antacid tablets (such as Rennie®), 200 mL beaker, 3 mL pipette, mortar and pestle, distilled water.

Step 1 Crush one antacid tablet using the mortar and pestle. Place in the beaker with 50 mL of distilled water and mix well.

Step 2 Measure the pH using the probe.

Step 3 After a minute, add around 1 mL of 1 M hydrochloric acid and monitor the change in pH. Stir the beaker regularly.

ISBN 978-1-108-61069-8

Enzymes act to *catalyse* (speed up) chemical reactions. The main enzyme in your gastric juices is called *pepsin* and its role is to begin the digestion of protein. Each enzyme has a specific shape that fits only one type of molecule, and therefore each food type has a special enzyme dedicated to breaking it down in the body. For example, pepsin can only break down protein.

The stomach absorbs some substances into the bloodstream, such as water, medicines and alcohol. The digested bolus is now called **chyme** and it leaves the stomach by passing through the pyloric sphincter into the small intestine.

chyme
a partially digested mass of food after it leaves the stomach

Figure 3.55 Each enzyme fits a specific type of molecule, like a key fitting a lock. An enzyme attaches itself to a food particle and speeds up the chemical reaction that breaks down the food particle, and then it releases the broken-down food particle.

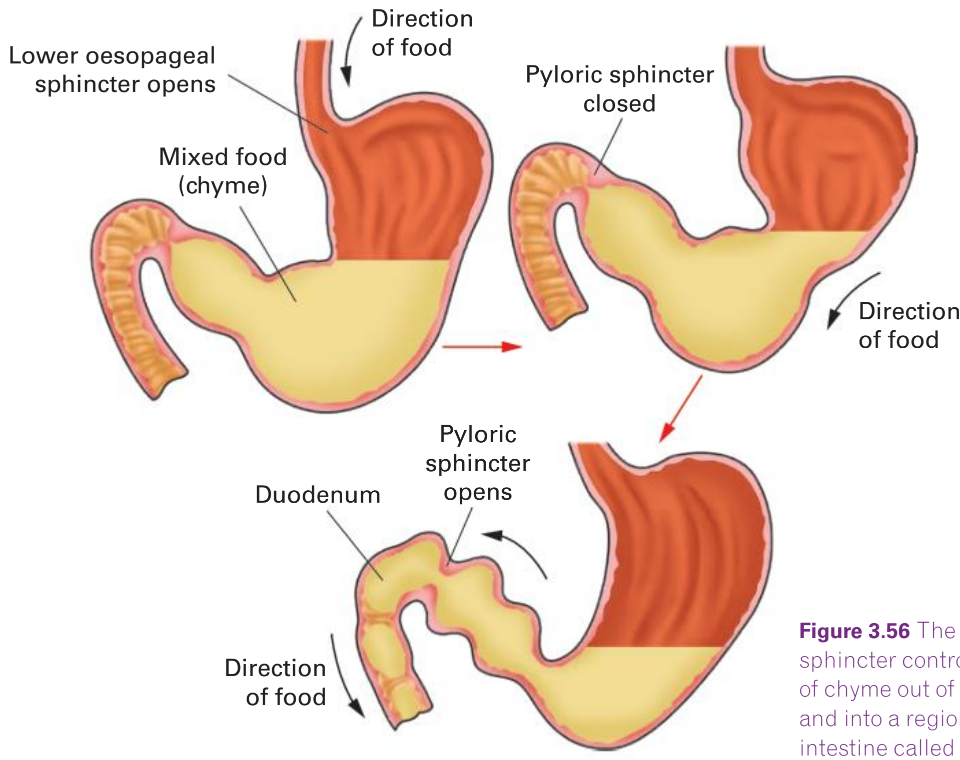


Figure 3.56 The pyloric sphincter controls the flow of chyme out of the stomach and into a region of the small intestine called the duodenum.

Quick check 3.12

1. State two sites of mechanical digestion.
2. Define 'chyme'.
3. Which enzyme catalyses the digestion of protein?
4. Explain why the stomach wall is lined with mucus.

ISBN 978-1-108-61069-8 Cambridge University Press

Small intestine, liver, gall bladder and pancreas

The small intestine is only called 'small' because it is narrower in diameter than the large intestine. It is actually very long, measuring nearly six metres. Because it is so long, the small intestine is divided into three main parts: **duodenum**, **jejunum** and **ileum**.

duodenum
the first section of the small intestine

jejunum
the second section of the small intestine, where food breakdown and nutrient absorption occur

ileum
the third section of the small intestine, where further food breakdown and nutrient absorption occur

bile
a substance produced in the liver and stored in the gall bladder that helps break down fats

gall bladder
a small gland near the liver that stores bile, and secretes it into the duodenum

The duodenum is the first part of the small intestine. Many digestive enzymes are secreted into it, to continue digestion of the chyme. Peristalsis is still propelling the chyme forwards and continues all the way along the digestive tract.

The liver produces **bile**, which helps to break down fats or lipids mechanically. The bile is stored in the **gall bladder** and is excreted into the duodenum if you eat a fatty meal. Bile acts like a detergent – it emulsifies or breaks big globs of fats and oils into little globs that can be easily moved and broken down further.

The **pancreas** secretes pancreatic juices, which help to neutralise the harmful acids from the stomach and prevent damage to the intestines. The pancreatic juices also contain more enzymes to keep chemically working on different food types.

pancreas
an organ that secretes pancreatic juices containing enzymes into the duodenum to assist with the digestion of food

villi
finger-like structures in the digestive system that have a high surface area and rich blood supply for absorption of nutrients

Most of the nutrient absorption takes place in the middle section of the small intestine, the jejunum. This section is lined with millions of finger-like structures, called **villi**. These structures have a large surface area and a high flow of blood, which increases the efficiency of nutrient absorption into the bloodstream.

The end section of the small intestine is the ileum. The main function of this portion of the intestines is to finish off any absorption of nutrients, and to compact the remaining digested food and pass it through into the large intestine.

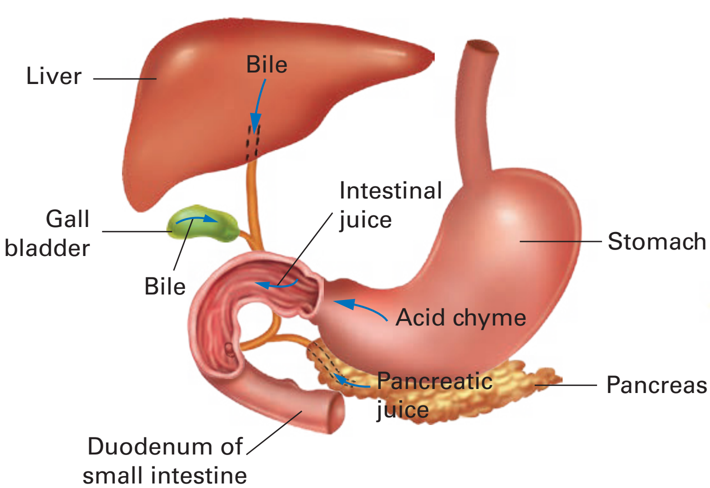


Figure 3.57 The liver, gall bladder and pancreas all contribute to the digestion of food and connect to the duodenum.

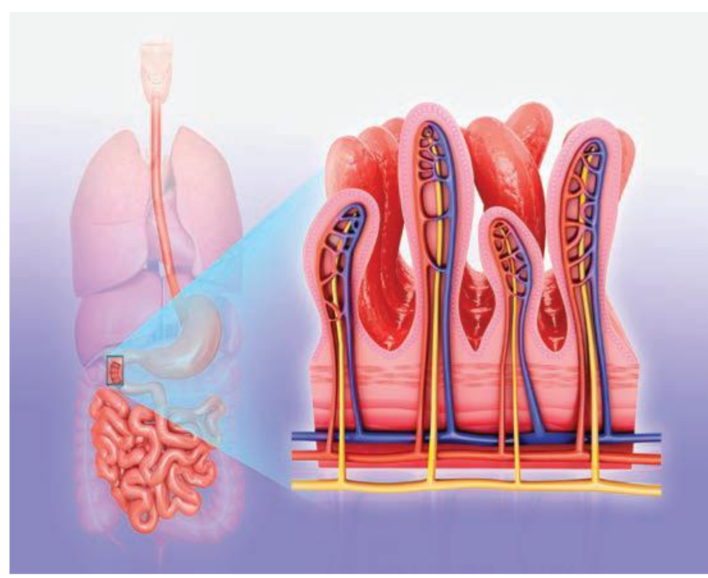


Figure 3.58 Finger-like villi in the intestines are specialised for absorption of nutrients.

ISBN 978-1-108-61069-8 Cambridge University Press

Large intestine

The large intestine is 1–2 metres long and has five parts: caecum, appendix, colon, rectum and anus. Its function is to absorb most of the water from the material left over from digestion. The large intestine also has large numbers of friendly bacteria that can produce vitamin K and vitamin B for your body to use. In humans, the caecum is a pouch at the end of the large intestine, where it joins the small intestine. The appendix has long been considered a useless organ that is a remnant of evolution, but there is ongoing debate about what its actual role is, other than getting inflamed and having to be surgically removed! As waste enters the large intestine and passes through the colon, water leaves the waste, resulting in a solid mass called faeces. Faeces are stored in the **rectum** and when the rectum is full, it sends a signal to your brain to tell you to go to the toilet. The faeces then pass out through a sphincter called the **anus**.

rectum
the second-last section of the large intestine; stores faeces

anus
the opening at the end of the digestive tract, through which solid waste leaves the body

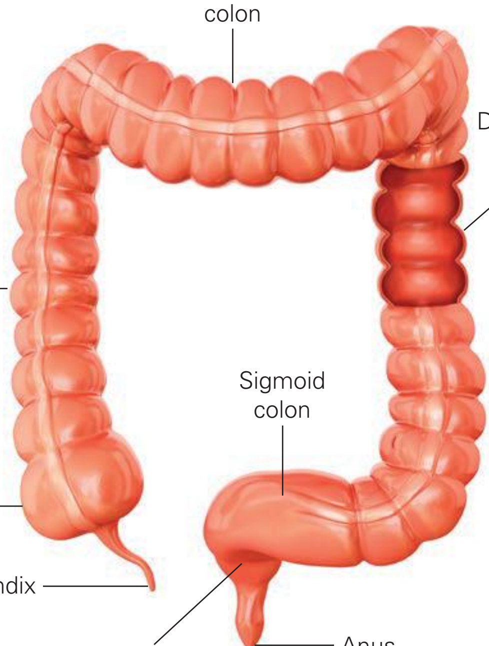


Figure 3.59 The five sections of the large intestine

Did you know? 3.9

A lot of you is not you!

The average person's body has around the same number of human cells as bacterial cells.

Until recently, it was thought that the number of bacteria in our bodies outnumbered our own cells 10:1. However, recent research in Canada suggests that the average person is more likely to have a 1:1 ratio of bacteria and human cells. Most of these bacterial cells are 'friendly bacteria' found in our digestive system that help our body break down and digest nutrients from the food we eat. So next time you eat a meal, think about all the bacteria hard at work in your digestive system, helping you break it down.

Figure 3.60 Most bacteria in your body are in the intestine.

ISBN 978-1-108-61069-8

Quick check 3.13

1 State the three sections of the small intestine.
2 The liver produces bile, which is stored in the gall bladder. Which type of food does bile help to mechanically digest?
3 Explain how villi improve absorption of nutrients.
4 Arrange the following sections of the large intestine in the correct order that faeces pass through: rectum, colon, anus, caecum, appendix.

Did you know? 3.10

Is your stomach rumbling?
Ever heard those gurgling stomach noises when you are hungry? Well, they are actually the sounds of hyperactive peristalsis in the intestines, and are named *borborygmi*.

Practical 3.8

Modelling the human digestive system

Aim
To create a model of the digestive system that simulates the passage of food through the body

Materials
- a sandwich/ food source
- blue liquid
- red liquid
- yellow liquid
- scissors
- one stocking leg
- paper towel
- zip lock bag
- metal spoon
- elastic band
- ice cream container

Method
Using the materials provided, create a model to demonstrate the function of the parts of the digestive system listed in the table.

Digestive system part	Item used to represent body part	Explain why you used the item
Teeth		
Saliva		
Tongue		
Stomach		
Acid		
Small intestine		
Enzymes		
Large intestine		
Anus		

Evaluation
1 Identify three features of the digestive system that your model was not able to show.
2 Evaluate the effectiveness of your model in explaining digestion to a primary school student.
3 Suggest two ways you could improve this activity (e.g. two new materials that could be used, or extra organs that should be included).

continued...

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Conclusion

1 What connections did you make while completing this activity? Begin your sentence with: 'During this activity I showed/learned that ... '.
2 Describe some of the shortcomings of the model. Begin your sentence with: 'Some shortcomings of the model were ... '.
3 In what way is the model still useful? Begin your sentence with: 'The model is still useful because ... '.

Digestion gone wrong

Food poisoning

Your body is very smart – it can detect hazardous substances in the food you eat. Sometimes food can be contaminated with toxins or micro-organisms that could do harm to your body. If your body senses the presence of these harmful substances, it signals your digestive system to empty fast. This causes the stomach to contract violently, causing vomiting, and it also causes the intestines to contract, causing diarrhoea. Even though getting sick is never fun, it is your body's way of protecting you from a much worse fate.

Figure 3.61 Vomiting is not pleasant, but it is an important protective mechanism.

Digestive disorders

Many people cannot eat certain foods, because of intolerance or allergy. An *intolerance* is when a food cannot be properly broken down by the body and results in an adverse reaction.

One of the most common intolerances in humans is lactose intolerance. Lactose-intolerant people are unable to digest the sugar in milk and dairy products, called lactose. Normally when somebody eats food containing lactose, the enzyme lactase is released in the small intestine to break down the carbohydrate into simple sugars. People who are lactose intolerant do not have lactase, and this means that the sugars do not get digested and absorbed. Instead, the bacteria in the intestines ingest these sugars, leading to bloating, lots of gas and diarrhoea.

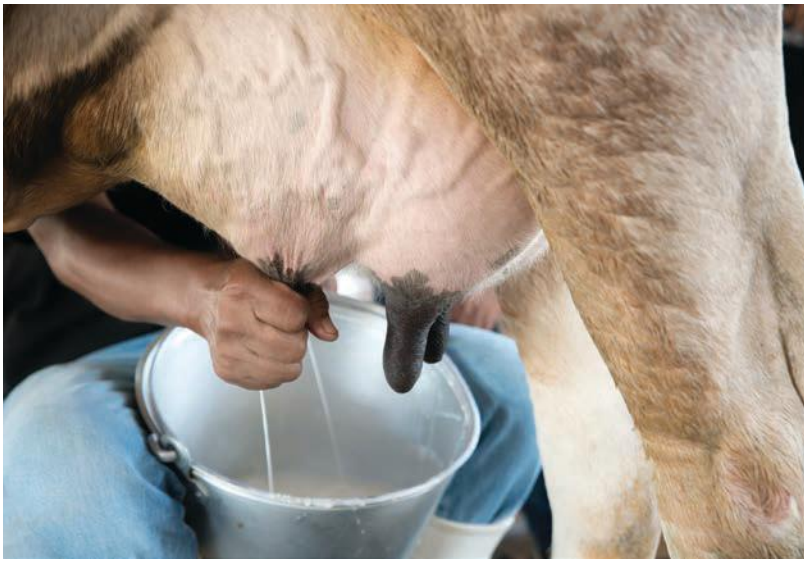


Figure 3.62 All mammals produce milk, but not all adult humans can digest it.

ISBN 978-1-108-61069-8 Cambridge University Press

Because humans are mammals, we can all drink milk as babies. This means that the enzyme called lactase, which breaks down lactose, is found in everybody when we are young. Anyone can become lactose intolerant at any stage in their life, although there are certain groups of people who are more likely to become lactose intolerant. Some examples:

- People of Asian, African, Indigenous and South American backgrounds are more likely to develop lactose intolerance at a young age.
- People who already have problems with their digestive system caused by disorders such as coeliac disease or Crohn's disease are more likely to develop lactose intolerance.
- Certain antibiotics can trigger temporary lactose intolerance, by interfering with the intestine's ability to produce the lactase enzyme.
- As people get older, their bodies can stop producing lactase.
- If you go for a long period of time without eating dairy, your body may stop producing lactase.

Coeliac disease

Explore! 3.6

People are becoming more aware of foods that contain gluten, and many people have started to follow gluten-free diets. Gluten is a protein in wheat, rye and barley-based products such as bread, pasta, pastry, cakes and biscuits. Bread has been a stable part of the human diet for thousands of years, and so many people view gluten intolerance and coeliac disease as new phenomena, but humans have been affected by these conditions throughout history. However, it was not until about 100 years ago that doctors began to diagnose and treat coeliac disease.

1. Find out how many people suffer from coeliac disease and how many people have gluten intolerance. You may like to find out the statistics for the world or investigate different countries.
2. Outline the symptoms of coeliac disease.
3. Research and then summarise what it is about gluten that makes people sick. Include an explanation of how a coeliac sufferer's body responds to gluten.

Figure 3.63 Foods such as this bread dough are high in gluten.

Figure 3.64 Coeliac disease is an immune disorder triggered by eating gluten.

ISBN 978-1-108-61069-8 Cambridge University Press

Science as a human endeavour 3.6

Seeing you from the inside

Imagine swallowing a pill-sized camera that captures images over the next 24 hours as it makes its way through your digestive system. Well, this technology is not new, and it gives doctors a unique view of what is going on inside your oesophagus, stomach and intestines. But there is a lot that a camera can't do: it can't deliver drugs, it can't grab a foreign object and remove it, and it can't perform a biopsy (slice off a tiny piece of tissue for analysis). This is why medical researchers are working with engineers to design tiny robots that can be put to work in your digestive tract. These robots need motors, sensors and smooth outer surfaces so they can pass through your digestive organs without damaging them, before finally being excreted just like any other waste product.

Figure 3.65 An artist's impression of a tiny robotic device crawling through an intestine

Figure 3.66 An illustration showing the scale of a robot frozen inside some ice, which the patient swallows. Once warmed up in the digestive tract, the robot unfolds into the shape on the left.

Section 3.5 questions

QUIZ

Remembering

1 State the food group that glucose belongs to.
2 Recall the route that food waste/faeces takes after it leaves the stomach. List the three sections of the small intestine and the five sections of the large intestine it passes through.
3 State the function of the tongue in digestion.
4 Name the type of acid that is found in the human stomach.

Understanding

5 Describe the role of the stomach in food digestion.
6 Explain how the structure of villi assists in the absorption of nutrients.
7 Explain how food is transported along the digestive tract.

Applying

8 Certain nutritional deficiencies in the body can be linked to damaged digestive organs. Suggest what deficiencies could be linked to a damaged large intestine.
9 Develop a hypothesis about what might happen if the large intestine was removed from the digestive tract.
10 A friend who is coming to your house for dinner suffers from coeliac disease and lactose intolerance. Suggest a meal you could cook that would be suitable for this friend.

continued...

ISBN 978-1-108-61069-8

...continued

Analysing

11 Compare the duodenum to the jejunum.

12 Classify the processes listed in the table as mechanical or chemical digestion.

Process	Mechanical or chemical?
Stomach churning and contracting	
Chewing food	
Bile released from gall bladder into duodenum to emulsify fats	

Evaluating

13 Crohn's disease is a bowel condition that causes flare-ups of inflammation in the ileum, which leads to impaired nutrient absorption. It also causes inflammation of the large intestine. Propose what effect this might have on the faeces.

14 Create a poster about the digestive tract that compares what happens to the portion of food that is digested and absorbed, versus the portion of what we eat that is not digested.

3.6 Other digestive systems

WORKSHEET

Have you ever had food poisoning? If so, it was probably from that time when you ate undercooked chicken or you finished the slightly questionable leftovers from several nights ago and ended up spending the following day on the toilet. Well, that was because the food that you ingested had too many bacteria on it for your body to deal with. But why does that happen to you, when some scavenger animals can eat half-rotten corpses and not get sick?

Figure 3.67 Vulture eating a rotting corpse

ISBN 978-1-108-61069-8

How is it that some animals eat only leaves and still manage to get all the protein, fats and iron they need to be healthy?

The answers to both these questions can be found in their specialised digestive systems.

Carnivores

The human digestive system is designed to process and break down both animal and plant products. However, unlike other animals, we have learned to cook our food, which vastly reduces the amount of harmful bacteria our digestive system has to contend with. **Carnivore** and scavenger species such as vultures have several traits that have evolved which allow them to eat food containing large amounts of bacteria that could kill a human.

carnivore
a consumer (heterotroph) that feeds on animal matter

Digestive system length

A carnivore's digestive system is shorter than a herbivore's or an omnivore's. Because animal cells do not have a cell wall (cell walls contain cellulose which is hard to digest), they are easier to digest and so it takes less time for them to pass through the consumer's digestive system. Because the food spends less time in the body of the carnivore, any harmful bacteria on the food have less chance to grow and cause illness.

Figure 3.68 Make sure you check the use-by date of meat.

Stomach acid

The stomach acid in humans is around 1.5 on the pH scale. This is quite strong and allows our bodies to kill many harmful micro-organisms, but not all of them. In comparison, a vulture's digestive acid is 0–1 on the pH scale, which is strong enough to dissolve certain metals and so is more than a match for any bacteria.

Did you know? 3.11

Bird vomit

As a defence mechanism when threatened, vultures and other birds, such as some seagulls, can projectile vomit onto predators. As you know, vomit smells bad at the best of times but just imagine how it would smell if you had been eating rotting flesh! If you add to that the corrosive levels of acid in the stomach, vomit makes a very effective warning system.

Figure 3.69 Vultures and many gulls use vomiting as a defence technique.

ISBN 978-1-108-61069-8 Cambridge University Press

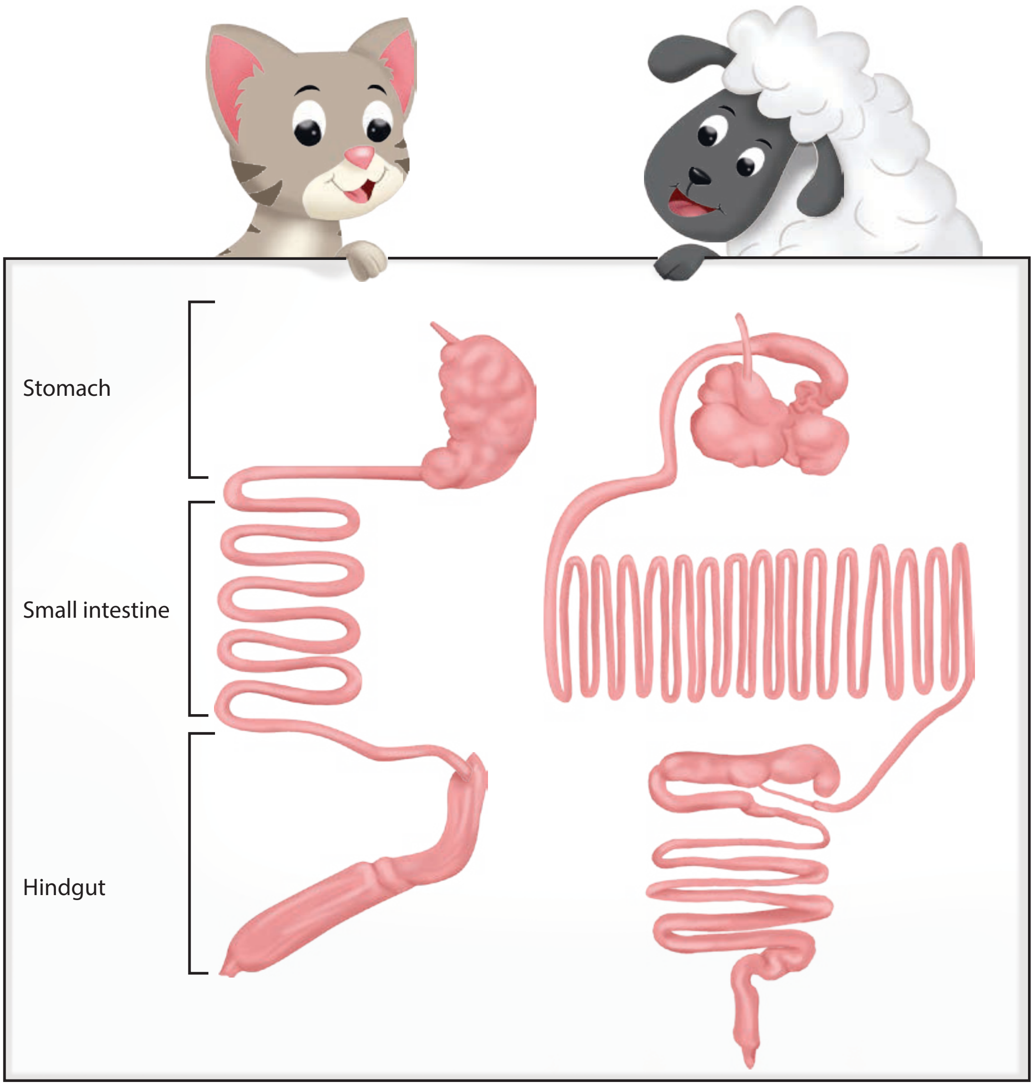


Figure 3.70 Cat (carnivore) and sheep (herbivore) digestive systems

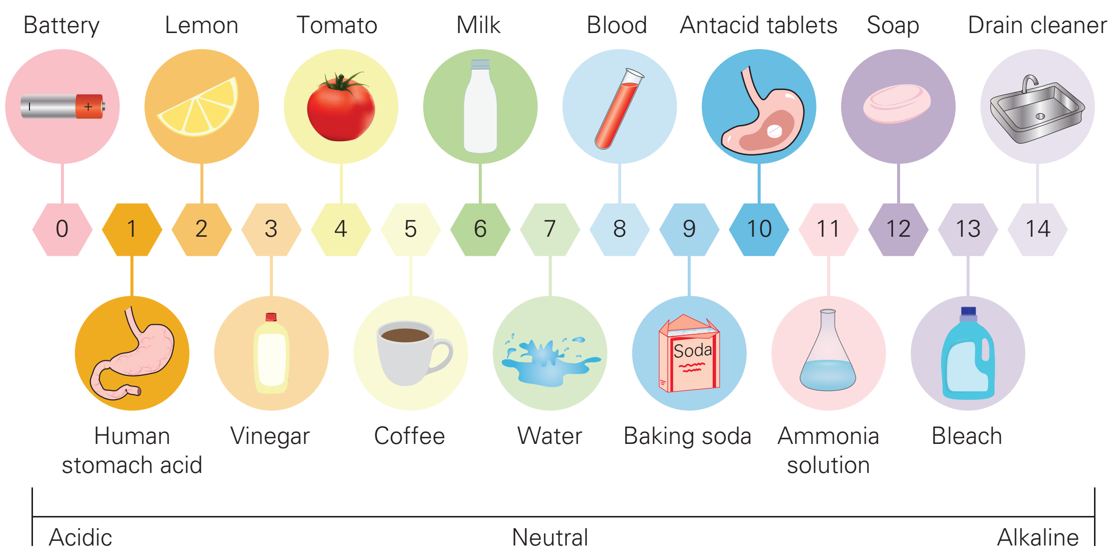


Figure 3.71 The pH scale

ISBN 978-1-108-61069-8

Practical 3.9

Acid and bacteria

Aim

To test the effect of acid on the growth of bacteria

Be careful

Ensure benches are cleaned and hands are washed before leaving the laboratory.

Materials

- probiotic drink
- agar plate
- sterile swabs
- incubator
- pipette
- hydrochloric acid 1 M
- hydrochloric acid 2 M
- lemon juice
- sulphuric acid 2 M
- sticky tape

Method

1. Identify the following variables in your experiment: independent (the variable you change and test), dependent (the variable you measure) and three controlled variables (variables you must keep the same).
2. Construct a hypothesis for your experiment: predict what effect the four different acids will have on bacterial growth.

Preparing the agar plate

3. On the underside of the agar plate, draw a cross using a permanent marker. This cross should intersect in the middle of the agar plate and form four equal quadrants.
4. Label each quadrant A, B, C or D on the outer edge of the plate.

'Lawn plate' technique

5. To create a lawn plate, dip your sterile swab into the probiotic mix and gently spread the probiotic over the agar plate, as shown in Figure 3.72 on the next page.
   With each 90 degree turn, dip your swab into the probiotic mixture to ensure full coverage.

Adding the acid

6. After creating the lawn plate, carefully lift the lid off of the agar plate and, using a pipette, place three drops of lemon juice into the quadrant labelled A.
7. Repeat step **6** for each of the acidic substances, as indicated in the results table.
8. Place the lid on the plate and, with 2–4 pieces of sticky tape, tape down opposite edges of the lid.
9. Place the agar plates in an incubator for two days. Never open them again.

Gathering results

10. After two days, remove the agar plates from the incubator and count the number of colonies that you can see on the agar plates. A colony looks like a slightly raised round dot on the agar plate.

Results

Quadrant	Treatment	Bacterial colony numbers
A	Lemon juice	
B	Hydrochloric acid 1 M	
C	Hydrochloric acid 2 M	
D	Sulphuric acid 2 M	

continued…

ISBN 978-1-108-61069-8

...continued

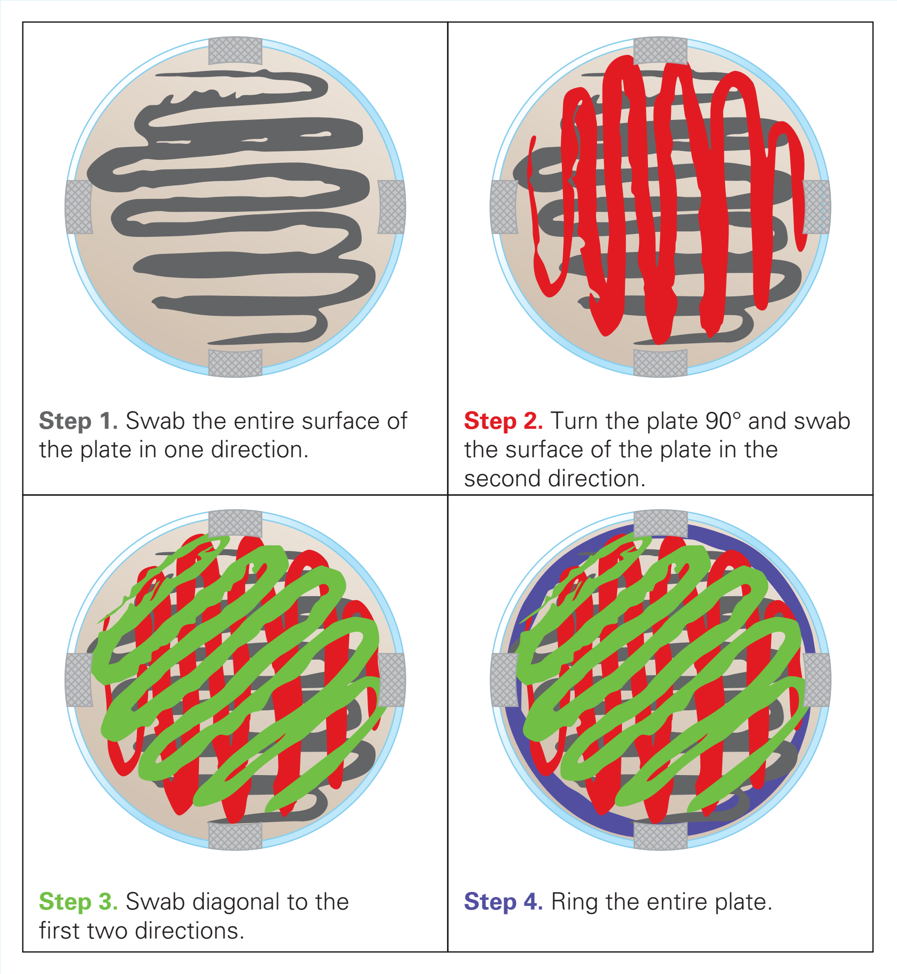


Figure 3.72 Making a lawn plate

Evaluation

1 Did your results support or not support your hypothesis?
2 Use your results to explain how different animals could eat dead organisms without getting sick.
3 Suggest how you could use this experimental design to test the effectiveness of different antibacterial products such as hand wash, mouthwash and surface sprays.
4 In this experiment you used probiotics that are found in the human body. How could you alter this experiment to increase its validity in the natural world?

Conclusion

1 What claim can be made from this experiment regarding the effects of different acids on bacterial growth, and how this relates to different organisms' stomach acids? Begin your sentence with: 'This experiment suggests that ... '.
2 What evidence did you gather? Begin your brief summary with: 'The results show that ... ' and remember to include possible sources of error.
3 Explain how the data supports your claim. Begin your sentence with: 'This means that ... '.

ISBN 978-1-108-61069-8 Cambridge University Press

Quick check 3.14

1 Explain how vultures defend themselves from predators.
2 How is the vulture's stomach acid different than a human's?
3 Who has a shorter digestive tract: carnivores or herbivores?

Explore! 3.7

Carnivorous plants

Not all plants rely solely on sunlight and water for their food. Some add meat to their diet to give them a nutrient boost. Most carnivorous plants live in swamps and marshes, where the soil doesn't have many nutrients such as nitrogen, and so they rely on breaking down insects to create their own nutrients.

Find out about each of the following carnivorous plants and summarise how they catch their prey, the structures they have that allow them to catch their prey, and how they digest their prey.

1 Venus flytrap

Figure 3.73 A Venus fly trap and an unsuspecting fly

2 Sundew

Figure 3.74 A sundew wrapping around an insect

3 Pitcher plant

Figure 3.75 A pitcher plant, and its possible prey

ISBN 978-1-108-61069-8 Cambridge University Press

Herbivores

Eucalyptus leaves are toxic for humans. In fact, if you ever tried to eat some you could find yourself struggling to breathe, losing your balance and feeling very dizzy. Leaves are also made of cellulose, which is not easy for humans (or carnivores) to digest and obtain any nutrients from. So it is surprising that eucalyptus leaves are the koala's primary source of nutrition.

Figure 3.76 Koalas can digest eucalyptus leaves, which are toxic to humans.

Koalas are **herbivores**, and so they have many adaptations that allow them to obtain the nutrients that they need from eucalyptus leaves. They have a long digestive tract with a special organ, called a *caecum*, that can digest cell walls. In herbivores, the caecum contains millions of friendly bacteria that are specialised to break down certain plant materials (such as eucalyptus leaves). Koalas get most of their water from the leaves they eat, and so they do not often need to climb down from the tree they are living in.

herbivore
a consumer (heterotroph) that feeds on plant matter

Eucalyptus leaves are very low in nutrients and so, even with a caecum, koalas need to eat for five hours a day to get enough food to sustain them. They spend most of the rest of their day sleeping, to conserve energy and to allow their bodies to digest their food.

In total it can take around four whole days for a leaf to pass through a koala's digestive system. This maximises the amount of nutrients and water that are absorbed from the food.

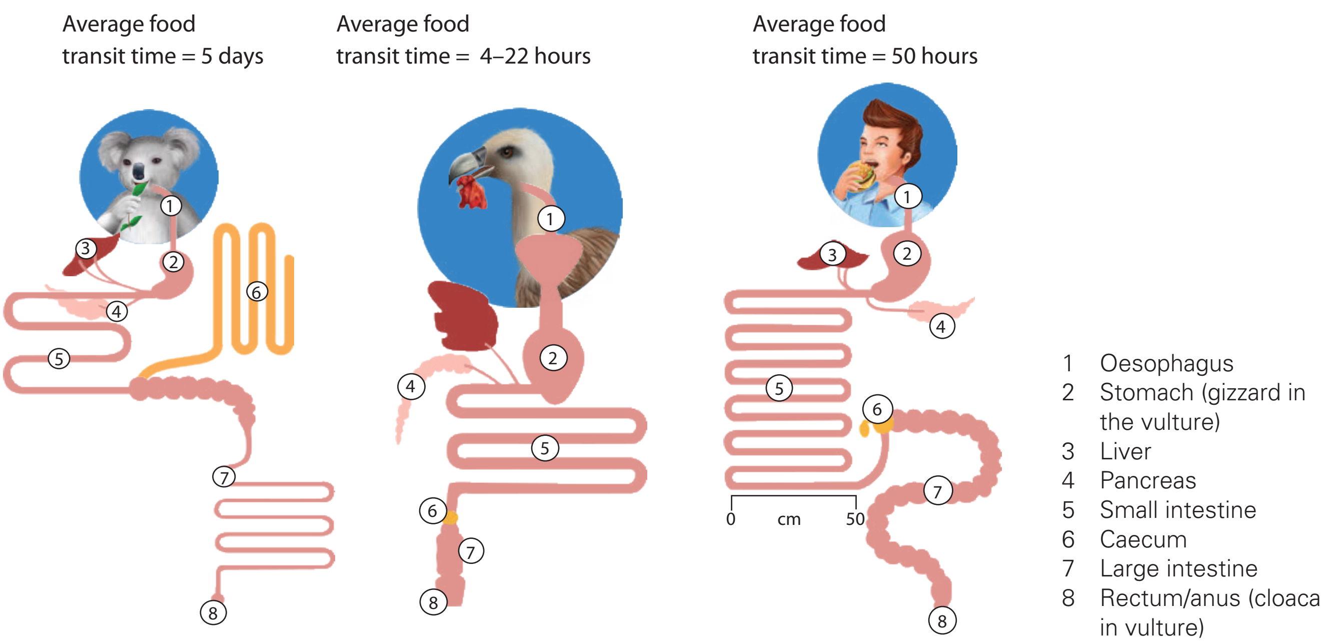


Figure 3.77 Food transit times for koalas, vultures and humans

ISBN 978-1-108-61069-8 Cambridge University Press

Did you know? 3.12

Eating Mum's faeces

Baby koalas are not born with the special friendly bacteria they need to digest eucalyptus leaves. They need to eat their mothers' faeces (called pap) in order to start their own colony of bacteria in their caecum.

Figure 3.78 A mother and baby koala

Science as a human endeavour 3.7

Cows and the climate

Cows burp a lot of methane gas, which is a naturally occurring product of fermentation in their rumen. The micro-organisms that colonise their digestive tract assist in breaking down the plant matter, producing methane as a waste product. Unfortunately, methane is also a potent greenhouse gas – cows account for about 25% of the methane produced in the USA.

Figure 3.79 Dairy cows being fed as they are milked

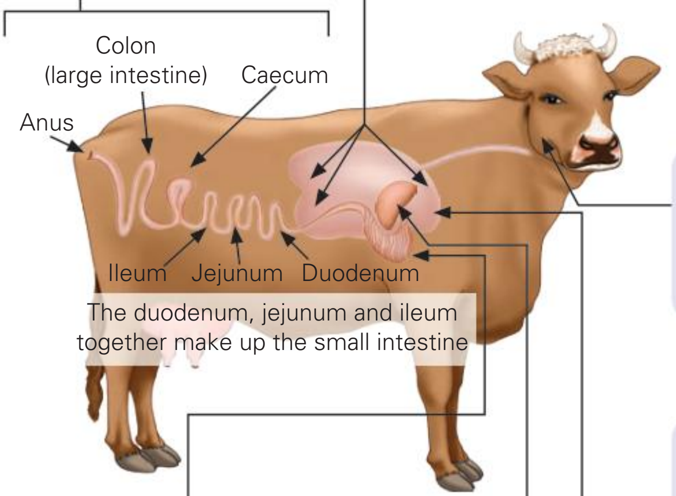
A recent study has experimented with supplementing the diets of dairy cows with a chemical compound that inhibits micro-organisms from producing methane. It showed a 30% reduction in methane, and the cows actually gained more weight without eating any extra feed, meaning they were extracting more energy. The feed supplement is in the early stages of development, but could be a helpful tool in the fight against climate change.

ISBN 978-1-108-61069-8 Cambridge University Press

WIDGET
The mammalian digestive system

Ruminants

If you've ever seen a cow, it was probably chewing. Cows are herbivores, just like koalas, so they need to eat for most of the day to gain as much nutrition from their food as possible. Cows are in a special category of herbivores, called *ruminants*. Ruminants, including antelope, sheep, buffalo and goats, deal with being a herbivore in a unique way. Figure 3.80 shows the path of food through a ruminant.



1 First chewing
Cows graze on plants using their incisor teeth to snip leaves and then chew their food using their molar teeth briefly before swallowing it for the first time.

2 Stomach round 1
The grass passes into the largest part of the four-part stomach, called the rumen (this is where the term 'ruminant' comes from). The rumen, like the caecum, contains bacteria that digest cell walls.

3 Second, third and fourth chewing
Food from the rumen is regurgitated back up into the mouth, with the help of the second chamber of the stomach, called the reticulum. This assists the bacteria in breaking the grass down ready to be digested. The regurgitated food is called 'cud'. Cows 'chew the cud' for around 6–8 hours during times of the day when they are not grazing.

4 Stomach rounds 2 and 3
When the cud is sufficiently broken down, it passes into the third chamber of the stomach, called the omasum, where most of the excess water and saliva are absorbed.

5 Stomach round 4
Finally, the food passes into the abomasum, or 'proper stomach', where enzymes and digestive juices start to properly digest and absorb the nutrients.

6
The food passes through the small intestine, caecum and large intestine in much the same way as it does in any other herbivore. The only difference is that the extended amount of time the food spends in the cow's stomach allows maximum nutrient absorption by the intestines.

Figure 3.80 The passage of food through a cow's stomach

Quick check 3.15

1 Outline the role of the caecum.
2 Define the term 'friendly bacteria'.
3 How does the length of the digestive tract of a herbivore differ from a carnivore's?
4 Describe the way a ruminant digests plant matter.

Try this 3.11

Digestive flow charts
Construct three flow charts on a poster showing the digestive tracts of a carnivore (not a human), a herbivore and a ruminant. Annotate the structures of the digestive tract, showing their specialised functions so that the key differences between these organisms are obvious.

ISBN 978-1-108-61069-8

Cambridge University Press

Section 3.6 questions

QUIZ

Remembering

1 Recall the four parts of a herbivore's digestive system.
2 How many chambers are there in the stomach of a cow?
3 Name the substance that leaves are composed of, which is difficult for humans to digest and gain nutrients from.
4 Fill in the gaps: Acids have a _______ pH and bases have a _______ pH.

Understanding

5 Identify the product in the stomach that kills bacteria.
6 Outline one way that the vulture uses its stomach acid other than for digestion.
7 Explain how the vulture's digestive system is adapted to eat rotting meat.
8 Describe how baby koalas gain their friendly bacteria.

Applying

9 Identify two ways in which a vulture's digestive system is different from a human's digestive system.
10 Copy and complete the table, by comparing the digestive system of a koala with that of a human.

Human	Koala

Analysing

11 Use the images in Figure 3.81 to answer the following questions.
  a Contrast the digestive system of a dog and a sheep.
  b Suggest which two of the animals in Figure 3.81 probably have a similar diet.

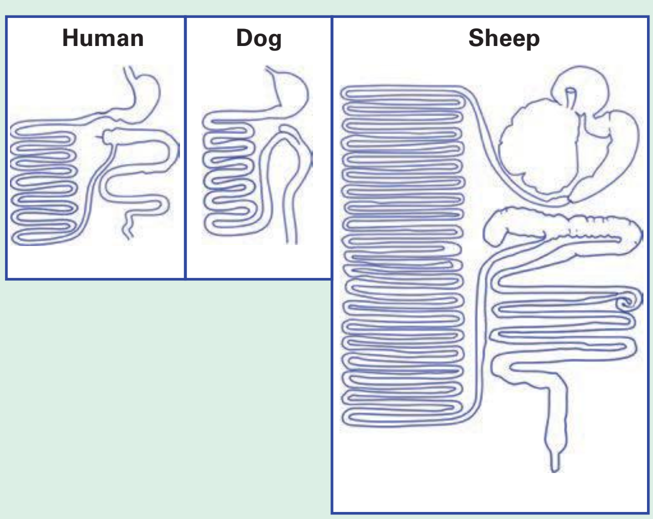


Figure 3.81 Digestive systems of a human, a dog and a sheep

Evaluating

12 Carnivorous plants tend to prey on small insects or amphibians. Give reasons why attracting larger mammals rather than insects might be a problem for carnivorous plants.

ISBN 978-1-108-61069-8

Cambridge University Press

3.7 Organ repair and replacement

WORKSHEET

Each of the organ systems in your body relies on the specialised function of many different organs working together to keep you healthy. But what happens when one of these organs is damaged, infected or cannot do its job properly? If one organ in a system cannot function at full capacity, it results in a chain reaction that can result in people becoming very ill and having to go to hospital.

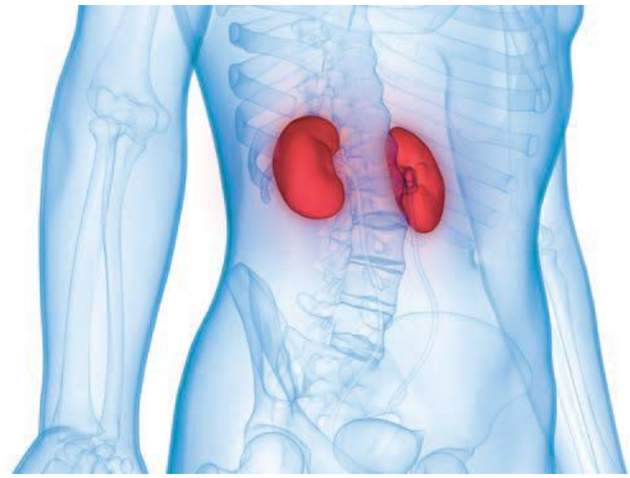


Figure 3.82 Most of us have two healthy kidneys. If they are damaged through disease, one option is a kidney transplant.

Organ transplants

Damaged organs can sometimes be given the chance to repair through certain medications, diet and lifestyle changes. However, if an organ becomes so damaged that it can no longer work at all, the only option may be to completely replace it. This is done through a medical procedure known as **organ transplantation**, in which a healthy organ from one body is used to replace the damaged organ in another.

organ transplantation the process of removing a donor organ and then surgically implanting it into a recipient, to improve their organ function or replace a diseased organ

One organ that is a commonly transplanted is the kidney. The kidney is located near your lower back. It filters waste products out of your blood and produces urine. Diseases and environmental factors that can damage your kidneys include medications, alcohol and diabetes. We have two kidneys in our body, but we can manage with only one. Therefore, some people volunteer to donate one of their healthy kidneys to a friend or family member who needs a replacement one.

Figure 3.83 Human organs being transported for transplant

ISBN 978-1-108-61069-8

Cambridge University Press

In order for an organ transplant to be successful, the donor (person giving the organ) and the recipient (person receiving the organ) must have similar matching markers on their cells. If these markers are not matched, the body will recognise the new organ as a foreign invader and attack the organ using the immune system. This is known as **organ rejection**. Unfortunately, the chances of two people being a match is extremely low, even within families. This means that there is a high demand for organs but a very low supply available.

organ rejection when an organ transplant recipient's immune system recognises the organ as foreign and attacks it

Figure 3.84 A surgeon performing a kidney transplant

Organ donation is sometimes possible when a person dies, and has previously indicated that they would like to donate their organs. This amazing gift can save multiple lives, as organs such as heart, lungs, kidneys, liver, large intestine and pancreas and some tissues such as skin and corneas from the eye can all be donated. In 2017, 1675 Australian lives were transformed by organs donated from 510 deceased donors and 273 living organ donors.

Not many deaths occur in a way that allows organ donation. For example, the person must pass away in a hospital, and very strict procedures must be followed to ensure the health of the organs being donated. Sometimes the families of registered organ donors refuse to give consent. This is why it is very important that people discuss their wishes with their families and consider registering their intentions on the Organ Donor Register.

Quick check 3.16

1. If an organ is damaged, what are the first treatment options before a transplant is considered?
2. Name some of the organs and tissues that can be donated in Australia.
3. Describe what would happen if a transplanted organ came from a donor who was not a good match for the recipient.

Explore! 3.8

Kidney transplants

A kidney transplant is a life-prolonging surgery but it does not provide a cure for end-stage kidney disease. The recipient must be medically suitable, and an available matching organ needs to be found. Conduct some research into kidney transplants in Australia and answer the questions below. The 'Kidney Health Australia' website is a great resource.

1. What are the steps involved in transplanting a kidney?
2. Where is the donor kidney positioned in the recipient's body?
3. What influences the success of the organ transplant? Give some statistics in your answer and discuss the anti-rejection drugs the person will need to take.

ISBN 978-1-108-61069-8 Cambridge University Press

Organ replacement

Because of the high demand but low supply of organs available for transplantation, scientists are developing new ways to overcome this problem. One new technique is **xenotransplantation**. This is the process of transplanting organs from a different species than the recipient.

xenotransplantation transplanting organs from one species into another

Figure 3.85 Pigs are mammals, just like us. Tissues from pigs have been successfully transplanted into humans.

Doctors have been transplanting porcine (pig) heart valves into humans since 1965. Now scientists are trying to find a way to transplant entire pig organs. Pig organs are a similar size and shape to human organs. There are two main biological challenges that scientists face with this procedure.

- The biological markers on pigs' cells and organs do not match those in humans, and so the human recipient's body would reject the organ.
- There are 64 viruses in pigs' genetic material that could infect and harm humans who receive a pig organ.

The first challenge that scientists are focusing on is to remove the viruses from the genetic material of pigs. This can be done using technology known as CRISPR, where an enzyme is used to cut out the parts of the genetic material of pigs that contain the viruses. CRISPR acts like a cut-and-paste tool, where the harmful parts of the genetic material are cut out and then a non-harmful section of genetic material is pasted in its place.

Scientists have used the CRISPR process to produce several healthy genetically modified pigs that do not contain the harmful viruses. Scientists now have to overcome the problem of the markers on pig organs that cause human bodies to identify the organs as foreign.

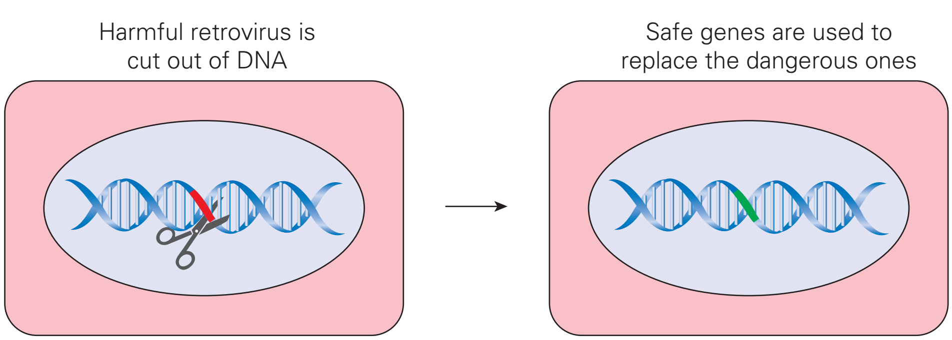


Figure 3.86 In the CRISPR process, the virus is cut out, and harmless genetic material is pasted in.

ISBN 978-1-108-61069-8 Cambridge University Press

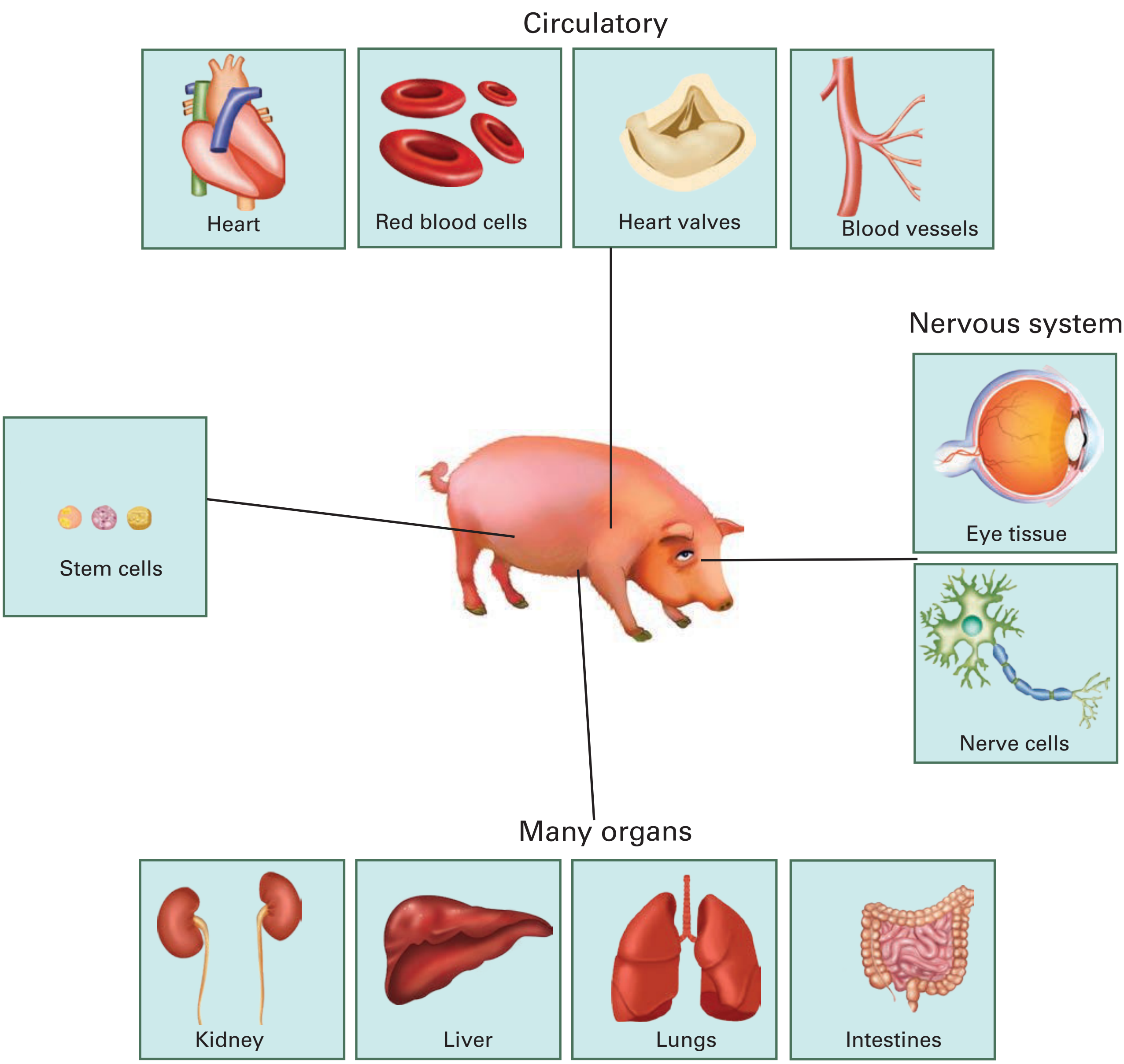


Figure 3.87 All the possible transplanted tissues and organs we could get from pigs

ISBN 978-1-108-61069-8

Cambridge University Press

Science as a human endeavour 3.8

Robots making organs?

Organoids are tiny clusters of cells that organise themselves into miniature and rudimentary versions of our organs. They present biomedical researchers with an opportunity to study organ development and experiment with drug technologies. Organoids develop from stem cells that have been grown in tiny 'wells' and induced to differentiate into a specialised type of cells, such as neurons. These neurons then make connections and begin to behave in a similar way to how they do in a patient's actual brain.

In 2018, researchers at the University of Washington successfully put robots to work in making trays of kidney organoids in the lab. The automated system completes a researcher's daily work in around 20 minutes and makes fewer mistakes. The robotic system has also been trained to analyse the genetic material in the organoids, and has led to new discoveries about the kidneys' blood supply and kidney disease.

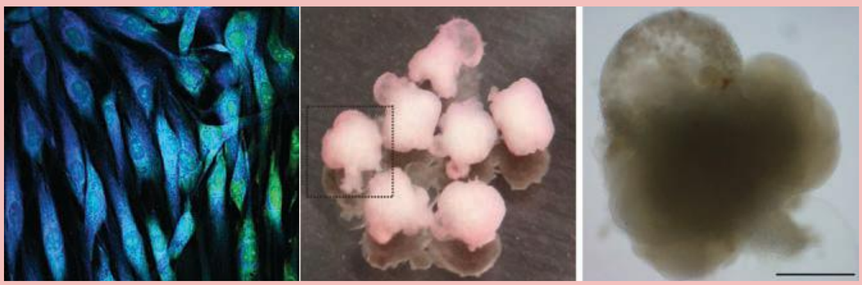


Figure 3.88 Mini brain organoids grown from stem cells. Left: Fibroblast cells (shown here) are used to produce stem cells. Middle and right: The stem cells are grown in culture and induced to form brain tissue, or 'mini brains'.

Organ regeneration

The liver is the largest organ in your body. It is located just below your ribs, on the right side of your body. The liver is involved in many important processes, such as producing enzymes for digestion, storing vitamins and removing toxins from your blood. If the liver is exposed to too many toxins over a long period of time, it can become damaged and not perform its job properly.

Figure 3.89 The position of the liver in a human

Alcohol is a toxin that the liver filters out of the blood. People who regularly drink too much alcohol can permanently damage their liver. Another toxin that your body naturally produces is hydrogen peroxide – the same chemical that people use to bleach their hair. Obviously, having too much of this substance dissolved in the blood could cause major damage throughout the body.

Figure 3.90 Your cells produce the same product that bleaches hair!

ISBN 978-1-108-61069-8 Cambridge University Press

The liver usually does a great job of turning hydrogen peroxide into the harmless substances water and oxygen. However, too much salt in the blood can reduce the liver's ability to break down hydrogen peroxide. Salt comes directly from our diet, and people who eat fast food or processed foods regularly consume high levels of salt and so are at risk of reducing their liver's ability to function. If caught early enough, a change in lifestyle habits can reverse or limit the damage done to the liver. In severe cases, however, liver transplantation surgery may be necessary.

As you learned earlier in this chapter, organ transplants come with many risks, and matching donors are hard to find. That is why scientists are working on the ability to regenerate or grow organs from living healthy tissue found in the patient. This process is called *tissue engineering* and it is a fast-growing area of research. The liver is the only human organ that can not only repair itself but can regrow dead or damaged areas. This means that healthy living organ donors can donate part of their liver and their liver can grow back to nearly the same size over time. Because of the regenerative properties of the liver, scientists can grow whole new organs from as little as a quarter of an original liver.

Figure 3.91 Hot chips are delicious, but you need to be careful how much salt you eat.

If scientists could grow and regenerate organs using the patient's own tissue, then the body would not reject the transplanted organ.

Quick check 3.17

1. What is the difference between organ replacement and organ regeneration?
2. Define 'xenotransplantation'.
3. Outline two potential problems with xenotransplantation.
4. Name two toxins filtered out by the liver.
5. A liver can regrow from what sized portion?

Practical 3.10

Investigating the impact of salt on liver function

During this experiment you will add hydrogen peroxide to blended cow's liver. If the hydrogen peroxide is broken down, then oxygen bubbles will be produced. You will add different amounts of salt solution, to test the effect of salt on liver function.

Aim

Construct an appropriate aim for this experiment, based on the background information above.

Materials

- 4 large test tubes
- liver solution (100 g of cow liver blended with 100 mL water)

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

- 10 mL measuring cylinder
- 0%, 10%, 20%, 30%, 40% salt solutions
- 3% hydrogen peroxide
- test tube rack
- disposable gloves
- marker
- stopwatch

Method

1. Identify the following variables in your experiment: independent, dependent and three controlled variables.
2. Construct a hypothesis for your experiment: predict what effect the four different acids will have on bacterial growth.
3. Place the test tubes in a rack and label them 0%, 10%, 20%, 30%, 40%.
4. Add 3 mL of liver solution and 3 mL of the first salt solution and allow to combine for 3 minutes.
5. Mark the level of the solution with a marker.
6. Add 2 mL of hydrogen peroxide to the first test tube and time until the bubbles stop being produced.
7. When the bubbles stop being produced record the time in the results table.
8. Repeat steps **6–7** with the remaining tubes.

Results

Salt (%)	Height of bubbles (mm)
0	
10	
20	
30	
40	

Evaluation

1. Draw a line graph to plot your results.
2. Describe how you could make your results more reliable.
3. Discuss whether your results supported or didn't support your hypothesis.
4. Explain the trend observed from your results.
5. Using your results, suggest a salt % range that you would test in a follow-up investigation.
6. Explain the reason that a test tube containing no salt was included in the experiment.

Conclusion

1. What claim can be made from this experiment regarding the effects of salt on liver function? Begin your sentence with: 'This experiment suggests that … '.
2. What evidence did you gather? Begin your brief summary with: 'The results show that … ' and remember to include possible sources of error.
3. Explain how the data supports your claim. Begin your sentence with: 'This means that … '.

ISBN 978-1-108-61069-8

Ethics

When we discuss organ transplants, we often have to think about the ethical implications of taking an organ from one person and using it in another. 'Ethics' is the term we use to discuss what is right and wrong in society. As there are many different beliefs, cultures and people around the world, ethics can vary from country to country or from person to person. When something is considered right, we say it is **ethical,** and if it is considered wrong, we say it is unethical.

ethical
relating to ethics, the field of considering what is right and wrong

Our laws are linked to the ethical beliefs of a nation and can change over time as people's perception of ethics evolves. However, just because something is considered unethical does not necessarily mean that it is illegal.

Figure 3.92 Judges make decisions based on law, but ethics may also be a consideration in the decision-making process.

Ethics of organ transplants

Some donated organs, such as kidneys and partial livers, come from living donors. This creates an ethical dilemma for the doctor who is performing the surgery. Should they risk the life of a healthy person to save or improve the life of a patient? Some questions they have to consider are:

- Does the living donor know and understand all the risks?
- What if something goes wrong during surgery and puts the donor's life at risk?
- What if the transplant is rejected by the patient and the organ goes to waste?
- What happens if the donor is left with long-term pain, infection or impaired health after the surgery?

The donor may be under a lot of pressure from friends or family, which can make them feel forced into donating.

At any one time, there are around 1500 people on the Australian organ transplant waiting list. There are many rules in place to ensure that organs are allocated to patients in a fair process that is not affected by race, religion, gender, disability, social status or age, unless an adult organ is too large for a child (or a child's organ is too small for an adult).

There are a very limited number of organs available at any one time, and so the wait for an organ could be anywhere from six months to more than four years. As a result of this, several factors are used to decide who gets an organ, such as:

- how long the person has been waiting for a transplant
- how well the organ matches the patient
- how urgent the transplant is for the patient's health
- whether the organ can be brought to the person in time.

The pros and cons of organ donation **Try this 3.12**

Create a two-way table showing the possible advantages and disadvantages (risks) for both an organ donor and a recipient.

ISBN 978-1-108-61069-8 Cambridge University Press

Explore! 3.9

Opt in or opt out?

In some countries, such as Spain, all adults are automatically registered as organ donors. These adults can 'opt out' of the registration if they do not wish to be an organ donor. Many do not opt out. Spain consequently has one of the shortest waiting times for organ transplants in the world.

Research the current percentage of Australians who are registered organ donors and our average waiting list times, and compare these with Spain's.

Answer the following questions and justify your opinion with evidence.

1 Do you think Australia would benefit from an 'opt out' organ donation system?
2 What are some of the advantages and disadvantages of an 'opt out' system?

QUIZ

Section 3.7 questions

Remembering

1 State the function of the kidneys.
2 Name two factors that can damage the kidneys.
3 List the two main challenges that scientists face with xenotransplantation.
4 Name the largest organ inside a human.

Understanding

5 Define 'organ donor'.
6 Define 'organ transplant'.
7 Explain why organs are rejected.

Applying

8 Summarise how too much salt can be harmful to a person.
9 Identify one organ that can regenerate.
10 Identify how Australian rules keep organ donation fair.

Analysing

11 Compare ethics to laws.
12 Patients who are waiting for a kidney transplant might undergo daily or weekly dialysis treatment. Dialysis involves attending a hospital and being connected to a machine that filters your blood, and then returns it to your circulation. The graph in Figure 3.93 shows percentage survival rates for patients on dialysis versus patients who receive a kidney transplant. Use the graph to answer the following questions.

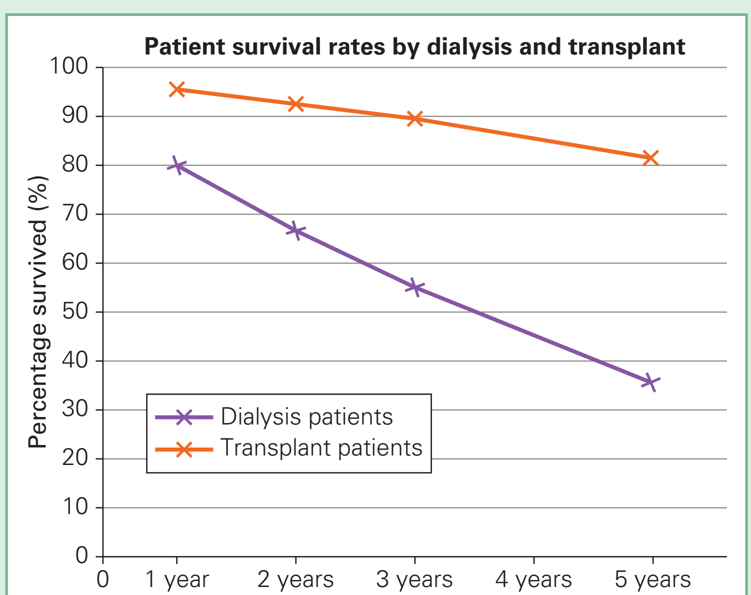


Figure 3.93

continued...

ISBN 978-1-108-61069-8

Cambridge University Press

...continued

- **a** What is the difference in survival rates at the 1 year mark for dialysis patients versus transplant recipients?
- **b** What is the difference in survival rates at the 5 year mark for dialysis patients versus transplant recipients?
- **c** Using your knowledge of organ transplantation, account for the difference in survival rates for these two patient populations. (What advantages does transplantation offer?)

Evaluating

13 Justify why liver regeneration would be more beneficial than a liver transplant.

Review questions

SCORCHER

Remembering

1 Define 'lenticels' and state where they might be found.

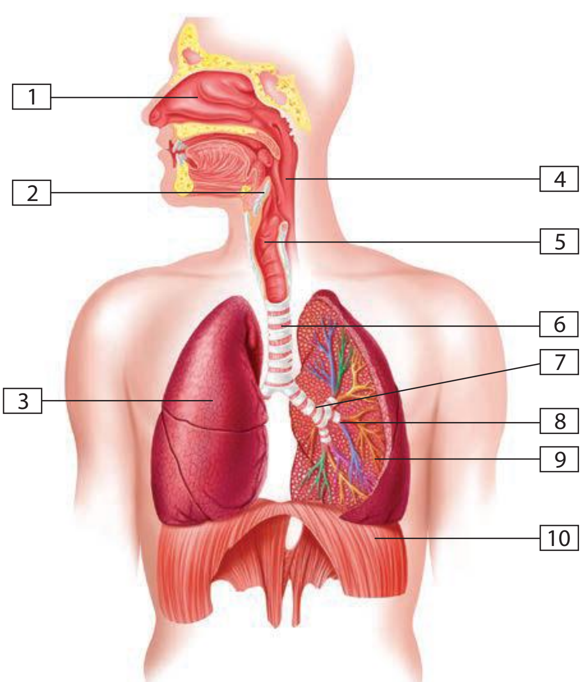
2 Name the blood vessel:

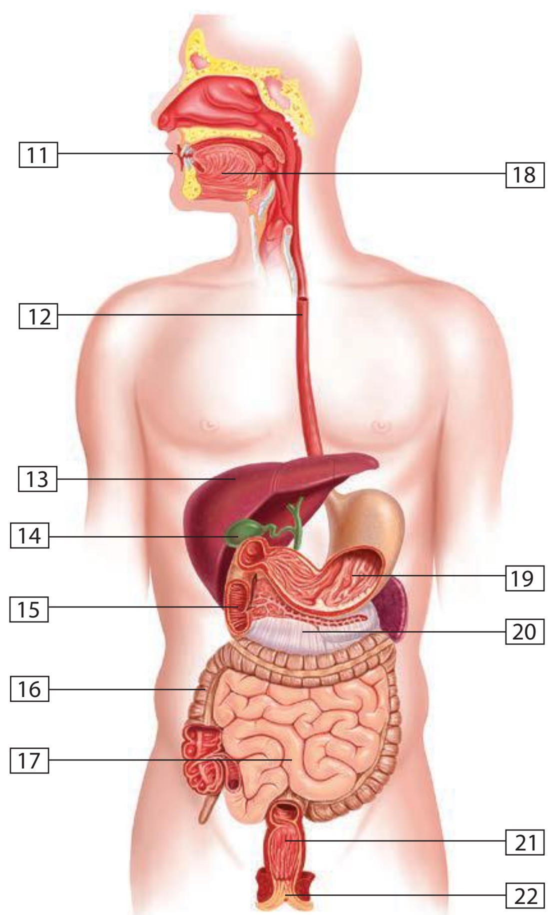
- **a** that carries blood away from the heart to the lungs to become oxygenated
- **b** that carries oxygen-rich blood out of the heart
- **c** that returns blood to the heart from the body.

3 State the key role of the small intestine and the large intestine in humans.

4 Define 'xenotransplantation'.

5 Match the numbers in the following diagrams of a human with the following terms:
mouth, liver, larynx, alveoli, diaphragm, tongue, anus, stomach, nasal cavity, trachea, rectum, lung, pancreas, gall bladder, epiglottis, duodenum, large intestine, oesophagus, pharynx, small intestine, bronchus, bronchiole.





ISBN 978-1-108-61069-8

Understanding

6 Describe the contents of blood.
7 Explain the role of enzymes in the digestive system, using examples.
8 Explain the function of the liver.
9 Outline the differences between the digestive systems of a carnivore and a herbivore.
10 Explain what is meant by 'living donor'.
11 Outline three essential features of gills if they are to efficiently exchange gases and act as lungs for fish.

Applying

12 Arrange these terms in order of increasing size/complexity: organ, organism, tissue, cell, organ system.
13 Explain why it could be harmful to treat a koala with antibiotics for an infection.
14 Other than breaking down food, propose another function of stomach acid.
15 Construct a flow chart or a story that depicts the path taken by a single molecule of oxygen, from when it enters the mouth, to when it enters a cell and diffuses to the mitochondria to be consumed in cellular respiration. Then show how a molecule of carbon dioxide is produced and follow its story until it is exhaled. Make sure you include all relevant parts of the respiratory and circulatory systems.

Analysing

16 Examine this statement: 'Lactose intolerance should be referred to as lactase deficiency'. Why is this the case?
17 Compare mechanical digestion to chemical digestion.
18 Contrast the contents of the blood as it leaves your heart to when it returns to the heart.
19 Copy and complete the table, to distinguish between an artery, a capillary and a vein in terms of both their structure and their function.

	Structure	Function
Artery		
Capillary		
Vein		

20 Construct a table to compare the structure and function of villi and alveoli.
21 Construct a Venn diagram to compare the gas exchange structures of fish, frogs and humans.

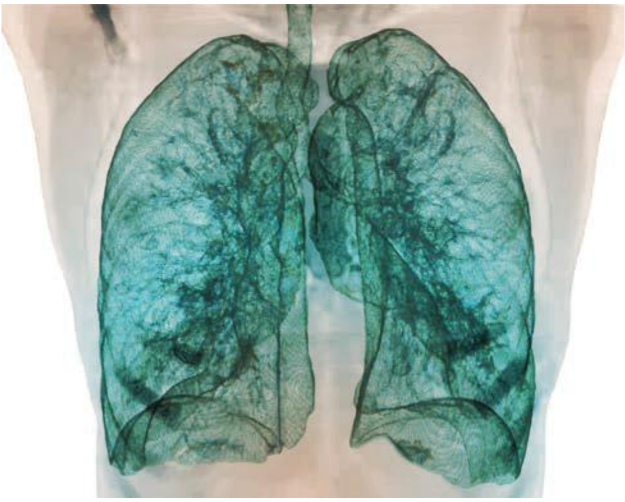


Figure 3.94

ISBN 978-1-108-61069-8 Cambridge University Press

22 Forced vital capacity (FVC) is a measure of how much air a person can blow out in one exhalation. The graph in Figure 3.95 shows the normal values for men (in red) and women (in purple) according to their age. Use the graph to answer the following questions.

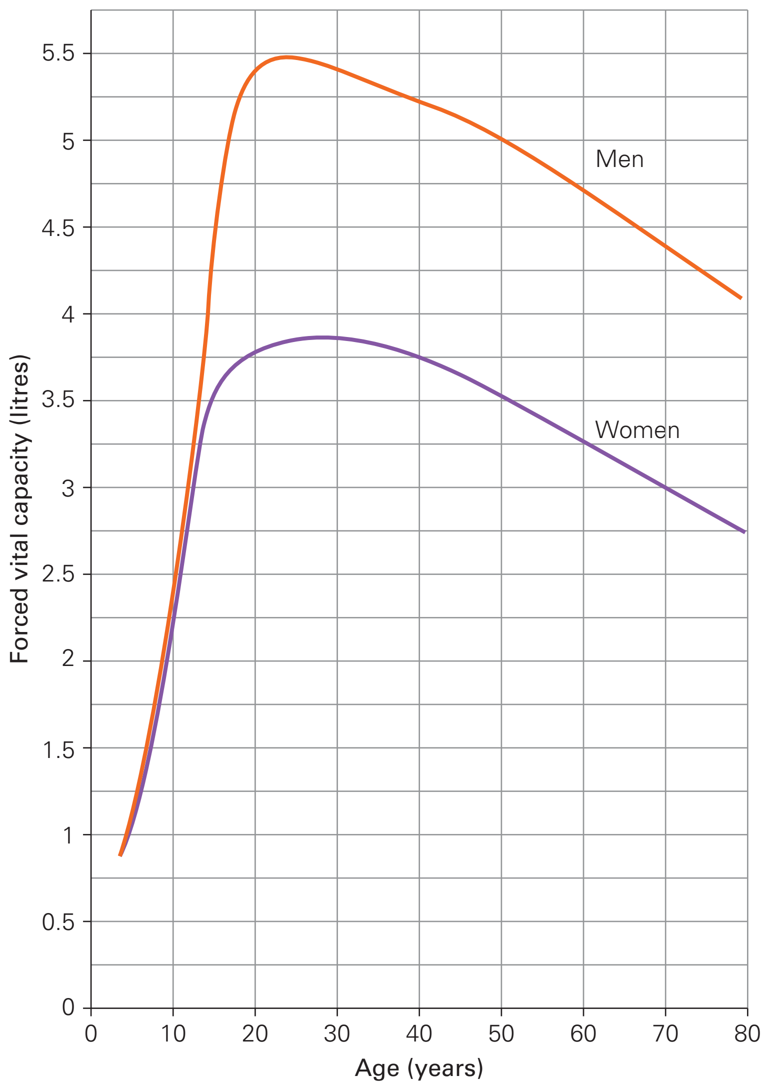


Figure 3.95 Forced vital capacity versus age, for men and women

- **a** What is the average FVC for a male and a female at age 30?
- **b** Between what ages does a person's lung capacity increase the most?
- **c** Propose a reason why males tend to have larger FVC than females.

Evaluating

23 Propose two reasons why most frogs need to remain near water.

24 A child is diagnosed with a rare and potentially fatal condition, but a bone marrow transplant from a matching donor will likely save their life. Neither of the parents is a match, but they are told by the doctors that a sibling is likely to be a suitable match. The parents decide to have another child, with the intention that when the baby is born, he or she can provide a bone marrow donation to their sibling. Research what is involved in bone marrow transplantation, and discuss the ethical dilemma these parents face. Evaluate the pros and cons of the parents' decision, and defend your personal opinion on whether they should or should not have the second sibling.

ISBN 978-1-108-61069-8 Cambridge University Press

STEM activity: Clearing a blocked artery

Background information

The heart is an incredible organ. It is responsible for pumping oxygen and nutrients around your body, to every cell. It continues to pump for your entire lifetime and you can't live without it. Unfortunately, many people around the world experience heart conditions that are life threatening. An example is coronary artery disease (CAD), a major cause of death in Australia. Many heart conditions can be treated with medication, and some require surgery. Other conditions, such as dilated cardiomyopathy, CAD and heart-related birth defects, can only be treated with a heart transplant. A donor heart can be used from a person who has died and has consented to being an organ donor. However, sadly, the number of people on waiting lists for heart transplants is far greater than the number of donor hearts available, and many people die while they are waiting for a transplant.

Like all our organs, the heart requires oxygen and nutrients. These are supplied to the heart in blood that comes via the coronary arteries. When a person has CAD, cholesterol, calcium, fat deposits and other substances deposit on the walls of their coronary arteries. These deposits make the coronary arteries narrower, reducing the blood supply to the heart, and therefore reducing the supply of oxygen to the heart muscle.

Two ways of using surgery to overcome this problem of blocked coronary arteries are shown in Figures 3.96 and 3.97.

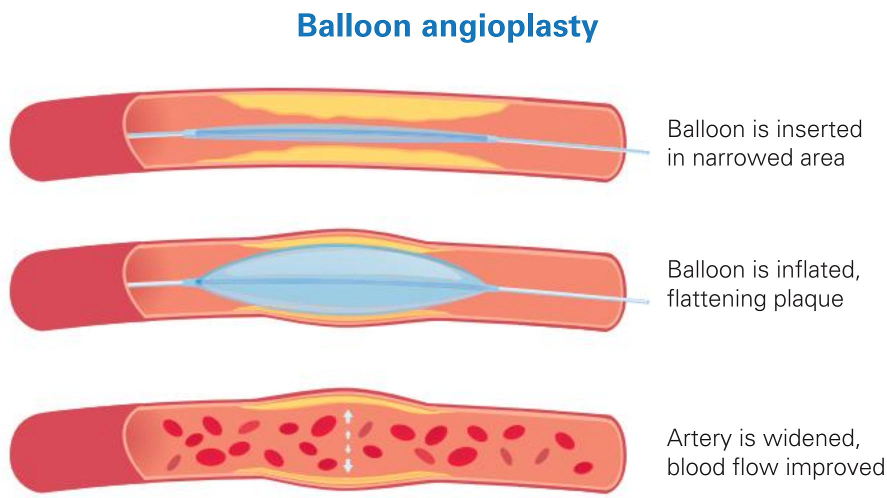


Figure 3.96 Angioplasty: a small 'balloon' is inflated inside the artery, which pushes the plaque aside and widens the vessel.

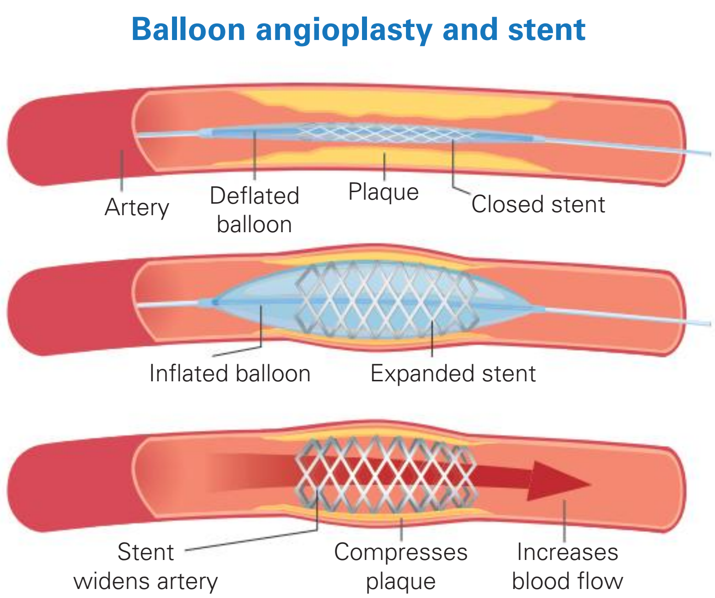


Figure 3.97 Many people also have a stent inserted inside the artery after the artery has been widened by angioplasty. A stent is a small tube made of plastic or metal that is inserted into the artery to prevent it narrowing again.

ISBN 978-1-108-61069-8

It is important to note that neither of these methods actually cleans the plaque away. This is because blood vessels are fragile, and cleaning the plaque would cause it to dislodge, which is dangerous because it might then completely block a narrower blood vessel, causing a heart attack.

Design brief: Design a device and a procedure to clear blocked arteries while trapping the dislodged plaque.

Activity instructions

In groups of three or four, you will design a device along with the procedure to unblock an artery. As part of the design brief, your device and procedure will also need to trap any of the plaque that is cleared out.

You can only insert any devices from the top end of the 'artery' tube (see Figure 3.98).

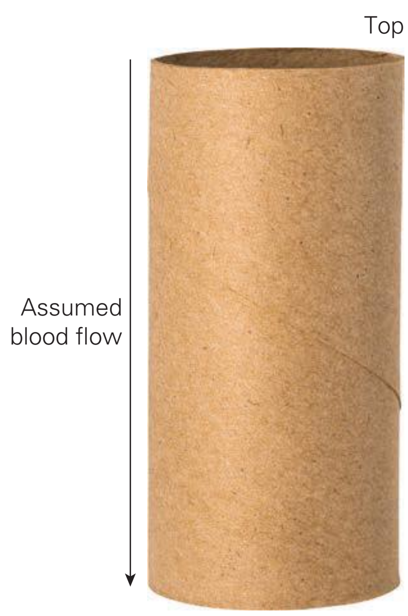


Figure 3.98 A model of an artery

Suggested steps

1. In your group, take some time to discuss ideas and come up with several possible designs.
2. Build your prototype.
3. Test the prototype and time how long it takes to clear the plaque.
4. Assess whether your prototype was effective and whether improvements could be made.
5. Modify your prototype and test it again.

Suggested materials

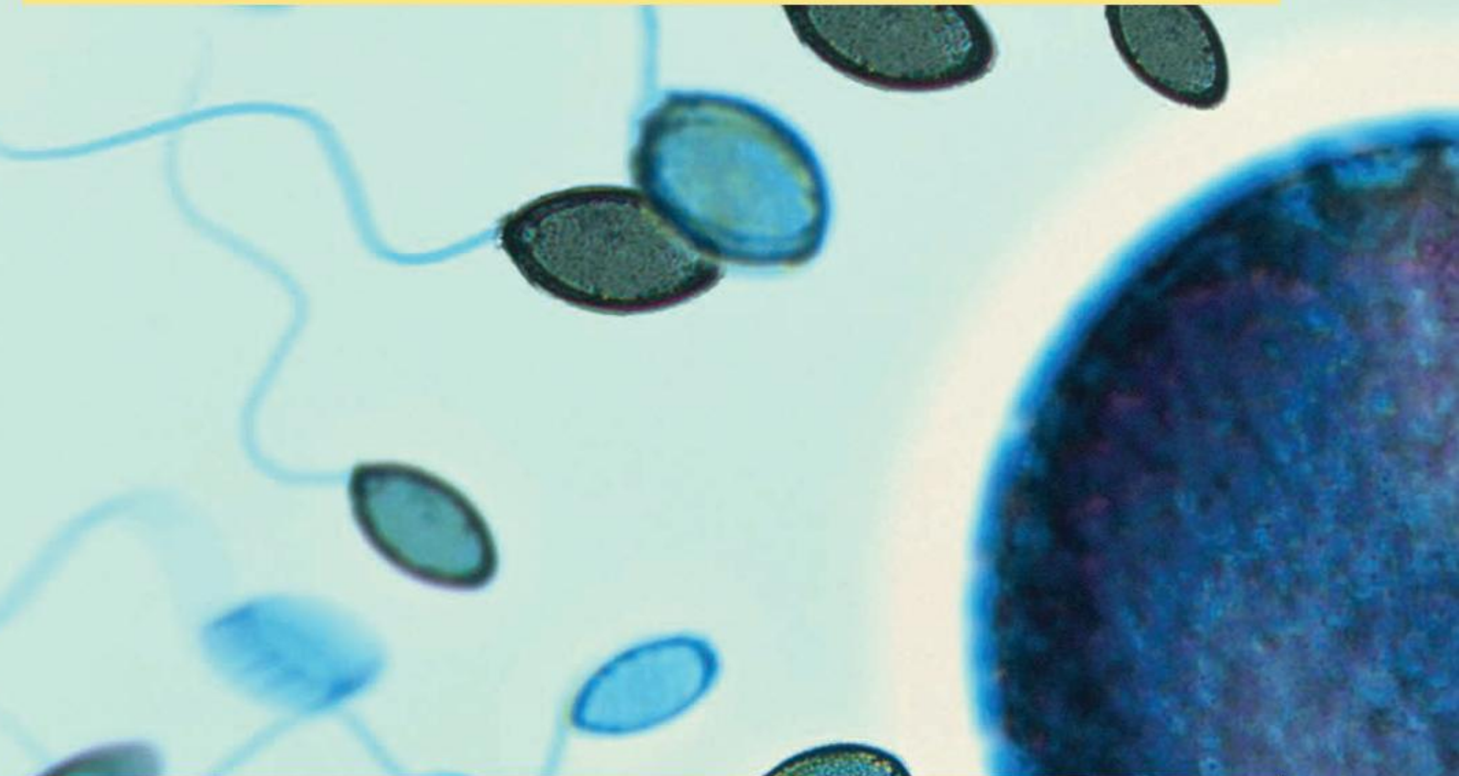
- model of a blocked artery, created using a tube or a toilet roll tube and Play-Doh
- paperclips
- string
- popsicle sticks
- cloth
- glue
- tape
- cardboard
- paper

Evaluate and modify

1. For each model that you created, discuss how effectively the model performed. Consider how long the procedure was and how difficult it was to carry out. Evaluate how effective the 'trap' was at catching the dislodged pieces – how much of the plaque did it catch?
2. Propose some improvements to your first design and prototype. Test it and compare it to your first prototype.
3. Imagine you had to do this procedure on a real patient. Discuss the limitations of your model of a blocked artery, and how your device and procedure might need to be modified to better reflect real life.

ISBN 978-1-108-61069-8 Cambridge University Press

Chapter 4 Reproduction



Chapter introduction

Reproduction is the means by which populations continue to survive on Earth. If a species fails to reproduce, it will become extinct. In this chapter you will explore the different modes of reproduction, and the structures and mechanisms behind them.

Humans have become adept at extending our lifespan, thanks to scientific discoveries and modern medicine. Technology such as IVF (in vitro fertilisation) now allows us to assist people who are finding it difficult to become pregnant. We also manipulate how some other organisms reproduce – examples are agricultural techniques for food crops and animals, and breeding programs for endangered animals.

Curriculum

Multicellular organisms contain systems of organs that carry out specialised functions that enable them to survive and reproduce (VCSSU094)	
• examining the specialised cells and tissues involved in structure and function of particular organs	4.2
• describing the structure of each organ in a system and relating its function to the overall function of the system	4.2
• identifying the organs and overall function of a system of a multicellular organism in supporting life processes	4.2
• comparing reproductive systems of organisms	4.1, 4.3

Victorian Curriculum F–10 © VCAA (2016)

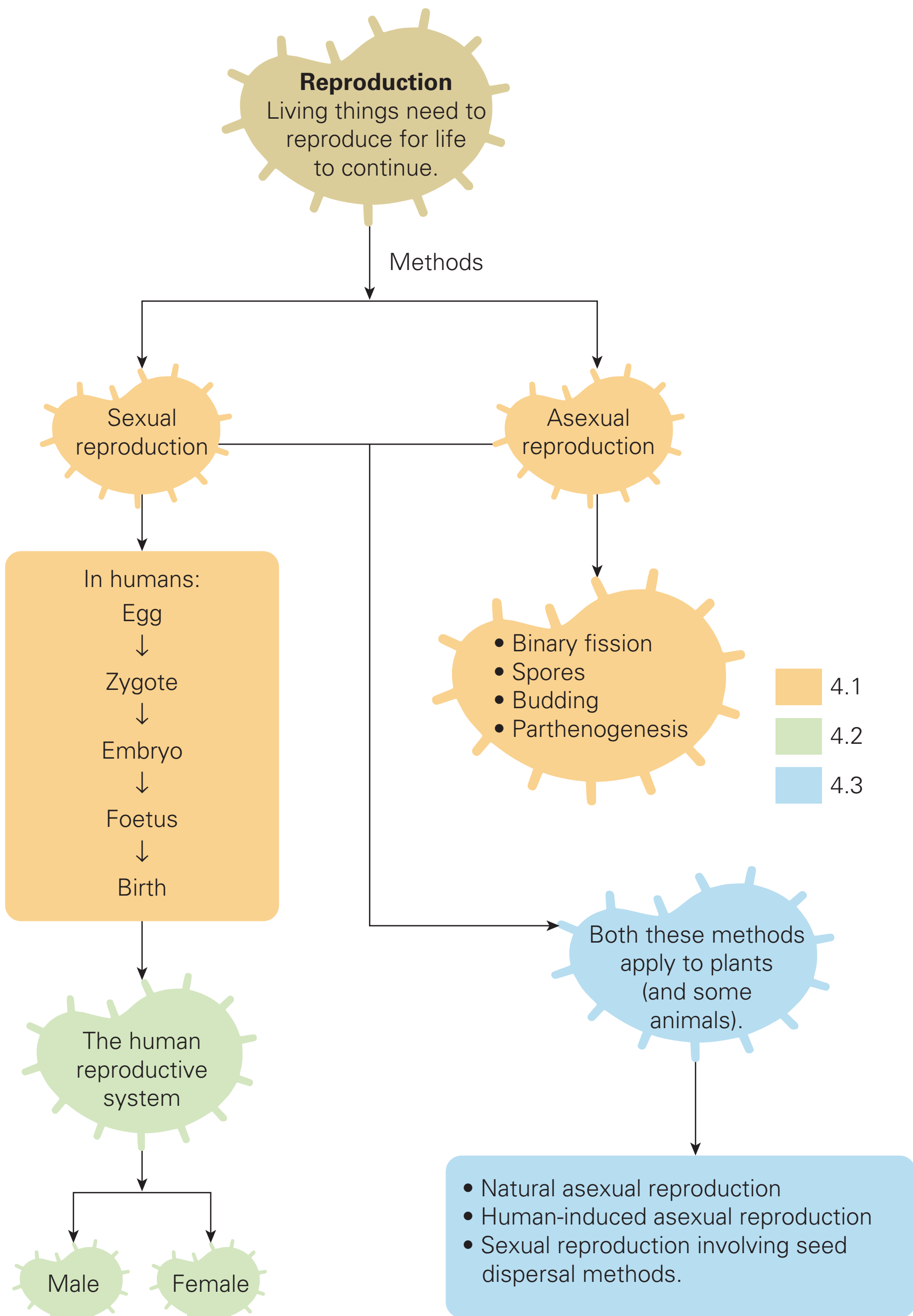
ISBN 978-1-108-61069-8

Glossary terms

asexual reproduction
binary fission
budding
cloaca
embryo
external fertilisation
fragmentation
gametes
gestation
gonads
internal fertilisation
menstrual cycle
menstruation
nectar
ovulation
ovule
ovum
parthenogenesis
pollen
pollination
puberty
scrotum
sexual reproduction
spore
vegetative propagation
zygote

ISBN 978-1-108-61069-8

Concept map



ISBN 978-1-108-61069-8 Cambridge University Press

4.1 Asexual and sexual reproduction in animals

WORKSHEET

Every living thing on the planet will eventually die. This means that, in order for life to continue, organisms need to produce more of their own kind through the process of reproduction.

There are two main types of reproduction: asexual and sexual.

Asexual reproduction occurs when organisms make an exact copy of themselves. There is no need for a second parent.

asexual reproduction
a method of reproduction in which there is one parent organism and all offspring are genetically identical

sexual reproduction
a method of reproduction in which there are two parent organisms and genetic variation in the offspring

Sexual reproduction involves the genetic input of two parents, and tends to result in offspring with lots of variety. Humans reproduce via sexual reproduction. This means that, while siblings might look similar, they are rarely identical.

Sexual reproduction

Sexual reproduction requires two organisms of the same species to each contribute a special cell that combines with the other to produce a new, unique offspring.

Sexual reproduction requires a sperm cell from the male and an egg cell from the female to combine. These cells each contain half the genetic information needed to form a new organism of the same species. We call these cells **gametes**

gametes
the sex cells (eggs and sperm), each of which contains half the genetic material required to make an organism

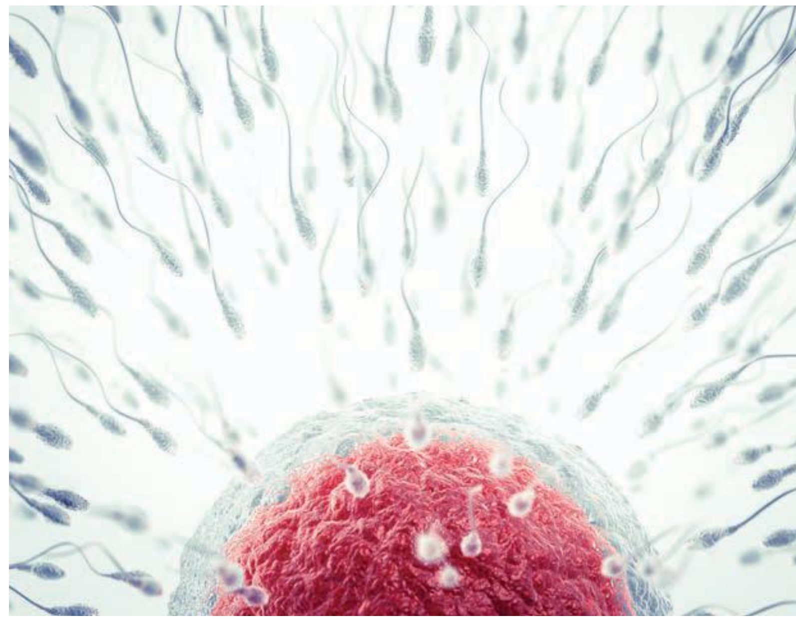


Figure 4.1 Many sperm cells will try, but only one will manage to fertilise an egg cell.

and they form in the **gonads** of males and females. The male gonads are the testes and the female gonads are the ovaries.

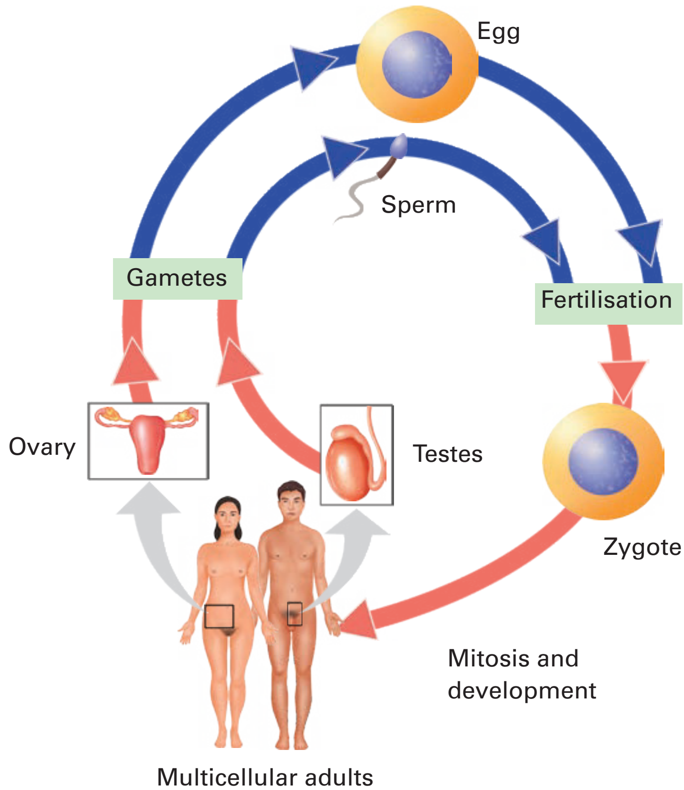
gonads
the reproductive organs, where gametes are produced; testes for males and ovaries for females

When an egg cell and a sperm cell meet, they combine to form a fertilised egg, called a **zygote**. This cell has the correct amount of genetic material and it can begin to replicate by mitosis, which you may remember from Chapter 2, in which eukaryotic cells make copies of themselves. As this new cell replicates and becomes many cells, it grows and the cells take on special functions. The zygote will eventually develop into the **embryo** of the organism.

zygote
a fertilised egg cell

embryo
a fertilised egg cell that has begun dividing

ISBN 978-1-108-61069-8 Cambridge University Press



VIDEO
Contrast asexual and sexual reproduction

Figure 4.2 The human reproductive cycle

Quick check 4.1

1 Define the following key terms: asexual reproduction, sexual reproduction, gametes, gonads, zygote, embryo.
2 How many parents are involved in asexual and sexual reproduction?
3 Name the female and male gonads, and name the female and male gametes.

Did you know? 4.1

Courtship

Attracting a mate is essential in sexual reproduction. Many animals, such as birds, use elaborate and impressive courtship rituals to signal to the opposite sex that they are ready to mate. Some adaptations stimulate the mating process and can include:

- behavioural adaptations, such as special mating calls (songs) or dances
- physical adaptations, such as special feathers or colour patches
- physiological adaptations, such as releasing attractive chemicals called pheromones.

The male peacock puts on an impressive display to attract prospective females. He has a vibrant train of feathers in iridescent colours. If the peahen is suitably impressed, she will crouch on the ground. The peacock then advances, emits a 'hoot' and makes a short dash towards the peahen.

Figure 4.3 A male peacock, starting his performance

ISBN 978-1-108-61069-8

Cambridge University Press

Fertilisation methods

In mammals, fertilisation and development of the embryo take place within the body of the female – this is known as **internal fertilisation**. This method of fertilisation is important for all animals that live on land, as it protects the gametes and zygote from drying out. It also protects the embryo from any threats in the outside world.

internal fertilisation a mode of fertilisation in which male gametes are delivered into the female reproductive system and fertilisation takes place inside the female

Figure 4.4 A pregnant gorilla

Figure 4.5 With internal fertilisation, the growing baby is protected inside the mother.

Although other land animals such as reptiles and birds also have internal fertilisation, the development of their young happens externally, in waterproof eggs.

Figure 4.6 A freshly hatched crocodile

External fertilisation takes place outside the parent animals and usually requires the animals to be aquatic or semi-aquatic. This is because the eggs and sperm are expelled from the organisms' bodies and unite in water.

external fertilisation a mode of fertilisation in which gametes are released into the environment and fertilisation occurs outside the body

Figure 4.7 A school of fish and a cloud of gametes that have been released

ISBN 978-1-108-61069-8 Cambridge University Press

Because the eggs and sperm are released outside the body, it is harder for them to meet, and the fertilised eggs have little protection. This means that organisms that reproduce in this manner have to produce lots of eggs and sperm cells, and release them all at the same time and reasonably close to each other.

Some potential problems with this method of fertilisation:

- The eggs and sperm may not meet (no fertilisation).
- The eggs may be eaten by predators.
- Environmental conditions may not be favourable (e.g. a strong current in the wrong direction).

Quick check 4.2

1. Define the following key terms: internal fertilisation, external fertilisation.
2. State the type of fertilisation that occurs in mammals.
3. List some advantages of internal fertilisation and some disadvantages of external fertilisation.

Gestation

Gestation is the term used to describe how long an embryo takes to develop inside the mother to the point where it can survive outside her body. In humans, the gestation period is called 'pregnancy' and usually takes about 280 days (9 months). This time varies in other mammals.

gestation
the pregnancy period, when the offspring are developing inside the mother

Figure 4.8 A heavily pregnant dog. Dogs have a gestational period of approximately 63 days.

Stages of embryonic development in humans

In humans, the time from fertilisation to birth is around 40 weeks.

Egg to zygote

The unfertilised egg is released from the ovary and travels along the Fallopian tube towards the uterus (see Figure 4.9). There is a 12-hour window in which the egg can unite with a sperm cell and become fertilised. When fertilised, it is referred to as a zygote.

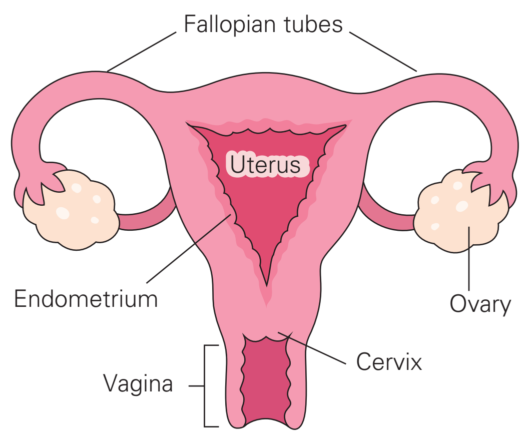


Figure 4.9 The female reproductive system

Zygote to embryo

The zygote undergoes cell division and splits into two cells, then these cells divide, and so on, forming a ball of cells. Over five days, the ball of cells moves along the Fallopian tube and then implants into the wall of the uterus. The cells continue to divide and begin to specialise, and it is now referred to as an embryo.

Embryonic stage

The embryo continues to divide repeatedly, and the cells specialise to become everything from neurons (nerve cells) to liver cells to skin cells. It is referred to as an embryo for the first eight weeks. In humans, during this critical period, the developing embryo is susceptible to the effects of alcohol, diseases and drugs, which can lead to birth defects

ISBN 978-1-108-61069-8

such as limb abnormalities or problems with brain development. By the eighth week, all major organs are present but not fully developed.

Foetal stage

The foetal stages lasts from around week 8 to birth. This is a time of rapid growth and the organs become fully developed and functional. Alcohol, disease and drugs can still have an impact during the foetal stage of development.

Figure 4.10 A model showing a foetus that is nearly full term and ready to be born

VIDEO
Microscopic view of an IVF procedure

Explore! 4.1

Investigating gestation and development

How much time does it take different animals to develop from an embryo to infant form? Conduct research to answer the question, and then copy and complete the table below.

Animal	Gestation period	Time until they can walk/move	Time relying on parent for food	Average life length
Human	280 days			
Pig				
Elephant				
Choose your own animal				

Science as a human endeavour 4.1

Reproductive technologies

Some people have difficulty conceiving (becoming pregnant) naturally, due to age or certain medical conditions. If a person or animal is unable to produce gametes, they are termed 'sterile'. Humans have developed sophisticated reproductive technologies such as IVF (in vitro fertilisation) to assist pregnancy. The first successful human IVF birth occurred in 1978, and the practice has become increasingly common.

Some features of the IVF method:

- The female might take extra hormones to encourage release of multiple eggs (called ovulation).
- Eggs are harvested surgically.
- An egg is fertilised by a sperm in a laboratory.
- The fertilised egg is incubated and allowed to begin cell replication. When it has reached a size of around four cells (after approximately 36–48 hours), it is implanted back into the woman's uterus.

Reproductive technology also has implications for conservation efforts. For example, bison numbers in Colorado, USA, are so low that these animals are at risk of becoming endangered. In 2018, eight bison, four calves and their mothers were released into a northern Colorado herd, where a 10-month-old calf known as IVF was among the newcomers.

Figure 4.11 American bison living in Colorado are at risk of becoming an endangered species. IVF technology may be a way to rectify this.

ISBN 978-1-108-61069-8

Quick check 4.3

1 Define the term 'gestation period'.
2 How long is the gestation period for humans?
3 Copy and complete the following table summarising the stages of embryonic development in humans.

Stage	Time	Description
Egg to zygote		
Zygote to embryo		
Embryonic stage		
Foetal stage		

Birth

When a baby is ready to be born, the woman goes into labour – which, as the name suggests, can be hard work, lasting anywhere from a few hours to days. The cervix dilates and the uterus contracts, pushing the baby out of the vagina. The baby is usually born head first. However, situations such as a breech birth, where the baby's feet come out first, can result in a medical emergency and the baby may need to be removed surgically. This is done by making an incision across the woman's abdomen, called a Caesarean section.

Development

Most mammals develop internally in the uterus of the mother and are born looking relatively similar to an adult organism. Internally developing organisms, including humans, receive nutrition directly from the mother, via the umbilical cord. Marsupials, such as kangaroos, are unique because the young are born in an extremely under-developed state and continue to develop inside the pouch.

Baby birds, reptiles, amphibians and insects tend to develop externally – outside the mother. They develop inside an egg and hatch once they are sufficiently equipped to survive in the world.

Figure 4.12 A baby joey. After being born, the joey wiggles its way into its mother's pouch to feed.

ISBN 978-1-108-61069-8 Cambridge University Press

Parenting

Not all animals are as suitable to parent as humans are. Insects, fish and some other simple organisms do not look after their young at all after they have laid their eggs. For example, moths lay their eggs on the under-surface of leaves, in order to hide them from the line of sight of predators and to provide them with a food source when they eventually emerge as a caterpillar. However, the female moths do not remain to protect them.

Figure 4.13 Caterpillars hatching under a leaf

Animals that do not look after their young often produce large numbers of eggs, resulting in an increased chance that some of the offspring will survive predation, disease and competition and develop to adulthood.

More advanced animals such as birds, mammals and even some frogs look after their fertilised eggs and their newborn offspring, which increases their chance of survival.

Figure 4.14 A kangaroo mother provides a safe environment for her offspring.

Did you know? 4.2

The male midwife toad

The male midwife toad is a dedicated father. He carries around 40 fertilised eggs, which he wraps around his back legs after mating. After about three weeks, when the eggs are ready to hatch, he will find an appropriate body of water where he will place the tadpoles, so that they can emerge from their eggs and begin their independent life.

Figure 4.15 A male midwife toad, carrying fertilised eggs

ISBN 978-1-108-61069-8

Asexual reproduction

Some organisms reproduce asexually, without the input of a partner. This method of reproduction is useful for organisms that are isolated from other members of their species or cannot move easily. Asexual reproduction can be useful, because it is fast and does not require time and energy to find a mate. The offspring produced are clones, genetically identical to the parent. If the parent is well adapted to the environment, this is a good thing. However, if environmental conditions change or a disease is introduced that the organisms are susceptible to, it can lead to the extinction of a whole species.

In asexual reproduction, one cell becomes two, and there are many different ways this can occur. You are going to look at binary fission, fragmentation, spore formation, budding and parthenogenesis.

Binary fission and fragmentation

Bacteria and some simple unicellular organisms, such as the amoeba, reproduce by splitting in half. This process is known as **binary fission**. The genetic material is copied, and then the cell constricts and splits down the centre, resulting in two identical daughter cells.

binary fission
a mode of asexual reproduction by bacteria, where genetic information is copied and the cell splits in half

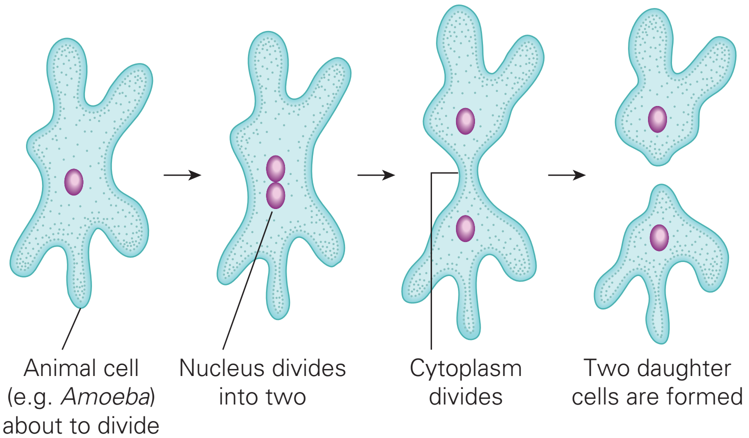


Figure 4.16 Binary fission in an amoeba

Some multicellular organisms, such as flatworms, also reproduce asexually by **fragmentation**. If you cut a flatworm in half, both ends can regenerate and it will become two flatworms.

fragmentation
a mode of asexual reproduction by flatworms, where they can be cut and regrow into two genetically identical organisms

Figure 4.17 Fragmentation in a flatworm

Spore formation

Fungi and some plants, such as ferns, produce single-celled **spores** that are released into the environment. These spores are carried by the wind, and land in a new location, where some develop into a genetically identical version of the parent organism. The spore is actually a clump of unspecialised cells surrounded by a protective coating.

spore
an asexual reproductive cell produced by organisms such as fungi and ferns

Figure 4.18 Common puffball fungus releasing spores

ISBN 978-1-108-61069-8 Cambridge University Press

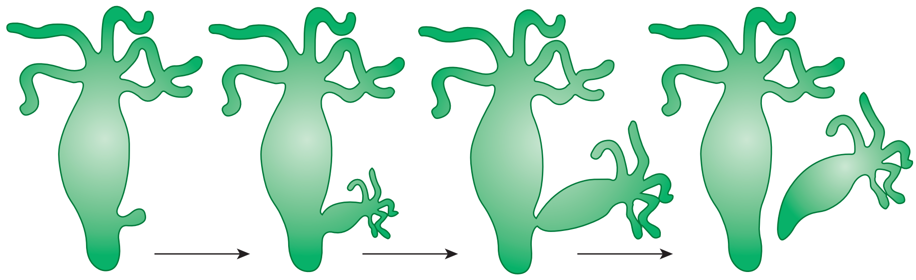


Figure 4.19 Budding in a hydra

Budding

Yeasts and simple aquatic animals, called hydra, reproduce asexually by **budding**. A genetically identical offspring grows and develops on the side of the parent organism, before dropping off and continuing to live independently.

Parthenogenesis

In organisms such as bees and certain lizards, the females are capable of 'virgin birth' – that is, they lay unfertilised eggs, which hatch to produce genetically identical copies of the mother. This mode of asexual reproduction is known as **parthenogenesis**. The resulting population is female.

budding
a mode of asexual reproduction by organisms such as yeast and hydra, where the daughter organism grows off the side of the parent and drops off

parthenogenesis
a mode of asexual reproduction by some insects and reptiles, where females give birth to unfertilised eggs that hatch to produce offspring that are genetically identical to the mother

Asexual reproduction in animals — Try this 4.1

Observe examples of asexual reproduction in animals. You will need a microscope, cavity slides, coverslips and a sample of pond water containing organisms such as protozoa (any of a large group of one-celled organisms, called protists) that live in water or as parasites, hydra (polyp) or rotifers (microscopic aquatic animals). Take care when looking at live organisms, as some, like the hydra, are relatively large and if you use a coverslip you will squash them. Try to see whether any of the organisms are reproducing. What is the evidence that they are doing so? What type of asexual reproduction can you observe?

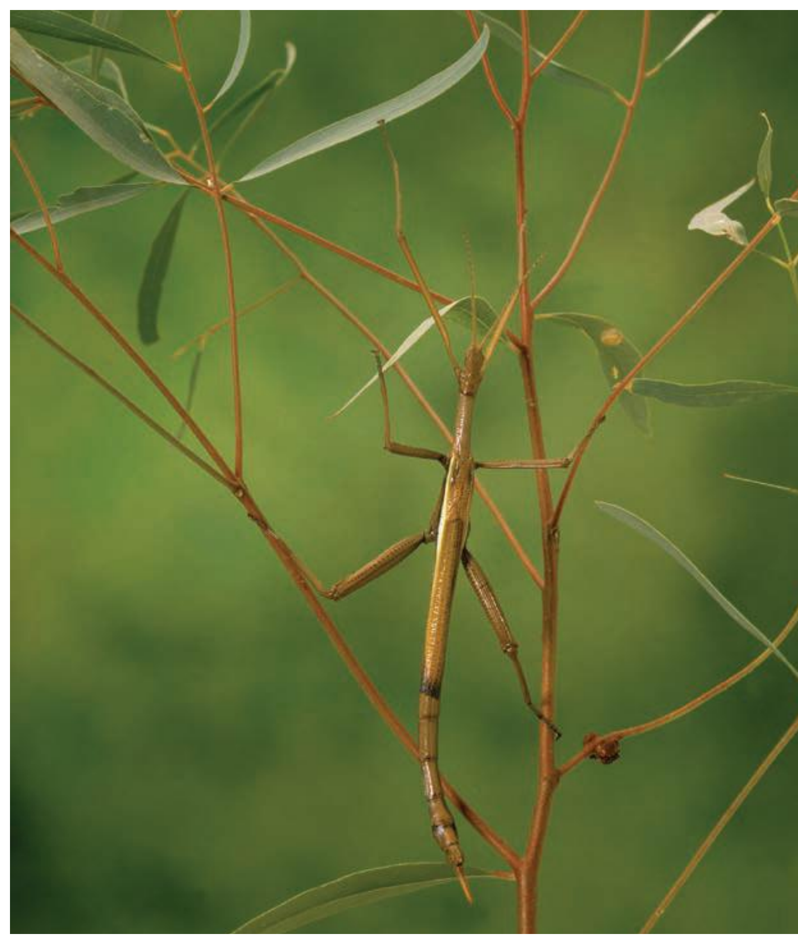


Figure 4.20 In some species, such as stick insects, the females can reproduce by parthenogenesis.

ISBN 978-1-108-61069-8 Cambridge University Press

Quick check 4.4

1 What are two advantages of asexual reproduction?
2 What is one disadvantage of producing genetically identical offspring?
3 Name five types of asexual reproduction and give an example of an organism that uses that method.
4 Make a table or poster summarising the five different types of asexual reproduction. Include five examples of organisms that reproduce in each of the five ways.

Try this 4.2

Asexual vs sexual reproduction

Draw a Venn diagram comparing asexual and sexual reproduction.

Remember, the overlapping section of the circles is for characteristics that both types of reproduction share.

QUIZ

Section 4.1 questions

Remembering

1 Recall the two types of reproduction.
2 State the two cells that sexual reproduction needs.
3 Define the term 'gamete'.
4 Recall where gametes are made.

Understanding

5 Explain why an aquatic animal can use external fertilisation more easily than a land-dwelling animal can.
6 Explain why it could be advantageous for an organism to reproduce asexually.

Applying

7 Construct a short timeline of the human gestation period. Ensure you include the terms egg, zygote, embryo and foetus.
8 Create a table to list the benefits and limitation of internal fertilisation.
9 Identify why organisms produced by asexual reproduction are sometimes called clones.

Analysing

10 Compare internal and external fertilisation.
11 Distinguish between sexual and asexual reproduction.

Evaluating

12 Many courtship displays demonstrate a male individual's strength through physical feats, or their health through the vibrancy of their colourings. Give reasons why this would be useful information for the female.
13 A brand new species of lizard is discovered, and a zoologist captures a female of the species. One year later, the lizard lays eggs that hatch into many female lizards. Hypothesise about the method of reproduction she has utilised.

ISBN 978-1-108-61069-8 Cambridge University Press

4.2 The human reproductive system

As discussed previously, humans reproduce sexually via internal fertilisation, and have highly specialised body systems to support this process. Both females and males share some structural similarities: both possess gonads, which are the site of gamete production, although many of the other structures are different.

The female reproductive system

WORKSHEET

When a female is born, she has around 400 000 eggs in her ovaries, in tiny sacs called follicles. Each month, one egg (**ovum**) is released into the Fallopian tube, through a process called **ovulation**. If this egg is not fertilised, then the uterine lining is shed (along with the egg) and the woman experiences **menstruation** (menstrual period).

ovum
egg

ovulation
the release of an ovum (egg) into the fallopian tube

menstruation
the cyclical shedding of the unfertilised egg and the uterine lining; also known as menstrual period

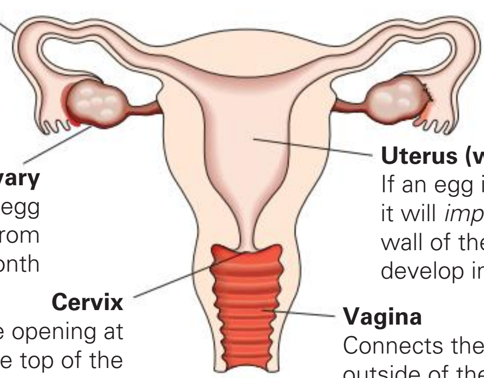


Figure 4.21 The female reproductive system

Did you know? 4.3

More than one uterus

Animals such as rabbits have a branched uterus, which allows for the development of multiple foetuses at the same time, even up to 14! However, this is not the only factor in the rabbit's rapid rate of reproduction. They also have a gestation period of 28–31 days, which means a single female could give birth to 168 live young per year!

Figure 4.22 Rabbits are excellent breeders.

ISBN 978-1-108-61069-8

The male reproductive system

Gamete production in males is a little different: once a male reaches puberty, he starts to produce sperm in his testes. The testes are suspended from the body in a sac called the **scrotum**, which is around three degrees cooler than core body temperature.

scrotum
a sac that encloses the testes

Sperm are around 0.5 mm long and are well adapted for swimming through the mucus of the vagina and the uterus to reach the egg. Each sperm has a long whiplike tail that beats in a corkscrew motion to propel the sperm forwards. Unlike eggs, sperm are produced in huge quantities throughout a male's life.

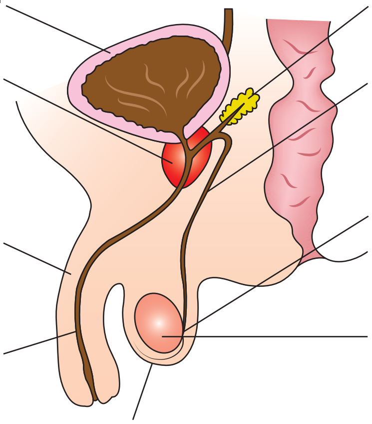


Figure 4.23 The male reproductive system

Quick check 4.5

1 Where does fertilisation usually occur?
2 Describe what happens when an egg is released but not fertilised.
3 What is the vas deferens?
4 Draw up a table summarising the parts of the female and male reproductive systems and their function.

Try this 4.3

Model/diagram

Construct a model or a diagram showing the structures of the female reproductive system, and the process of fertilisation (from ovulation until the zygote implants in the uterine wall).

Puberty

All animals develop from a juvenile form into their adult form early in their lives. This process involves many hormones that stimulate growth and changes in their bodies. This process of change is called **puberty**.

puberty
the time of transition from juvenile form to adult form

Goats, chickens, sheep and cows all go through puberty within their first year of life. In humans, puberty comes later. Girls go through puberty at around the age of 9–14 years, and boys go through puberty at around 12–16 years. This is why girls are often taller than boys in Years 7 and 8.

ISBN 978-1-108-61069-8

Cambridge University Press

However, puberty happens at different times for everyone and this is perfectly normal.

When humans go through puberty, they grow rapidly, start getting hair around their genitlia and become sexually mature, meaning that they can produce offspring. The main hormones involved in puberty are testosterone, follicle-stimulating hormone (FSH), lutenising hormone (LH), growth hormone, oestrogen and progesterone. Growth hormone and LH make you grow taller and stimulate hair follicles around the body to produce more hair, most noticeably on the face, legs, groin and armpits. FSH triggers eggs to develop in the ovaries of females.

Puberty

Explore! 4.2

Some of the changes you experience during puberty have already been mentioned, but what else happens?

1 Draw outlines of a female and a male on two separate pieces of paper.
2 Do some research and annotate your diagrams with the changes that occur during puberty and where they occur. If you can explain what causes the change, include that too.

Figure 4.24 Hair development is common during puberty

In males, testosterone causes the testes to enlarge and produce sperm, the voice deepens and muscle size increases. Increased testosterone levels can also lead to more oil production on the skin and an increase in sweating. Both these attributes can lead to an increase in acne and body odour.

In females, oestrogen and progesterone stimulate the eggs in the ovaries to develop and breast tissue to grow. Females might also notice that their hips widen and they begin to develop more fat around this area. These hormones prompt the **menstrual cycle** to begin.

menstrual cycle
a cycle controlled by hormones to prepare the body for fertilisation of an egg; if fertilisation does not occur, menstruation will follow

Figure 4.25 Some unpleasant side effects of puberty: body odour and acne

ISBN 978-1-108-61069-8

The menstrual cycle

Hormones control a woman's menstrual cycle, which usually lasts around 28 days. Follicle-stimulating hormone (FSH) and luteinising hormone (LH) trigger ovulation, and the egg bursts out of the follicle in the ovary. Once released, the egg will travel down the Fallopian tube, ready to be fertilised.

While this is occurring, the follicle also secretes oestrogen, which causes the uterine wall to thicken so that the egg can implant there if fertilised. If the egg is not fertilised, the uterine lining is shed and the woman experiences a 'period', also known as menstruation.

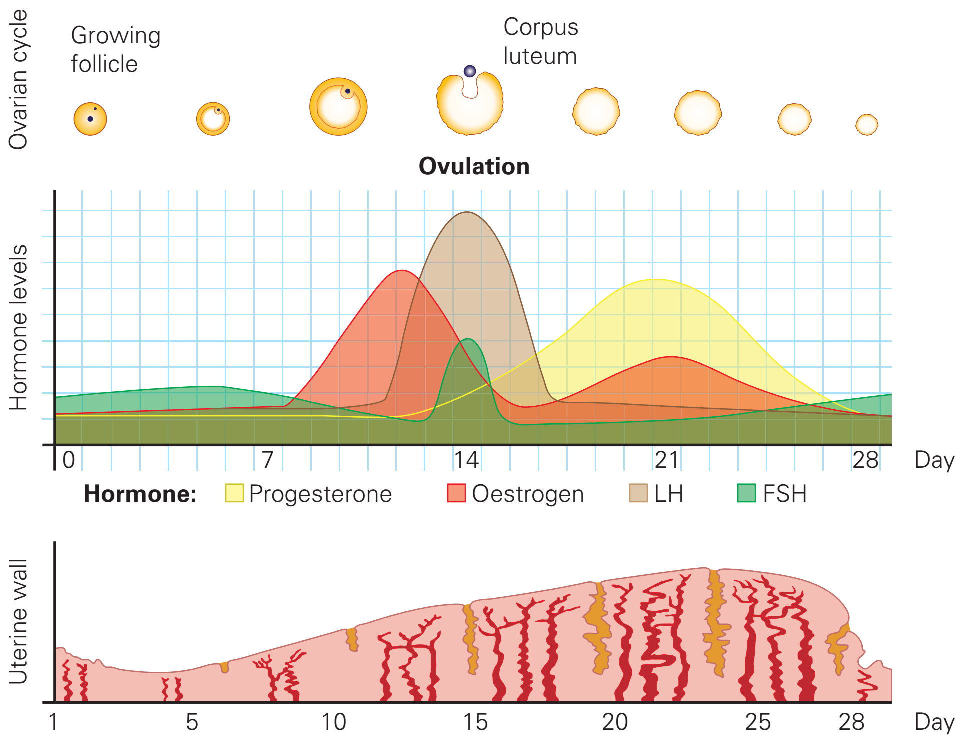


Figure 4.26 The link between the different hormones in the female reproductive system and the action of the follicles. After the follicle releases an egg, it is known as the corpus luteum.

Cloaca – one hole does it all!

Did you know? 4.4

Humans have an anus to defecate out of, a urethra to urinate out of and, if you are a female, a vagina to push babies out of. But not all animals are like that. In fact, it is much more common to have one hole that does all of the above. This organ is called the **cloaca** and it is found in amphibians, reptiles, birds, some fish and even monotremes. This is why it can sometimes be tricky to distinguish between the sexes of certain animals. For example, birds mate by pressing their cloacas together in a process known as a 'cloacal kiss', where muscular undulations move the sperm from the male to the female.

cloaca
a hole used for defecating, urinating and giving birth that is present in some amphibians, reptiles, birds, fish and monotremes

Figure 4.27 A turtle laying an egg through its cloaca

ISBN 978-1-108-61069-8

Cambridge University Press

Quick check 4.6

1 Define the term 'puberty'.
2 Name the hormones involved in puberty in males, and explain what their roles are.
3 Name the hormones involved in puberty in females, and explain what their roles are.
4 Draw a flow chart to summarise the female menstrual cycle. Use the diagram in the text to help you.

Explore! 4.3

Contraceptives

There are many contraceptive methods available in Australia, and some of them work by interrupting the action of hormones. Examine the following options and select one question to investigate, or chat with your teacher about something else relevant to this section of the text, that you would like to investigate.

1 Investigate three different female contraception methods, and determine how they interfere with hormones and how this acts as a contraceptive. Examples include oral contraceptive pills, the 'mini' pill, implants (Implanon®), injections (Depo Provera®) and vaginal rings.

OR

2 Investigate three hormonal contraceptive options being developed for men, and determine how they interfere with hormones and how this acts as a contraceptive. Examples include the male birth control pill, contraceptive injection and contraceptive gel.

Figure 4.28 The female oral contraceptive pill is one option for regulating hormones and preventing pregnancy.

Science as a Human Endeavour 4.2

Early puberty caused by plastic

The chemical called bisphenol A (BPA), used since the 1960s, is found in plastic containers, water bottles, inside tin cans used for storing food, and in cash register receipts. BPA is an endocrine-disrupting chemical (EDC), as it has been found to copy the action of the female sex hormone oestrogen. BPA can affect human reproduction and puberty, and has been linked to early puberty, low sperm counts and infertility in men, as well as breast and prostate cancer. Consequently, many BPA-containing products are banned in Australia. This is another good reason why you should minimise your use of plastics, especially those that are in contact with food.

Figure 4.29 Wherever possible, use BPA-free plastics. If you can't, ensure you wash all food products before use.

ISBN 978-1-108-61069-8 Cambridge University Press

QUIZ

Section 4.2 questions

Remembering

1 Where are the female and male gametes produced?
2 List three signs of puberty for males, and three signs of puberty for females.
3 What does the onset of puberty indicate?

Understanding

4 Outline the function of the cervix.
5 Outline the function of the testicles.
6 Describe the cloaca.

Applying

7 Referring to the graph of the menstrual cycle in Figure 4.26, answer the following questions.
   a Which hormones peak just before ovulation (when the egg is released)?
   b Which hormone is at its greatest concentration when the uterine wall is at its thickest?

Analysing

8 Classify the following structures as belonging to the female reproductive system, the male reproductive system or both systems:
   Fallopian tube, penis, gonads, prostate gland, bladder, scrotum, ovary, vas deferens, cervix
9 Conclude why a woman who has blocked Fallopian tubes might find it difficult to become pregnant.

Evaluating

10 As a man ages, his prostate can increase in size. Suggest a reason why this could affect urination.

4.3 Plant reproduction

WORKSHEET

Plants can reproduce both asexually and sexually.

Sexual reproduction in plants requires the production of flowers, fruit and seeds. This means that the plant has to divert many resources to the production of a new unique offspring. This method of reproduction is great for increasing the variation and genetic diversity of a population; however, it can take quite a long time.

In order to take advantage of favourable conditions, such as heavy rainfall, high levels of sunlight, regeneration after fire or sudden access to new space, most plants can reproduce asexually, which is a relatively fast process that requires less energy.

Asexual reproduction in plants

All asexual reproduction in plants is classed as **vegetative propagation**. It involves part of a plant growing into a new plant, and can occur naturally or humans can manipulate it.

vegetative propagation a form of asexual reproduction where only one plant is involved

Natural methods and human-induced methods of asexual reproduction are summarised in Tables 4.1 and 4.2.

ISBN 978-1-108-61069-8

Cambridge University Press

Natural methods

Vegetative propagation method	Definition	Examples	Image
Bulb	• Underground stem for food storage • Food is stored in large leaves • Each bulb develops into a new plant	Onions, hyacinths, daffodils	 **Figure 4.30** An onion bulb with leaves and roots
Runner	• A stem that grows on top of and across the ground, from the existing stem • New plants grow from the runners	Strawberries, some grasses	 **Figure 4.31** Strawberry leaves and runner
Tuber	• Underground stem that contains stored food • The eyes of a potato can develop into new plants	Potatoes, sweet potatoes	 **Figure 4.32** A potato with eyes beginning to sprout
Rhizome	• Long modified stem that grows horizontally under the ground • New plants grow from the rhizome	Long grasses, ferns, irises, ginger, asparagus	 **Figure 4.33** Ginger rhizome with sprout

Table 4.1 Natural methods of asexual reproduction in plants

ISBN 978-1-108-61069-8 Cambridge University Press

Human-induced methods

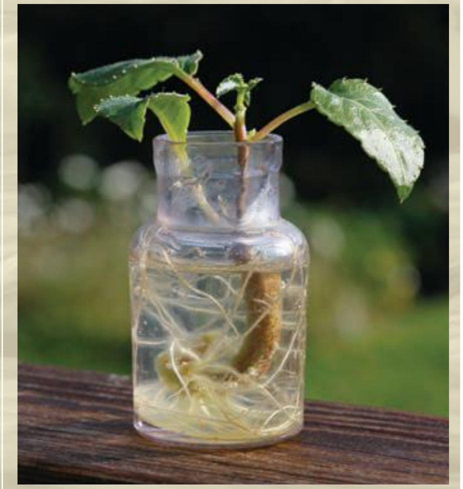
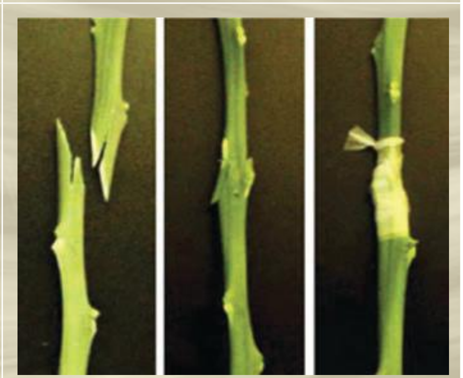
Vegetative propagation method	Definition	Examples	Image
Cutting	• Taking pieces of a root or stem • Each piece grows into a new plant	Bananas, roses, sugar cane	 **Figure 4.34** Some cuttings grow roots when placed in water
Grafting	Taking part of a plant and connecting it to another plant, combining the two plants	Citrus, grapes, apples, roses	 **Figure 4.35** The two pieces of stem (left) are tied in place and will eventually grow into one stem.

Table 4.2 Human-induced methods of asexual reproduction in plants

Figure 4.36 Some trees can have multiple fruits grafted onto the same tree. For example, plums, nectarines and peaches can be grafted together.

Figure 4.37 Growing new plants from cuttings is a way of making clones.

ISBN 978-1-108-61069-8

Practical 4.1

Asexual reproduction in plants

Aim

To model the process of asexual reproduction, using tubers in carrots

Materials

- carrots
- cotton wool
- Petri dish
- windowsill
- water
- knife
- chopping board

Method

1 Place the cotton wool in the Petri dish.
2 Add enough water to make the cotton wool damp but not wet.
3 Cut the top off the carrot, leaving about 3 cm of flesh.
4 Press the top of the carrot into the wet cotton wool. What changes do you predict will occur over the next weeks?
5 Re-water the cotton wool every few days, to prevent it from drying out completely.
6 Once the stem begins to grow, measure and record the growth each day over two weeks.
7 Plant the carrot top and stem in your garden.

Figure 4.38 Grow your own dinner!

Results

Use your data and the data from three other groups from your class to calculate the average stem growth each day. Use the average data to produce a line graph.

Day	Stem length (mm)			
	Group 1	Group 2	Group 3	Average
1				
2				
3				
4				
5				
6				
7				
8				

Remember:

- Place the independent variable on the *x*-axis.
- Place the dependent variable on the *y*-axis.
- Label both axes.
- Write a title.
- Use over 75% of your graph paper.
- Use equal spaces between each number plotted.

Evaluation

1 Describe a trend you see in your graph.
2 Explain why you calculated an average using other groups' data as well as your own.
3 Suggest another plant that could be used for a similar activity.
4 Propose an independent variable that you could add to this activity to turn it into an experiment.

Conclusion

1 Make a claim regarding carrots and their mode of reproduction. Start your sentence with: 'This experiment suggests that carrots … '.

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

2 Support your claim by using what you observed of the growth over the two weeks. Start your sentence with: 'It was observed that ... ' and include potential sources of error.
3 Explain how the data supports your claim. Start your sentence with: 'This means that ... '.

Quick check 4.7

1 Define the terms 'asexual reproduction' and 'sexual reproduction'.
2 What are two advantages of asexual reproduction in plants?
3 What is a rhizome?
4 Name one plant that can be grown from a cutting.

WIDGET
Sexual and asexual reproduction

Sexual reproduction in plants

If you sit near a patch of flowers on a summer day, you may see a bee or a butterfly pay them a visit. Many flowers rely on these insects to help them reproduce by sexual reproduction. The flower is the sexual organ of the plant.

The **pollen** it produces is the male gamete (similar to sperm) and the female gamete is known as the **ovule**.

Pollination is the fertilisation process, in which the pollen from one flower reaches the ovule of another flower. Bees and other insects are attracted to flowers by the sweet **nectar** they produce, and pick up pollen while they are feeding. When the bee moves to the next flower, some of the pollen on the bee sticks to the stigma of the new flower, and the pollen grain then grows down the style to the ovule. This is where fertilisation occurs and seeds (offspring) develop.

pollen
the male gamete in flowering plants

ovule
a structure in a flowering plant where the female gamete is produced and where seeds develop

pollination
the process by which pollen sticks to the female structures of a plant and fertilises the ovule

nectar
a sweet liquid produced by flowers to attract pollinators

Figure 4.39 A bee with large yellow pollen sacs on its legs

ISBN 978-1-108-61069-8

Cambridge University Press

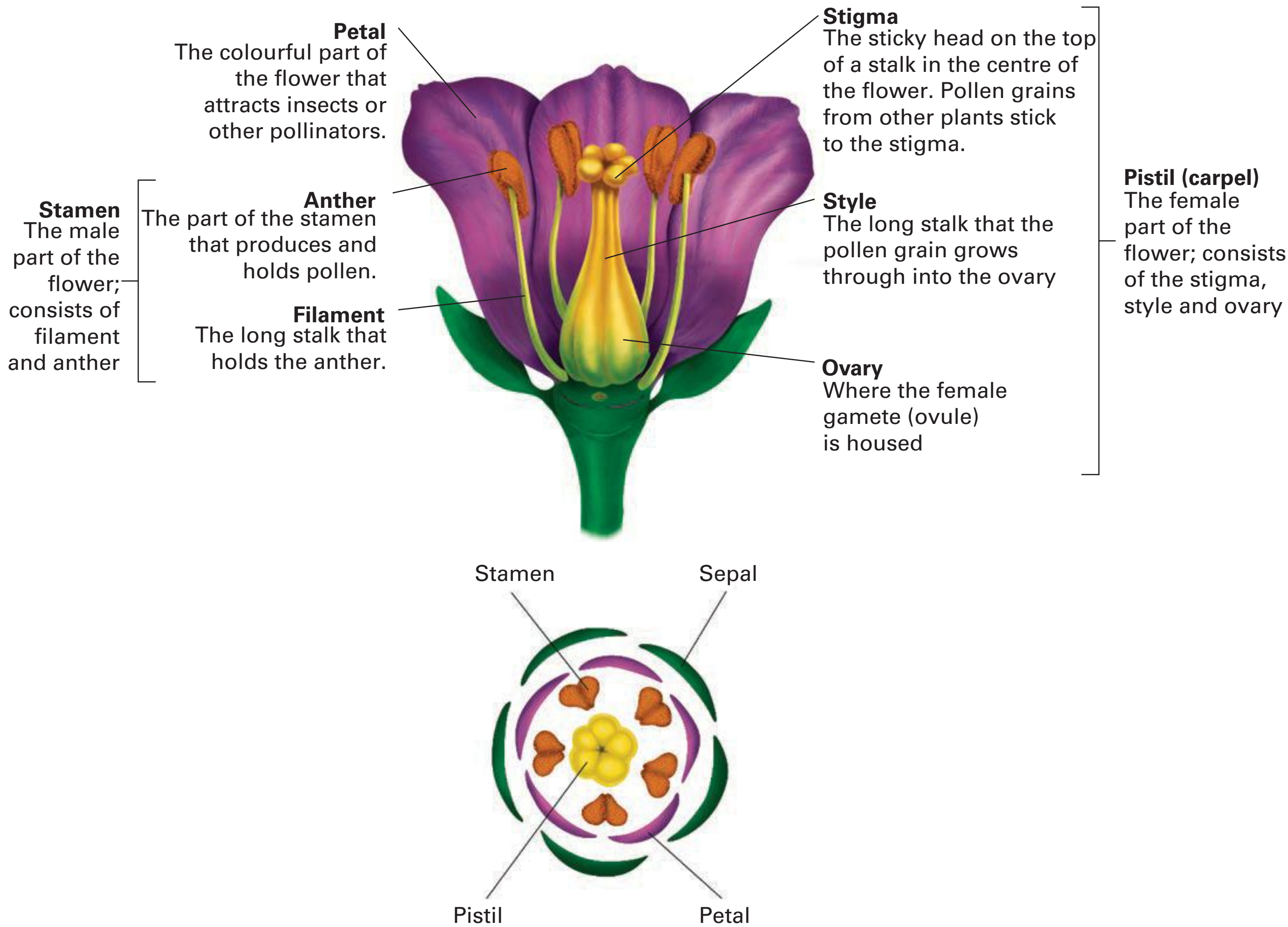


Figure 4.40 Top: a cross-section of a flower. Bottom: view of the flower from above

Pollination **Explore! 4.4**

Pollination is an important process. It allows plants to reproduce. After fertilisation, the ovary swells and grows into a fruit. There are different methods by which pollen can be transported from one flower to another and allow pollination to occur – examples are wind, insects, birds and animals.

When male gametes (pollen) fertilise female gametes (ovule) on the same plant, this is called *self-pollination*. When pollen from one plant fertilises the ovule of another plant, it is called *cross-pollination*. Cross-pollination results in genetically diverse offspring that increase variation in the species, making it more likely to be able to survive changes in the environment.

1 Draw up a table with two columns. In the first column, list the four methods of moving pollen from one flower to another. Then research the types of flowers that use each method of pollination. In the second column, summarise what you have found out about the characteristics (shape/colour/size) of the flowers, their stamens and pistils.
2 What are the advantages and disadvantages of self-pollination? Do some research to find out how plants prevent self-pollination occurring.

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Figure 4.41 These flowers are pollinated by different methods. Can you identify which is using which method?

Did you know? 4.5

Palynology

Pollen grains come in many shapes and sizes, depending on the plant that produces them. This is why pollen from certain plants can trigger an allergic reaction in some people, while other pollen has no effect. Palynology is the name for the study of pollen grains. Palynologists study pollen samples found on archaeological digs, as well as pollen samples found at crime scenes.

Figure 4.42 There are many types of pollen in the air.

ISBN 978-1-108-61069-8 Cambridge University Press

Humans are attracted to flowers because of their beautiful and varied colours and scents, but the colourings that we see are just the tip of the iceberg. Many insects can see further into the electromagnetic spectrum than we can. If you view flowers under ultraviolet light, you will see that many have patterns that resemble a bullseye target or a landing strip. These patterns are designed to tell the insects exactly where they need to go to get the nectar.

Figure 4.43 Flowers with (left) a bullseye pattern and (right) a landing strip pattern

Quick check 4.8

1 Name the male gamete and the female gamete of plants.
2 Bees and insects can transfer pollen from one flower to another flower. Name some other ways that pollen can be transferred.
3 Draw up a table summarising the parts of the flower and their role in sexual reproduction.

Practical 4.2

Flower dissection

Aim

To identify the parts of a flower, and link their structure to their role in reproduction

Be careful

Take extreme care when handling the razor blade.

Materials

- a variety of flowers for dissection
- hand lens
- stereomicroscope
- tweezers
- single-sided razor blade
- chopping board

continued...

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Method

1 Draw a diagram of your first flower. Note the number of petals and sepals, and label these on your diagram.
2 Holding the flower carefully with tweezers on the chopping board, cut the flower in half vertically. This means you should now be looking at a cross-section of the flower, similar to the top picture in Figure 4.40.
3 Draw a diagram of the flower in cross-section, and label all the parts of the flower you can recognise. Add 'M' next to the male parts of the flower and 'F' next to the female parts of the flower.
4 Gently remove the sepals and petals, by pulling them down towards the stem. Use a microscope to look at the tip of the petal at low magnification. Record your observations of the petal's texture in your results.
5 Remove the flower's stamens, by breaking or gently cutting them off the stem. Examine the pollen with your microscope. Record your observations of the pollen's shape and texture in your results.
6 Gently remove all parts except the pistil, so that it remains alone on the stem. Carefully cut the pistil in half lengthwise, and use your hand lens to look at the inside of it. Record your observations of the style, ovary and ovules in your results.
7 Repeat steps **1–6** with the other flowers.

Results

Your results should consist of:

- Labelled diagrams of the whole flower and cross-section of the flower
- Observations made during the dissection.

Evaluation

1 Consider the different flowers you looked at. List the similarities and differences between them.
2 Explain why these differences between flowers might exist.
3 Use a flow chart to summarise the process of sexual reproduction in plants. Use the names of the parts of flowers that are involved and their role in reproduction.

Healthy bees need diversity

Science as a Human Endeavour 4.3

Bees pollinate most of our crops, but bee numbers are decreasing rapidly. Bees can fly between flowers at about 25 km per hour and visit up to 5000 flowers in one day. In fact, bees are so important that artificial hives are moved all around the country to help pollinate new crops.

Imagine that you were only allowed to eat one type of food. That would become boring and you probably would not be very healthy. Australian and German researchers have discovered that a diversified plant environment helps bees maintain stable populations. The bees' quality of life is highest in gardens and biodiverse forests, and lowest in mono-crop areas. As plant biodiversity declines, bees produce less offspring, and eventually bee colonies shrink in size. This means we need to protect our biodiverse environments in order to help prevent the extinction of bees.

ISBN 978-1-108-61069-8 Cambridge University Press

Did you know? 4.6

The blue-banded bee

In 2017, residents living near the Merri Creek in Melbourne worked together to raise money to improve the quality of the habitat of the native blue-banded bee, as the area had lost the diversity of wildflowers that the bee needs for nectar. Blue-banded bees cannot travel very far and so their home needs to offer all their requirements for a healthy existence. The special thing about blue-banded bees is that they can perform a special type of pollination, called 'buzz pollination'. Some flowers hide their pollen inside tiny capsules, but a blue-banded bee can grasp a flower and shake it so much that the pollen shoots out of the capsules. The bee can then collect the pollen and carry it from flower to flower, pollinating the flowers.

Figure 4.44 The blue-banded bee

Seed dispersal

Instead of an embryo, flowering plants produce a seed. This is just as valuable to the plant as a foetus is to an animal, and so the plant grows a protective cover for the seed, known as a fruit. (Note that not all fruit are edible.)

Figure 4.45 Peaches produce a large seed surrounded by tasty flesh.

Pine trees produce wooden cones instead of flowers, which also protect their seeds. When the seeds are fully developed, the cones open and release the seeds.

Figure 4.46 Pine cone ready to drop its seeds

Plants produce many seeds, to increase the chances of survival. Many seeds will be eaten by herbivores, or land on areas where they cannot grow, or be destroyed. Adult plants often take up a lot of space and resources and so, in order for their offspring to thrive, the seeds need to spread to new places. This is known as *seed dispersal*, and plants have many clever ways of doing this.

VIDEO
Australian plants and seed dispersal

ISBN 978-1-108-61069-8 Cambridge University Press

Exploding!

The seed pods of a group of plants know as *Impatiens* are ticking time bombs. When the fruit is ripe, the slightest touch can trigger the pod to explode suddenly, flinging the seeds it contains in many directions, although the seeds often do not travel far.

Figure 4.47 Exploding seed pod

Hitching a ride on the outside

Certain plants, including grasses, use spikey pods (burrs) that latch onto an animal's fur or a human's clothing to disperse. The spikey pod stays on the animal's fur until the animal gets itchy and scratches it off, and then the pod falls to the ground in a new location.

Figure 4.48 Burrs caught on a dog's fur

Hitching a ride on the inside

As you know, fruit not only protects the seeds, but also can be very tasty. Some plants make their fruit extra sweet, to encourage animals to eat the seeds. The seeds have a tough coat in order not to be digested. If by chance they eventually pass intact through the animal, they are in a brand new spot if conditions are favourable, they may grow in this new environment.

Figure 4.49 Animals ingest seeds in fruit and then defecate the seeds in a new location.

Shooting the breeze

Dandelion seeds are so light that they are blown extremely long distances by just a gust of wind. A fluffy tuft that acts as a parachute carries each seed away. A dandelion head is not just one flower

Figure 4.50 Dandelion seeds caught in the breeze

ISBN 978-1-108-61069-8 Cambridge University Press

but is made up of many florets that each produce individual seeds. One dandelion head can make around 500 seeds. This is why dandelions are such an effective weed.

Floating away

A coconut is one giant seed. It is hollow and so it can float. This is how coconuts are able to move between islands and across oceans.

Quick check 4.9

Draw up a table to summarise the different ways in which seeds can disperse. Include examples where appropriate.

Figure 4.51 A floating coconut

Practical 4.3: Self-design

Seed germination

Aim

To design a valid, reliable and accurate experiment to test the conditions necessary for a seed to germinate, using the materials provided. You may investigate other factors that contribute to the plant's germination (light levels, water, nutrients, heat, etc.)

Materials

- Petri dish or glass jar
- paper towel
- water
- seeds
- sugar
- salt
- water
- black paper
- heat lamp
- cotton wool
- fertiliser

Method

1. Construct a hypothesis for your experiment. State the independent variable, the dependent variable and the controlled variables.
2. Once you have chosen the independent and dependent variables for this experiment, write a hypothesis.
3. Construct a detailed method to explain the procedure you will follow in your experiment. Include all the instruments and exact measurements you will use. Set it out in step-by-step form. Include the number of repeats you expect to conduct. Do not forget to mention how the data is recorded. Remember, another scientist should be able to read this procedure and replicate your experiment exactly, so be precise.
4. After confirming with your teacher that your method is satisfactory, carry out your investigation.

Results

Construct an appropriate results table to document your experiment.

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Evaluate

1 What do your results show?
2 Did something beyond your control go wrong?
3 How would you alter your experiment next time, to prevent this?

Conclusion

1 Make a claim regarding seeds and germination conditions. Start your sentence with: 'This experiment suggests that seeds ... '.
2 Support your claim by using what you observed of the seeds germinating. Start your sentence with: 'It was observed that ... ' and include potential sources of error.
3 Explain how the data supports your claim. Start your sentence with: 'This means that ... '.

QUIZ

Section 4.3 questions

Remembering

1 List four ways in which plants can reproduce asexually.
2 State the purpose of the petals of a flower.
3 Define the term 'pistil'.

Understanding

4 Explain the purpose of fruit.
5 Explain how seed dispersal by the wind is effective.

Applying

6 Outline how a plant is pollinated.

Analysing

7 Compare a peach with a pine cone.
8 Distinguish between self-pollination and cross-pollination.

Evaluating

9 Evan lived in England for 15 years and never experienced hay fever. Hay fever is caused by pollen irritating the nasal passageways. Since moving to Australia, Evan has had hay fever every summer. Suggest a reason for this.
10 A new volcanic island has formed in the middle of the Pacific Ocean. Suggest the first type of plants that will grow on the island, and justify your answer, based on its method of seed dispersal.

Figure 4.52

ISBN 978-1-108-61069-8 Cambridge University Press

Review questions

SCORCHER

Remembering

1 What mode of asexual reproduction is used by:
  - a a yeast cell
  - b a bacterial cell
  - c a strawberry plant
  - d fungi?

2 State the function of the following structures in the human reproductive system:
  - a ovary
  - b scrotum
  - c Fallopian tube
  - d prostate
  - e uterus.

3 Name the parts of a flower that have the following function:
  - a attracts pollinators
  - b the site of seed development
  - c produces the male gametes
  - d produces the female gametes
  - e site where the male gamete sticks to the female part of the plant.

4 State the two methods of fertilisation in animals, and for each method give an example of one animal that uses it.

Understanding

5 Explain why internal fertilisation is generally more efficient than external fertilisation.

6 Explain four different ways that seeds might be dispersed.

Applying

7 Construct a timeline of the human gestation period, indicating the names of the structure at each stage and approximate timeframes.

8 If a female reptile reproduces via parthenogenesis due a lack of male mates in the area, what conclusion can you draw about her offspring?

9 Construct a comic strip or series of diagrams to model how sexual reproduction occurs in a flowering plant. Ensure the reproductive organs are labelled appropriately.

Analysing

10 Compare sexual and asexual reproduction to show the advantages and disadvantages of each method.

11 Distinguish between external and internal development of offspring, naming an example organism for each.

12 Compare the changes in male and female bodies during puberty by using a Venn diagram.

Evaluating

13 Evaluate this statement: 'When a male and a female animal have sexual intercourse, there is always the same chance of getting pregnant, no matter what time of day/month/year'. Do you agree or disagree?

14 A biologist is investigating a species of frog that lives in an environment that is changing rapidly. Propose a reason why sexual reproduction would be better for this species of frog.

15 Certain orchids have flowers that closely resemble the shape of a female wasp. Suggest a reason for this adaptation, and justify your answer.

ISBN 978-1-108-61069-8 Cambridge University Press

STEM activity: Help or hinder seed dispersal

VCSSU094 VCDSTC048 VCDSCD049 VCDSCD051 VCSIS113

Background information

To reproduce effectively, many plants rely on the wide distribution of their seeds. If the parent plant has a method of distributing its seeds away from itself, rather than simply dropping the seeds in the immediate area, this will give the offspring a better chance of being able to grow. Plants have developed many creative ways of spreading their seeds, including being carried by the wind, attaching to or being carried by animals, floating in water and even flying. These adaptations have resulted in seeds and seed pods that are specifically suited to a particular type of dispersal, allowing plants to cover most of our planet.

Sometimes effective seed dispersal can be damaging, as seed contamination can destroy farmers' crops, and can be particularly difficult to combat. If you have ever done your own gardening, you will know how difficult it is to keep weeds out of your garden, so you can imagine the problems farmers would have to deal with over large areas if their seed supply was contaminated with weed seed, for example. Today, farmers use several methods to combat weed growth, including the use of chemicals called herbicides to kill the weeds. Some herbicides are selective and only kill specific types of plants, while other herbicides kill all plants.

Figure 4.53 Dandelion seeds are carried by the wind.

Figure 4.54 A bird carries seeds in its beak.

ISBN 978-1-108-61069-8

Design brief: Design a device to help or hinder seed dispersal

Activity instructions

Your first task is to design and construct a seed or seed pod that can be used to disperse seeds effectively. Choose one method of seed dispersal described on the previous page or in the chapter, and think about what features your new seed will need to have to help it stick to animal fur, be carried by wind or float in water. Remember that the seed eventually needs to fall to the ground or soil.

Your second task is to design a product that will be helpful to farmers in dispersing seeds or in combatting contamination by weeds, without chemicals. You do not need to construct this product, just describe what the product is and how it might work.

Suggested materials/presentation formats

- paper
- cardboard
- sticky tape
- string
- scissors
- elastic bands
- balloons
- plastic bottles
- paddle pop sticks
- plastic containers
- toothpicks
- drinking straw
- glue
- felt or woollen fabric scraps

Evaluate and modify

1. Make modifications to the design of your seed after the testing phase, and see if you can make it more effective or travel further.
2. Evaluate the effectiveness of your seed design and suggest any improvements to it.
3. Describe any challenges you encountered when designing or testing your seed. Explain how you and your colleagues worked to overcome that challenge.
4. Describe the product you have come up with to aid in seed dispersal or control weed seed, and evaluate its potential in the real world.

Figure 4.55 A seed pod floats on a river.

Figure 4.56 The 'wing' on a maple seed is designed to create lift (upwards force) as the seed spins through the air.

ISBN 978-1-108-61069-8

Chapter 5 **Particles**

Chapter introduction

This chapter goes beyond the idea of there being many small particles in matter and further into the exciting world of chemistry, to look at atoms, elements, compounds and mixtures. You will learn about the arrangement of these substances, their symbols, how to write formulas, and compare the characteristics of elements, compounds and mixtures. It's like learning a brand new language!

Curriculum

Differences between elements, compounds and mixtures can be described by using a particle model (VCSSU097)	
• modelling the arrangement of particles in elements and compounds	5.1, 5.2, 5.3
• recognising that elements and simple compounds can be represented by symbols and formulas	5.2 5.3
• explaining why elements and compounds can be represented by chemical formulas while mixtures cannot	5.2, 5.3

Victorian Curriculum F–10 © VCAA (2016)

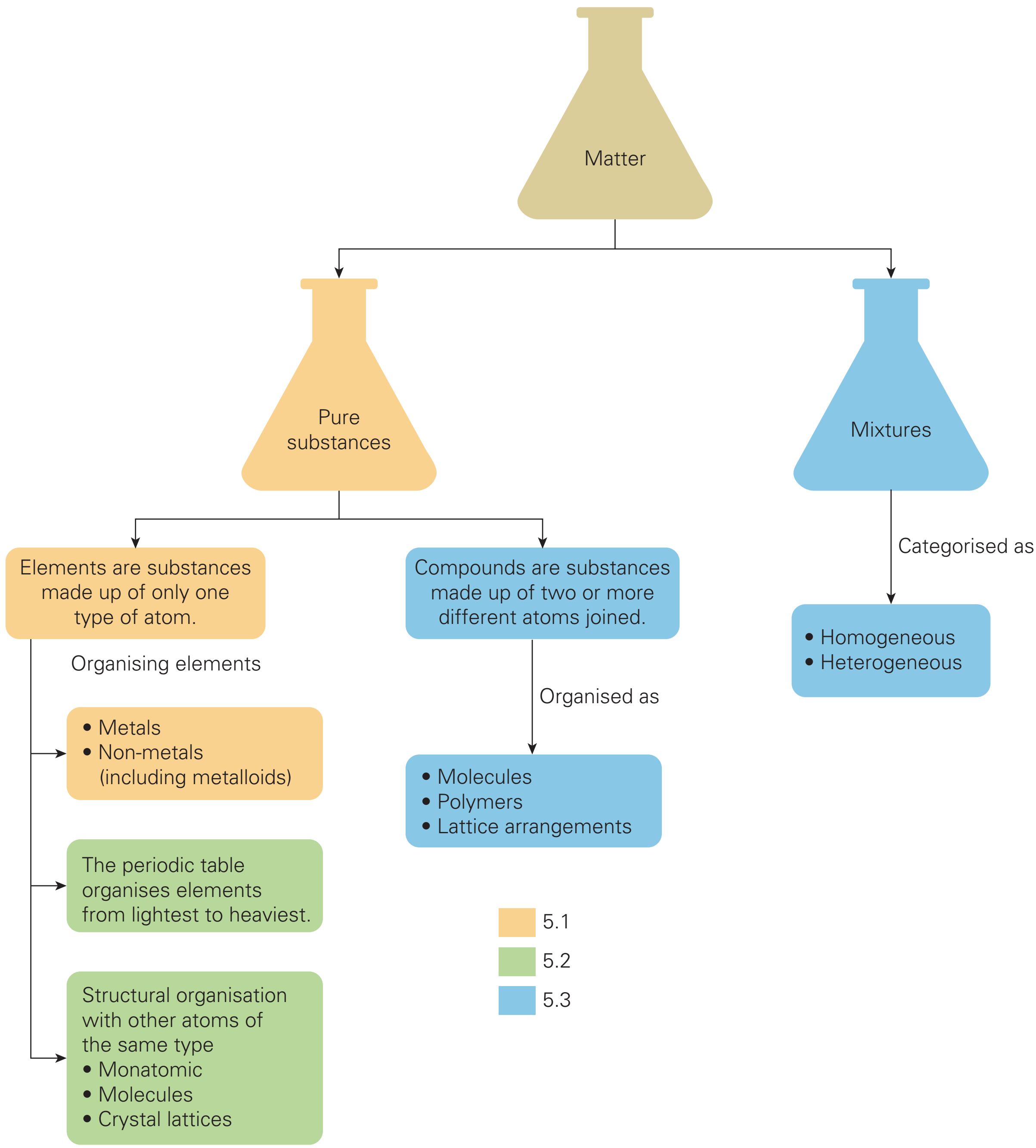
ISBN 978-1-108-61069-8

Glossary terms

atom	element	molecule
bonds	flammability	monatomic
chemical formula	heterogeneous	non-metal
chemical properties	homogeneous	periodic table
compound	lustre	physical properties
conductivity	malleability	polymer
crystal lattice	metalloid	pure substance
diatomic	metal	
ductility	mixture	

ISBN 978-1-108-61069-8

Concept map



ISBN 978-1-108-61069-8 Cambridge University Press

5.1 Atoms and elements

You may remember learning about the particle theory of matter in Year 7. If you can't quite remember, here is a reminder:

The particle theory of matter
All matter is made up of tiny particles that are too small to see.
There are very small spaces between the particles.
There are attractive forces between the particles: when the particles are close, the bonds are stronger than when they are far apart.
The particles are always moving and/or vibrating.
The particles move or vibrate faster at higher temperatures than at lower temperatures.

Table 5.1 The particle theory of matter summarised

Scientists refer to some of the tiny particles using the scientific term '**atom**'. This word comes from an ancient Greek word that means 'uncuttable'. As you go through secondary school, you will learn more about atoms, but we are going to keep it simple for now. If you want to imagine how small atoms are, there are about 10 000 000 000 000 000 atoms in the dot at the bottom of this exclamation mark!

atom
the smallest possible piece of any substance; it makes up all matter

Try this 5.1

Cut a strip of paper 28 cm x 1 cm. Now cut it in half, and you will have two 14 cm lengths of paper. This is cut 1. Repeat this as many times as you can, counting your cuts as you go.

How many cuts were you able to make? Name one item that is the same size as the paper with 1 cut, 3 cuts, 5 cuts. How do you think you could keep cutting the paper smaller and smaller? Imagine this: it takes 31 cuts to get a piece of paper the size of an atom!

Pure substances and mixtures

WORKSHEET

In Chemistry, substances are often classified into pure substances or mixtures. You investigated this idea in Year 7, but now let's take it further.

A **pure substance** is made up of only one type of atom. Atoms don't usually exist on their own – often there are two or more atoms joined together. In this case, the combination of atoms is called a **molecule**, and the atoms are held together by strong forces of attraction, called **bonds**. So we can now say that a pure substance is made up of one type of atom or one type of molecule. There are several different types of bonds, such as covalent bonds, hydrogen bonds and ionic bonds.

pure substance
a substance made up of only one type of atom or one type of molecule

molecule
two or more atoms joined together by bonds

bonds
forces of attraction that hold atoms together

In this chapter you will learn about two types of pure substances: elements and compounds.

An **element** is a substance made up of only one type of atom. These can be single atoms or molecules, but they are all the same type of atom. For example, gold is an element and is made up of many single gold atoms. Hydrogen gas is another element, but hydrogen atoms like to bind together to form molecules, each with two hydrogen atoms.

element
substance made up of only one type of atom or molecule

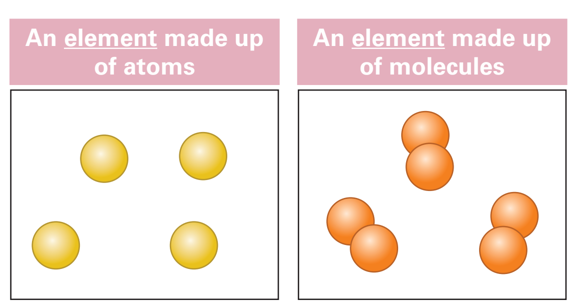


Figure 5.1 In an element, all the atoms are the same.

ISBN 978-1-108-61069-8 Cambridge University Press

compound
substance made up of two or more different types of atoms

A **compound** is a substance made up of two or more different types of atoms joined into a molecule. For example, water is a covalent compound, as it is made up of two hydrogen atoms bonded to one oxygen atom, joined by strong covalent bonds.

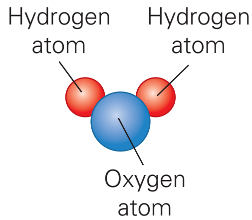


Figure 5.2 A water molecule is a compound, because it has two different types of atoms: one oxygen atom bound together with two hydrogen atoms. Water is also a pure substance, as it is made up of only one type of molecule, the one shown here.

mixture
a substance made up of two or more different pure substances (compounds or elements) that are not bonded together

A **mixture** is a substance that is made up of two or more different pure substances (compounds or elements) that are not bonded together. For example, air is a mixture of several different elements and compounds.

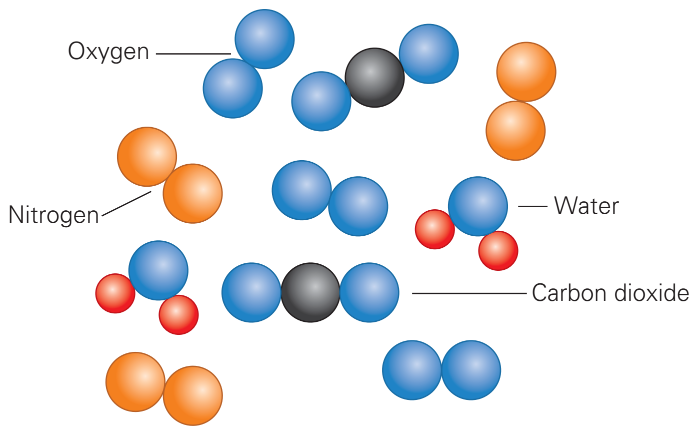


Figure 5.3 Air is a mixture of nitrogen, oxygen, argon, carbon dioxide, water vapour and very small amounts of other gases.

Putting it all together

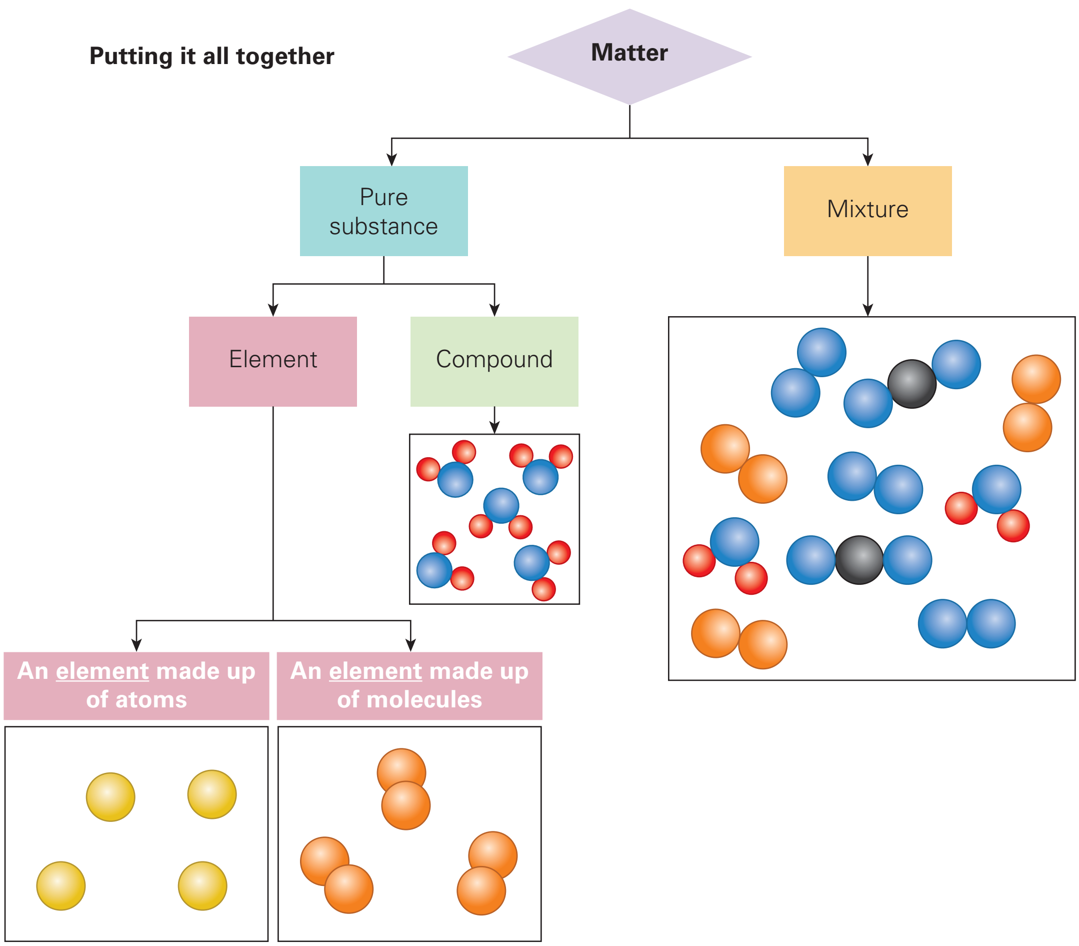


Figure 5.4 Putting it all together: matter is made up of pure substances (elements and compounds) and mixtures.

ISBN 978-1-108-61069-8

Try this 5.2

Use Lego® or molymod® kits to model different elements, compounds and mixtures.

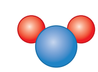
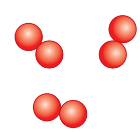
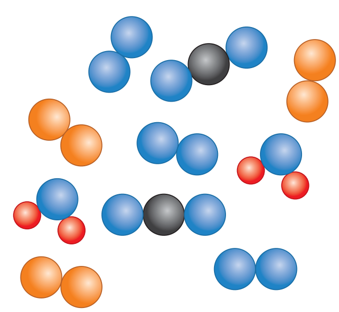
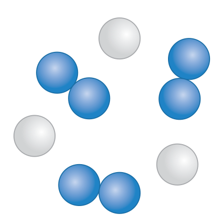
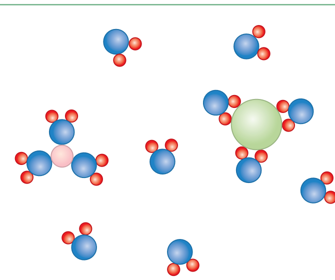
For a challenge, take it a step further: model pure elements, pure compounds, a mixture of elements, a mixture of compounds, and a mixture of elements and compounds.

Quick check 5.1

1 Rewrite the following terms matched with their correct definitions.

Molecule	The smallest piece of substance you can have; it makes up all matter
Compound	Substance made up of only one type of atom
Bond	Substance made from two or more different types of atoms
Element	Two or more atoms joined together (same or different)
Atom	Strong force of attraction that holds atoms together

2 Rewrite the following table, matching each term with the correct example and the correct diagram (A–E).

Term	Example	Diagram
Mixture of elements	Hydrogen	**A** 
Pure compound	Water	**B** 
Element	Salt and water	**C** 
Mixture of compounds	Air	**D** 
Mixture of elements and compounds	Oxygen and helium	**E** 

ISBN 978-1-108-61069-8

Cambridge University Press

Did you know? 5.1

Scanning tunnelling microscopes

You cannot see an atom with a light microscope, which is the type of microscope you may have at school. In 1981, a type of microscope called a scanning tunnelling microscope (STM) was developed, and now scientists can not only see atoms but even manipulate them! The developers won a Nobel Prize in Physics for their amazing invention.

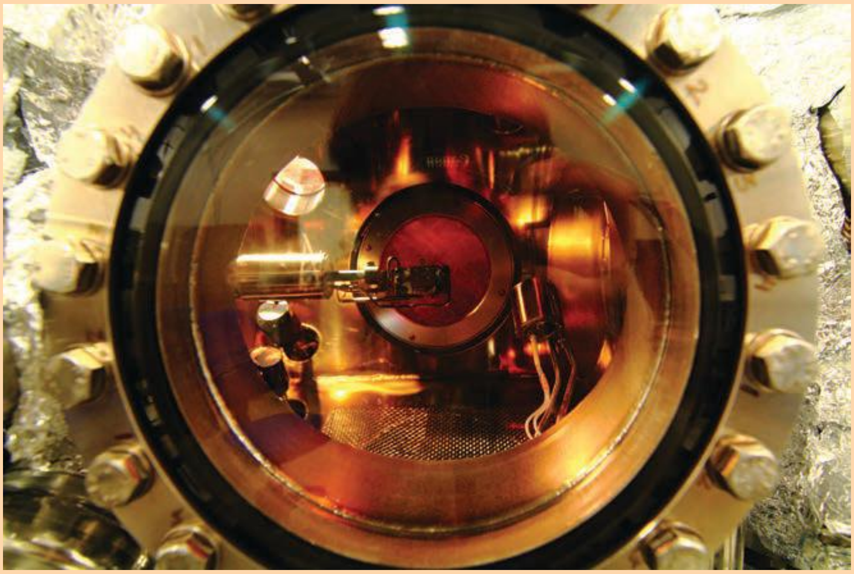


Figure 5.5 Scanning tunnelling microscopes are now used all over the world, as scientists conduct experiments to try to find out more about the structure of the atom and the forces that hold it together.

VIDEO
How does a scanning tunneling microscope work?

Elements

You have learned that elements are an example of a pure substance that is made up of just one type of atom or one type of molecule. Elements are the purest substances we can find or extract from matter, and they make up everything we know of. But what makes the different elements different? They are made of different atoms.

The first elements to be identified were the metals gold, tin, copper and iron, and this happened thousands of years ago. Since then, more and more elements have been discovered in the Earth's rocks, soil, air and water. Can you find out how many elements have been found in nature? Scientists have also made synthetic elements, but these artificial elements are highly radioactive and, because they are so heavy, most of them break down almost as soon as they are created.

Each element has particular qualities, or properties, and these properties allow us to determine how different elements can best be used. Last year you learned about the **physical properties** and **chemical properties** of different substances. These are summarised in Table 5.2.

physical properties the way substances look and act, e.g. colour, melting point, hardness, boiling point and density

chemical properties the behaviour of a substance when it reacts with another substance

Science as a human endeavour 5.1

In 2016, scientists announced that four new elements had earned a permanent place in the periodic table: elements 113, 115, 117 and 118. They are called nihonium (Nh), moscovium (Mc), tennessine (Ts), and oganesson (Og). In December 2017, two teams of scientists from the USA and Japan joined forces in the hope of discovering the elements 119 and 120.

ISBN 978-1-108-61069-8

	Property	
	Physical	**Chemical**
Definition	The way a substance looks and acts	The behaviour of a substance when it reacts with another substance
Examples	Colour, **ductility** (see Figure 5.6), hardness, melting/boiling point, **malleability**, solid/liquid/gas, **conductivity**, shape, strength, density, **lustre**	**Flammability**, rusting or corrosion (see Figure 5.7), acidity, biodegradability, combustibility, toxicity

Table 5.2 The two types of properties we investigate when looking at matter: physical and chemical

Figure 5.6 Steel is ductile – it can be made into long rods and wires.

ductility
the ability of a substance to be drawn into a wire

malleability
the ability of a substance to be bent or flattened into a range of shapes

conductivity
the ability of a substance to conduct or carry electricity and heat

lustre
the ability of a substance to become shiny when polished

flammability
the ability of a substance to ignite

Figure 5.7 An old car rusting

Grouping elements

Metals and non-metals

As in all other areas of science, in chemistry we like to group similar things together: pure substances/mixtures, solids/liquids/gases and so on. One of the first steps in grouping elements is to determine whether the substance is a **metal** or a **non-metal**. To do this, scientists look at the general properties that the elements have in common (see Table 5.3).

metal
a substance that is shiny, can conduct electricity, can be bent, is usually silver/grey and is ductile

non-metal
a substance that is dull, cannot conduct electricity, is brittle and is not ductile

Metalloids

Some of the elements in the non-metal group look like metals. One example is silicon (see Figure 5.8 on the next page). Silicon can conduct heat and electricity a little, but it cannot be bent or made into wire. It is shiny when polished but is brittle and can shatter like glass. When an element has properties of both metals and non-metals, it is called a **metalloid**. There are eight metalloids: antimony, arsenic, astatine, boron, germanium, polonium, silicon and tellurium.

metalloid
a substance that has some of the properties of both metals and non-metals

ISBN 978-1-108-61069-8 Cambridge University Press

Property	Metals	Non-metals
State at room temperature	Solid (exception is mercury)	Solid, gas or liquid
Colour	Silver/grey	A range of colours, including colourless
Lustre	Shiny when polished	Shiny or not shiny. Often dull or glassy
Conductivity	Conducts electricity and heat	Does not conduct electricity or heat
Malleability	Can be bent or flattened	Cannot be bent or flattened. Often brittle
Ductility	Can be made into a wire	Cannot be made into a wire
Melting point	Usually high temperature (exception is mercury)	Usually low temperature

Table 5.3 The general properties of metals and non-metals

Figure 5.8 Three examples of metalloids. Left: Silicon is shiny and brittle, and can conduct electricity but not as well as a metal. Middle: Antimony is shiny like a metal, but brittle like a non-metal. Right: Boron conducts electricity but is brittle.

Practical 5.1: Teacher demonstration or student practical

Metals vs non-metals

Aim

To investigate the properties of metals and non-metals

Materials

- light bulb (LEDs can also be used)
- connecting wires and alligator clips
- battery or power pack
- fine sandpaper
- samples of six metals and non-metals – for example, sulphur, magnesium, silicon, copper, iron/steel, tin, zinc, aluminium, carbon

Be careful

Electrical shocks may occur. Elements may become hot. Ensure the voltage output is not exceeded. Turn the power supply off when changing the circuit.

Method

1 Draw up a table like the one in the Results section. Include the six metals and non-metals you are investigating. Also select a property you would like to investigate as well as those already listed.

continued…

...continued

2 Use the fine sandpaper to rub each substance and determine its lustre – is it shiny or dull? Record your observations in your table.
3 Try to bend each of the substances – is it malleable or not? Record your observations in your table.
4 Make a prediction about the conductivity of each of the substances.
5 Connect each substance as shown in Figure 5.9 – does it allow electricity to pass through, making the globe glow? Record your observations in your table.

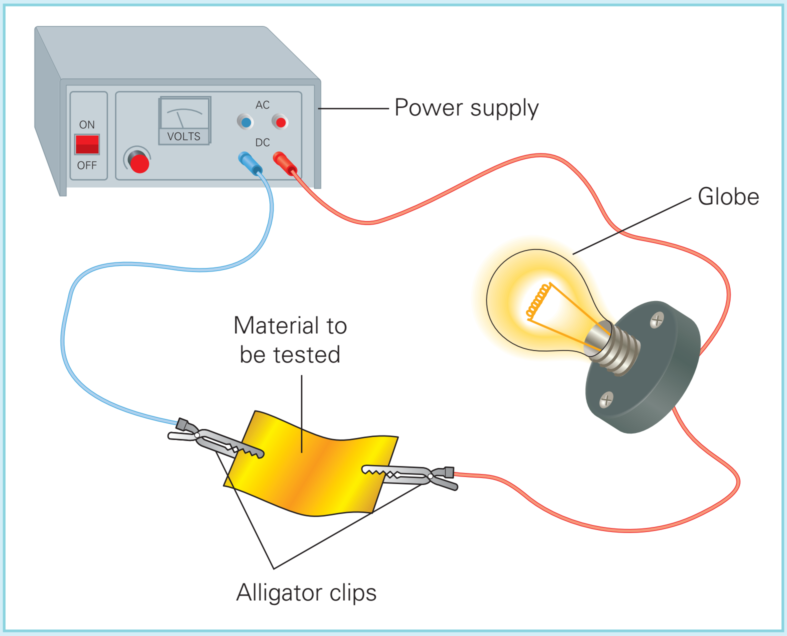


Figure 5.9 Experimental set-up for testing the conductivity of different substances

6 Investigate your choice of property.

Results

Element	Lustre	Malleability	Conductivity	Your choice of property
			Prediction: Observation:	
			Prediction: Observation:	
			Prediction: Observation:	
			Prediction: Observation:	
			Prediction: Observation:	
			Prediction: Observation:	

continued...

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Evaluation

1 Which of the substances you tested were metals and which were non-metals? Were there any exceptions? List them and name the group that these exceptions belong to.
2 Explain how you tested for your choice of property.
3 Recall the difference between a physical property and a chemical property. Then summarise the properties that metals have in common and the properties that non-metals have in common. What properties do the exceptions have in common?
4 Are the substances you tested elements, compounds or mixtures? Explain your answer by including definitions of these terms.
5 Imagine you have discovered a new element. What tests would you carry out in order to determine whether the substance was a metal or a non-metal?
6 Describe some possible sources of experimental faults for this investigation, and explain how you might resolve these errors in future investigations.

Conclusion

1 What claim can be made from this experiment regarding the properties of metals and non-metals? Begin your sentence with: 'This experiment suggests that … .'
2 What evidence did you gather? Begin your brief summary with: 'The results show that … '.
3 Explain how the data supports your claim. Begin your sentence with: 'This means that … '.

Quick check 5.2

1 Define the following key terms: element, physical properties, chemical properties, metals, non-metals, metalloids, malleability, lustre, conductivity, ductility. Provide examples where possible.
2 Rewrite the following table so the properties of metals and non-metals are in the correct columns.

Metals	Non-metals
Solid, liquid or gas	Dull or glassy surface
Solid	Shiny surface
Unable to conduct electricity or heat	Can conduct electricity and heat
Ductile	Unable to be made into a wire
Low melting temperature	Malleable
Silver/grey	Unable to be bent

Explore! 5.1

Uses of the elements

There are many different elements, each with their own properties. Some are rare, and some are common. Some have more uses when they are combined with other elements than they do when they are on their own. Some have several different forms.

1 Investigate and report on three uses of carbon. Keep in mind that carbon has different forms.
2 Investigate and report on the medical uses of iodine.
3 Investigate and report on the uses of hydrogen in the chemical industry.

ISBN 978-1-108-61069-8 Cambridge University Press

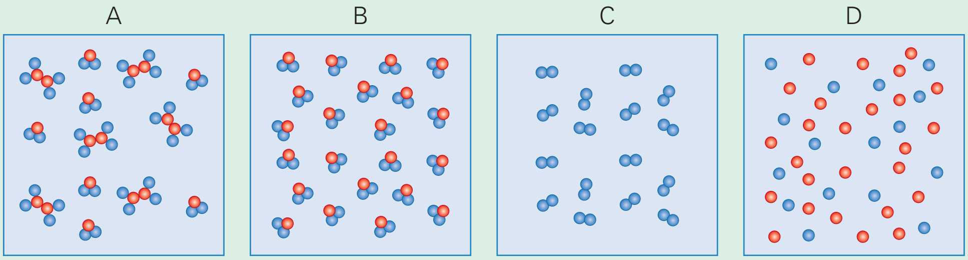
Section 5.1 questions

Remembering

1 Define the terms 'pure substance' and 'mixture', providing examples of each.
2 List three properties of metals and three properties of non-metals.
3 What is it that holds two or more atoms together in a molecule?
4 The smallest part of an element is called ________________.

Understanding

5 Describe how elements are like Lego® blocks.
6 Look at diagrams A to D below. Which diagram is:
   a an element
   b a compound
   c a mixture of elements
   d a mixture of compounds?



Applying

7 Distinguish between:
   a an atom and a molecule
   b an atom and an element
   c an element and a compound
   d a molecule and a compound.
8 Summarise three of the tests you can do to find out whether a substance is a metal or a non-metal.

Analysing

9 Imagine using symbols, such as ❏, ♦ and ❖, to represent different atoms. How many different molecules can you make by joining these atoms together two at a time? How many can you make by joining three at a time?
10 Consider what elements are and what compounds are. Discuss why there are many more compounds than there are elements.
11 Distinguish between chemical properties and physical properties, and include examples.

Evaluating

12 Justify why the metalloids are considered a separate group from the metals and non-metals. Use an example to illustrate your point.
13 Here are the answers to some questions. Determine three options for what the question could be, for each answer.
   a properties
   b atom
   c conducts electricity
   d compound

ISBN 978-1-108-61069-8

Cambridge University Press

5.2 Organising elements

WORKSHEET

Symbols for elements

Chemistry has its own language, with all the elements represented by symbols. It is a shorthand way of writing the name of the element so that every scientist in every country can understand it.

In Table 5.4, notice that sometimes an element's symbol comprises of the first and second letters of the English name. For example, the symbol He for Helium, or O for Oxygen. Note that the first letter of the symbol is always capitalised and the second letter is never capitalised. But what about chlorine? You would think that chlorine would have the symbol Ch, but it is actually Cl. In this case it is distinguished by its third letter.

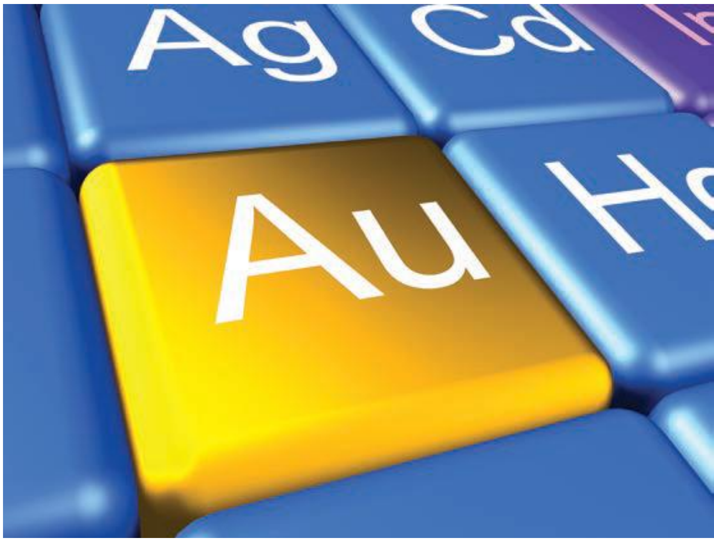


Figure 5.10 Every element has a symbol, and Au is the symbol for gold.

Element	Symbol	Metal/non-metal	Melting point (°C)	Date of discovery
Hydrogen	H	Non-metal	−259	1766
Helium	He	Non-metal	−272	1895
Lithium	Li	Metal	180	1817
Beryllium	Be	Metal	1278	1797
Boron	B	Metalloid	2300	1808
Carbon	C	Non-metal	3500	Ancient
Nitrogen	N	Non-metal	−210	1772
Oxygen	O	Non-metal	−219	1774
Fluorine	F	Non-metal	−220	1886
Neon	Ne	Non-metal	−249	1898
Sodium	Na	Metal	98	1807
Magnesium	Mg	Metal	650	1808
Aluminium	Al	Metal	660	1825
Silicon	Si	Metalloid	1410	1824
Phosphorus	P	Non-metal	44	1669
Sulphur	S	Non-metal	119	Ancient
Chlorine	Cl	Non-metal	−101	1774
Argon	Ar	Non-metal	−189	1894
Potassium	K	Metal	64	1807
Calcium	Ca	Metal	850	1808

Table 5.4 Twenty elements, their symbols and some of their properties

ISBN 978-1-108-61069-8

Sometimes the letters from the element's Latin or Greek name are used. For example, the symbol for copper is Cu. The Latin word for copper is *cuprium* and this is where its symbol comes from. Another example is mercury, which has the symbol Hg, taken from its Latin name *hydragyrum*, which means 'shining water'. Some elements are also named after famous people or places, like einsteinium and francium.

Quick check 5.3

1 Explain why not all the elements are named after the first letter of their name.
2 What is the reason for using symbols instead of the elements' full names?
3 Refer to Table 5.4 with the 20 elements listed.
 a Which elements have the following symbols?
  K, S, Mg, Be, B
 b Which element has the lowest melting point?
 c Which of these was the most recently discovered element?
4 Write each element name followed by its correct symbol.
 Names: hydrogen, carbon, oxygen, nitrogen, helium, sulphur, magnesium, aluminium
 Symbols: Mg, O, Al, S, N, H, C, He

Did you know? 5.2

The fabulous four!

The ancient Greeks believed that there were four elements that everything in the world was made up of: earth, water, air and fire. These elements are referred to as the classical elements. This theory was first suggested around 450 BCE and was the cornerstone of philosophy, science and medicine for around two thousand years. At one stage, the four elements were even used to describe the four temperaments a person could have! Even though we no longer categorise things like this, in a way the four elements do align with the four states of matter that modern science has agreed on: solid (earth), liquid (water), gas (air) and plasma (fire).

Figure 5.11 Earth, water, air and fire

ISBN 978-1-108-61069-8

Cambridge University Press

Periodic table

A list of all the known elements and their symbols is called the **periodic table** (see Figure 5.12). It shows the elements in order from lightest to heaviest, and even clearly shows which elements are metals, which are non-metals, and which are metalloids. We know scientists like grouping similar things together, but imagine the challenge it would have been to organise 118 elements according to size and properties! Some elements are naturally occurring, and others have been created by humans. Some elements are radioactive.

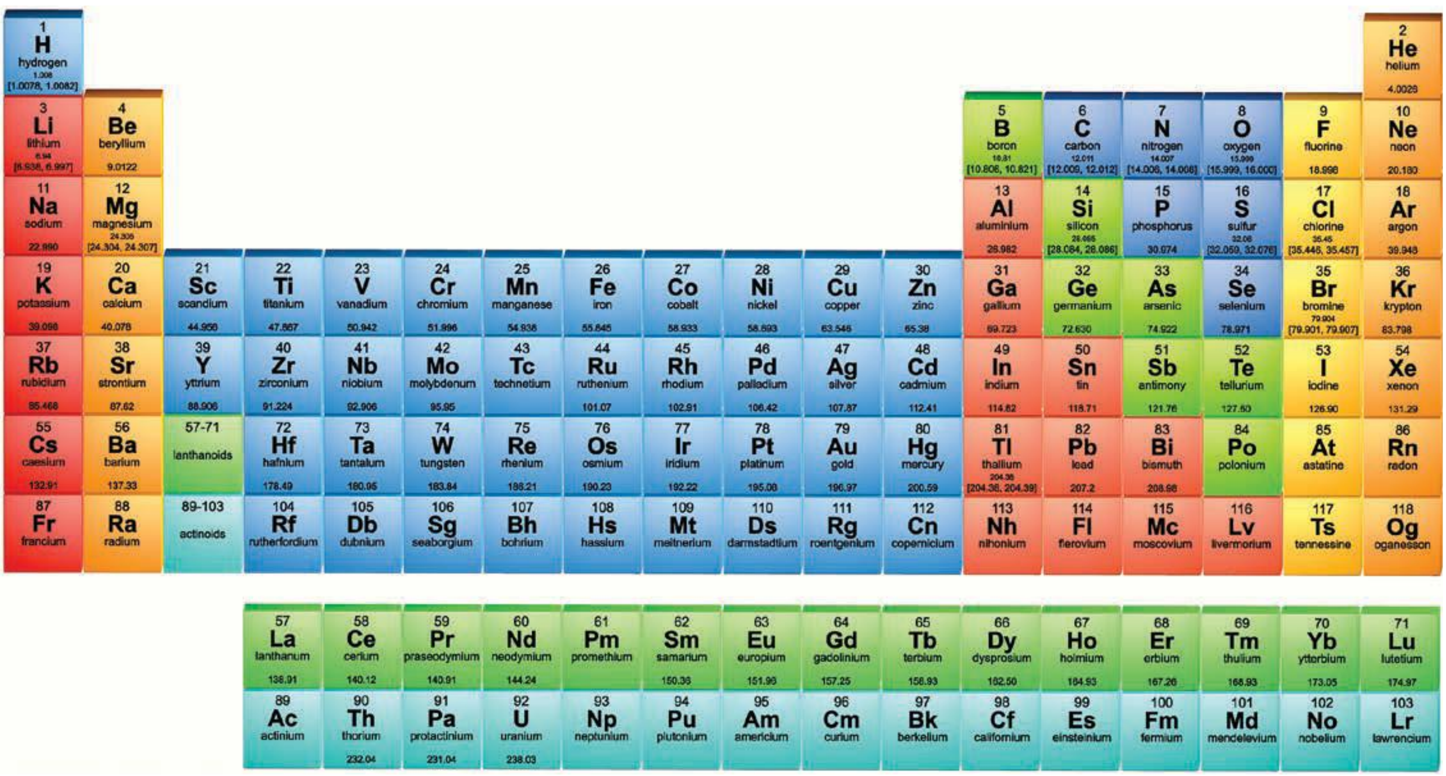


Figure 5.12 This periodic table includes all 118 known elements as of May 2017.

Try this 5.3

Look at the periodic table in Figure 5.12.
Begin by finding some of the metalloids you know of, like boron (B), silicon (Si) and germanium (Ge). What colour are they in the periodic table? All the metalloids are the same colour. What are the symbols for the other metalloids?

Next, identify some of the metals you know of. Where are they in relation to the metalloids? What about the non-metals – where are they positioned in the table?

Quick check 5.4

1. What is the periodic table?
2. Here are some of the symbols in the periodic table that start with C or S. List each symbol with its element name.

C	Si
Cl	S
Ca	Sc
Cr	Se
Co	Sr
Cu	Sn
Cd	Sb
Cs	Sm
Ce	
Cm	
Cf	

ISBN 978-1-108-61069-8 Cambridge University Press

Practical 5.2

Flame tests

Be careful

Ensure appropriate personal protective equipment is worn.

Aim

To investigate the colour that a flame will go when an element is heated, and use this information to determine the metal element in four unknown samples

Figure 5.13 A substance burning in the flame of a Bunsen burner, producing an orange flame

Materials

- heatproof mat
- Bunsen burner
- 10 flame test wires
- 5 M hydrochloric acid in labelled test tubes
- known test solutions in a test tube rack:
  - barium (barium chloride)
  - calcium (calcium chloride)
  - copper (copper(II) chloride)
  - strontium (strontium chloride)
  - sodium (sodium chloride)
  - four unknown samples

Method

1. Clean your flame wires by holding the metal loop in the hottest part of the blue Bunsen burner flame. If it is not clean, a coloured flame will appear, so clean it by dipping it into the hydrochloric acid provided and then holding the loop in the Bunsen burner flame again.
2. Dip the clean flame test loop into one of the known test solutions, then hold the metal loop in the hottest part of the Bunsen burner flame. Record the colour of the flame in your results table.
3. Clean the flame test wire, then test another known test solution. Keep going until you have recorded the colour for all the known solutions.
4. Flame test the four unknown solutions and record their flame colours in a second results table.
5. Work out which metals are in each of the unknown samples and record in your table.

Results

	Barium	Calcium	Copper	Strontium	Sodium
Flame colour					

Flame colours of known substances

	Sample 1	Sample 2	Sample 3	Sample 4
Flame colour				
Metal				

Flame colour of each unknown substance, and the metal indicated by the colour

continued…

ISBN 978-1-108-61069-8

Cambridge University Press

...continued

Evaluation

1. Suggest why a blue flame, not a yellow flame, on the Bunsen burner is necessary.
2. Outline the key safety concerns in this experiment.
3. List the elements that produced the most easily identified colours. Were there any colours that were tricky to identify?
4. Based on your observations, would this method be useful to determine the identity of metals that are in a *mixture*? Why or why not?
5. Give at least two reasons why the flame test may not always provide the right answer.
6. Describe some sources of faults for this experiment and the improvements you would make if you were to repeat this task.

Conclusion

1. What claim can be made from this experiment regarding burning different materials and flame colours? Begin your sentence with: 'This experiment suggests that … '.
2. What evidence did you gather? Begin your brief summary with: 'The results show that … ' and remember to include possible faults in the method.
3. Explain how the data supports your claim. Begin your sentence with: 'This means that … '. Remember to state what the four unknown elements were.

A closer look at the organisation of elements

In Section 5.1, you learned that elements are substances made up of only one type of atom. These can be single atoms or molecules, but all are the same type of atom. Let's now look at the different ways that elements can be organised: as single atoms (**monatomic**), as molecules and as **crystal lattices**.

monatomic made up of single atoms, all of one type

crystal lattice a three-dimensional shape that allows metal atoms to pack together very tightly and form bonds that are extremely strong because the atoms bond to each other in all directions

Monatomic

Monatomic literally means 'single atom'. A monatomic element is made up of single atoms, all of one type. There aren't many of these elements in the periodic table, and all of them are non-metallic gases. You are probably most familiar with neon, as neon signs are everywhere! But perhaps you are not as familiar with the monatomic elements helium (He), argon (Ar), krypton (Kr), xenon (Xe) and radon (Rn). Can you see where these elements all sit in the periodic table? (Refer back to Figure 5.12.)

Some gases are **diatomic**, such as hydrogen and oxygen. These gases are composed of one type of atom, but the atoms are bonded into pairs (two atoms).

diatomic a molecule consisting of two atoms of the same type

Molecules

Most non-metal elements have atoms organised as molecules. Remember that molecules are two or more atoms joined together by bonds. We are discussing elemental molecules, and so the atoms in these molecules are all the same type. Some examples of different molecular elements are shown in Figure 5.14. It is important, as you look at the diagram, to notice not only the range of molecules, but also how to write the chemical formula for elements that are molecules. For example, look at the oxygen molecule. It has two oxygen atoms, so we write O_2, where O is the elemental symbol for oxygen, and 2 shows how many atoms are joined by bonds in the molecule. Now you try: how would you explain O_3 and S_8?

ISBN 978-1-108-61069-8 Cambridge University Press

Crystal lattices

All metals in their solid state (and some non-metals, such as diamond) are organised in what we call a crystal lattice formation. A crystal lattice is a three-dimensional shape that allows the atoms to pack together very tightly and form the strongest bonds. The bonds are extremely strong because the atoms bond to each other in all directions, and so it is hard to separate them completely. It is easier to make them slide past each other, provided they stay in contact with each other. What properties of metals does this behaviour remind you of?

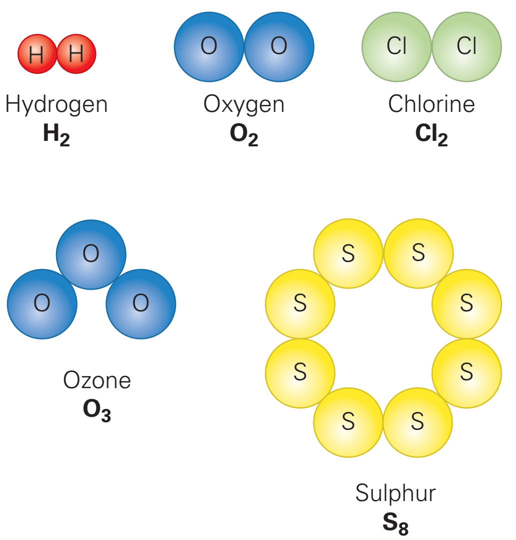


Figure 5.14 Some elemental molecules: hydrogen, oxygen, chlorine, ozone and sulphur

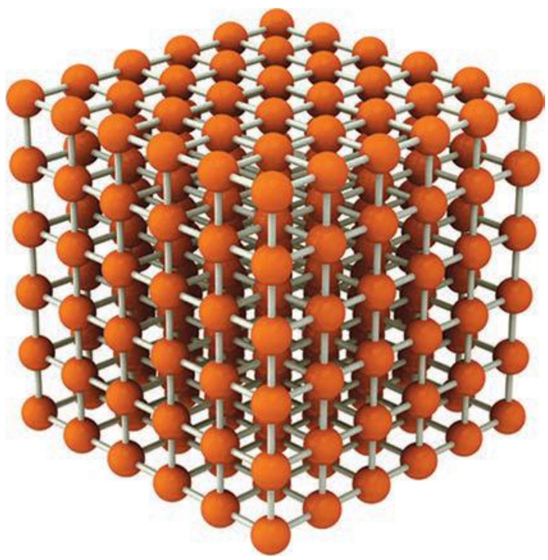


Figure 5.15 A crystal lattice: every atom is attached tightly to other atoms in all directions

Try this 5.4

To imagine how metal atoms pack together and form a lattice, imagine marbles that need to be packed in a box. The marbles would be placed on the bottom of the box in neat, orderly rows and then a second layer of marbles would move into the spaces between marbles in the first layer. Give this a try, to model the lattice formed by metal atoms.

Figure 5.16 Stacking glass marbles of the same size in a box can be used to model how metal atoms pack together and form a lattice.

ISBN 978-1-108-61069-8 Cambridge University Press

Quick check 5.5

1. Define the three ways in which elements can be organised.
2. Draw a simple diagram to show the arrangement of atoms in a monatomic element, a molecule of an element and a crystal lattice of an element.

Explore! 5.2

Carbon is an element that occurs in many different forms. The atoms are the same in all the different forms, but the way the atoms are organised differs. This affects the properties of the different forms.

1. Investigate one of the hardest substance in the world: diamond. Find out its uses and its properties.
2. Investigate the substance that is in the middle of your pencil: graphite. Find out its uses and its properties.
3. Investigate the coolest-sounding molecules: buckyballs. Find out their uses and their properties.
4. Compare the structure of the crystal lattices of diamond, graphite and buckyballs. Do this by describing what each looks like and including a picture.

Science as a human endeavour 5.2

Carbyne

We know that carbon is amazing, but there is more! It comes not just as diamond and graphite, not just buckyballs and nanotubes, but now there is carbyne. In 2013, scientists in the USA calculated the properties of this superstar material and discovered that it would have more strength than any known material. In 2016, scientists in Austria made carbyne! It is difficult to build, as it is a long, one-dimensional chain of carbon atoms that are linked to each other, and it is unstable – as quickly as it is made, it is destroyed. The Austrian scientists got around this by building the carbyne inside a tube made of graphene (another form of carbon).

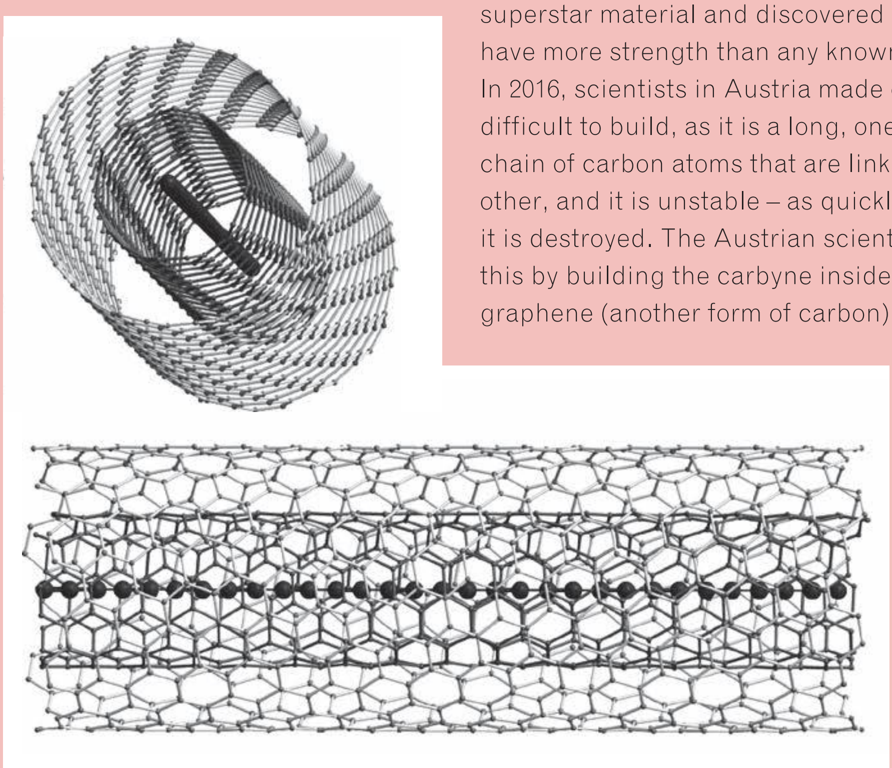


Figure 5.17 Scientists have made carbyne, a very strong material that lasts for a very long time.

ISBN 978-1-108-61069-8

Cambridge University Press

Section 5.2 questions

QUIZ

Remembering

1 What is the chemical symbol for the following elements?

a carbon
b oxygen
c hydrogen
d silicon
e sodium
f copper
g chlorine
h potassium

2 Find out the names of these elements.

a Ag
b Au
c Sn
d Si
e Hg
f Na
g Zn
h Pb

3 List all the elements in the periodic table that have symbols beginning with A.

Understanding

4 Complete the sentences below by selecting the appropriate word from this list: elements, compound, symbol, properties, sulphur, pure, letters, carbon dioxide, periodic table.

a ________________ cannot be separated or broken down any further chemically.
b An element's name can be written as a ________________ , which consists of one or two ________________.
c Elements are organised in the ________________ .
d When two or more elements are chemically combined, the end result is a ________________.
e ________________ is an example of an element and ________________ is an example of a compound.
f Elements and compounds are called ________________ substances because they have specific chemical and physical ________________.

5 Identify each of the following as either an element (E) or a compound (C).

a silver
b water
c wood
d plastic
e tin
f silicon dioxide
g chromium
h arsenic
i carbon dioxide
j sodium chloride (table salt)

Applying

6 Classify the following elements as monatomic, molecular or lattice: helium, diamond, hydrogen, aluminium, oxygen, argon, chlorine, copper, neon.

Analysing

7 Distinguish between a monatomic element and an elemental molecule.
8 Distinguish between an elemental molecule and a crystal lattice. Include examples in your answer.

Evaluating

9 We use symbols to describe elements. Give reasons why we do this.

ISBN 978-1-108-61069-8 Cambridge University Press

5.3 Compounds and mixtures

WORKSHEET

Compounds

At the start of this chapter it was mentioned that, in chemistry, substances are grouped into either pure substances or mixtures. Elements and compounds are both examples of pure substances. In Section 5.2 you learned about elements. Now you will look at compounds. To recap: a compound is a substance made up of two or more different types of atoms joined up into a molecule. For example, water is a compound. It is made up of two hydrogen atoms linked to one oxygen atom, so it has two different types of atoms joined up into a molecule. Just as the 26 letters of the alphabet can form thousands of words, elements can form millions of compounds.

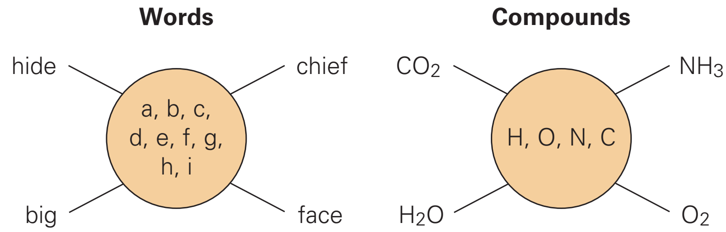


Figure 5.18 Elements are like the letters of the alphabet – letters can form thousands of words, and elements can form millions of compounds.

Compounds can be *covalent* or *ionic* – these terms describe the types of bonds that hold the compound together. A molecule can also be a compound – water is an example. The properties of a compound depend on a couple of things: the elements that are in the compound, and how they are arranged. For example, the properties of carbon vary depending on the arrangement of the carbon atoms. You learned about some of the different forms of carbon in Section 5.2 (in the Explore! box): graphite, diamond and buckyballs. Hydrogen has the following properties: it is colourless, odourless, tasteless, non-toxic, non-metallic and highly combustible. However, the properties of the compounds formed from carbon and hydrogen are very different from the two elements on their own. Figure 5.19 shows examples of the uses and properties of compounds made of only carbon and hydrogen.

Figure 5.19 Substances that contain only carbon and hydrogen. From top to bottom: methane (natural gas); hexane (glue for shoes); octane (a component of automobile fuel)

Organisation of compounds

A molecular compound is always the same size and shape, and it always has the same elements and number of atoms. It can be relatively small – a few atoms joined together – or it can be huge, like plastics that are made up of thousands of atoms and stretch for metres. The atoms in compounds can be arranged in three different ways: as a molecule, a **polymer** or a lattice. These are summarised in Table 5.5.

polymer
a compound made of molecules that are long chains of atoms in a pattern that repeats

Arrangement	Description	Examples
Molecule	Groups of different atoms held together by bonds. A particular compound always has the same elements in the same ratio	Carbon dioxide (CO_2) Water (H_2O)
Polymer	Molecules that are long chains of atoms in a pattern that repeats over and over	Proteins Plastics
Lattice	Larger structures with atoms held together in three-dimensional shapes	Sodium chloride (NaCl) Silicon dioxide (SiO_2)

Table 5.5 The atoms in a compound can be arranged into a molecule, a polymer or a lattice.

Science as a human endeavour 5.3

More plastic has been produced in the past 10 years than in the previous 100 years! Because of plastic pollution, in the past decade companies have been developing bioplastics. Bioplastics differ from conventional plastics in that they can be:

- biodegradable – tiny micro-organisms that are in the environment convert these materials into natural substances, such as water, carbon dioxide and biomass
- biobased – the material is derived from biomass (plants) to some degree; for example, some bioplastics are made from corn
- both biodegradable and biobased.

The term 'bioplastic' refers not just to biodegradable plastics, but also to petroleum-based plastics that are degradable, plant-based plastics that are not biodegradable, and plastics that contain both petroleum-based and plant-based materials that may or may not be biodegradable. Given that many retailers now do not provide single-use plastic bags, scientists and engineers are hopeful that the way we use plastic polymer products will change.

Figure 5.20 There are companies around the world making plastic bags from biodegradable materials such as starch. Some companies are even developing plastic that can dissolve in water and claim that the water is still drinkable!

ISBN 978-1-108-61069-8 Cambridge University Press

Summing up

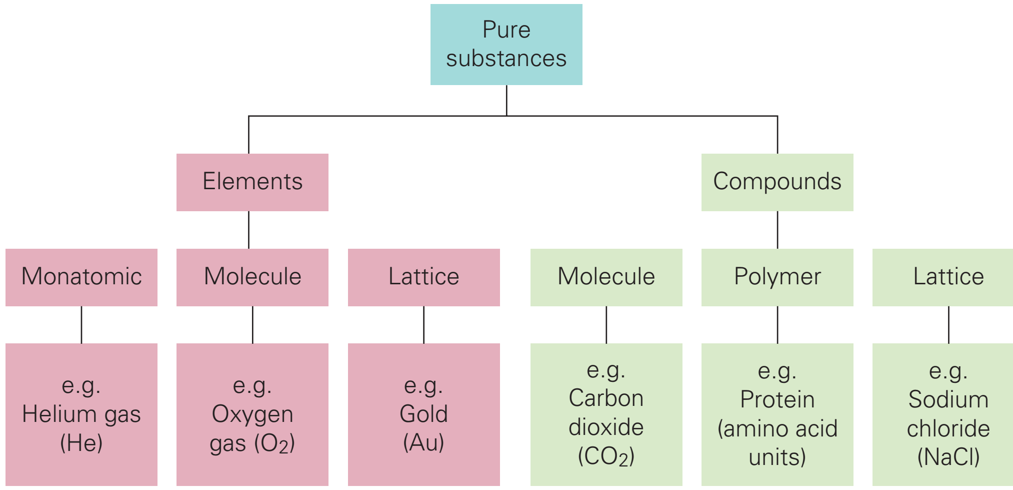


Figure 5.21 Summing up: the organisation of atoms in elements and in compounds

Did you know? 5.3

Polymer bank notes

In 1988, Australian scientists at the CSIRO developed the polymer bank note – the first in the world. Now polymer bank notes are also used in thirty other countries. Australian bank notes start out as plastic pellets, which are melted and blown into a bubble three storeys high! The walls of the bubble are pressed together and cooled to form laminated polymer film.

Figure 5.22 Australian polymer bank notes

Quick check 5.6

1 Define the terms 'compound' and 'molecule'.
2 Explain why the properties of elements, and the compounds made up of those elements, are different.
3 List two examples of compounds that have a molecule structure, two that have a polymer structure and two that have a lattice structure.

Symbols for compounds

A **chemical formula** is a shorthand way of describing the elements that are in a compound, and it includes the symbols of all these elements. The formula tells you which elements are present in the compound, and how many atoms of each element are present in one molecule of that particular compound.

chemical formula
a symbol for a compound that shows which elements, and how many atoms of each element, are present in one molecule of that compound

Let's go through some examples.

- Carbon dioxide in the air has the chemical formula CO_2. This means that one molecule of the compound carbon dioxide has two elements in it: carbon (C) and oxygen (O). There is one carbon atom and two oxygen atoms.
- Sodium sulphate, found in common detergents, has the chemical formula Na_2SO_4. This means that one molecule of the compound has three elements in it: sodium (Na), sulphur (S) and oxygen (O). Each molecule of sodium sulphate contains two atoms of sodium, one atom of sulphur and four atoms of oxygen.

ISBN 978-1-108-61069-8 Cambridge University Press

Figure 5.23 Sodium sulphate is a compound used in common household detergents.

What if the formula has a bracket in it? Consider the compound aluminium carbonate. Its formula is $Al_2(CO_3)_3$. The brackets tell us that there is more than one CO_3 unit. In this case there are three units of CO_3. So, from the formula, we can see that there are three elements in each molecule of this compound: aluminium (Al), carbon (C) and oxygen (O). Each unit of aluminium carbonate is made of two atoms of aluminium, three atoms of carbon and nine atoms of oxygen.

Try this 5.5

Consider the compound sodium bicarbonate, more commonly known as baking powder, $NaHCO_3$. First identify the elements in one molecule of the compound, and then how many atoms there are of each of the elements.

Practical 5.3: Self-design

Making models of molecules in compounds

Aim

To model the molecules of a variety of compounds

Materials

Decide what you would like to use to represent different atoms of elements. Perhaps you would like to use stationery items, plasticine or coloured polystyrene balls – the list is endless. However, you will need about five or more elements, so choose about five or more different colours or items.

Method

1. Research common household items, what they are made of and their chemical formula.
2. Make a list of five compounds you would like to model, with no more than three elements in each.
3. Using your chosen materials, make models of your chosen compounds.

Results

Copy and complete the following table by including details from your five compounds. Include photos of each of the molecules of compounds that you create.

Compound	Formula	List of elements	Number of atoms of each element	Photo

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Evaluation

1. Were there any compounds that contained the same elements? In which way are they similar or different?
2. Would the compounds you have modelled have the same properties as the elements that make them up? Explain.
3. Discuss your choice of materials for the models you built. Were they appropriate? Were there any challenges with the items you chose? Would you use different materials next time?
4. Discuss your choice of compounds to model. Were they appropriate? Were there any challenges with the molecules you chose? Would you use different compounds next time?
5. Explain the value of using models in science.

Conclusion

1. What claim can be made from this activity? Begin your sentence with: 'This practical activity shows that ... '.
2. What materials did you use? Were your materials and compounds good choices?
3. Explain how your choices affected how smoothly the activity went, or how complicated it became. Summarise your activity with a sentence beginning with: 'In completing this activity, we discovered ... '.

Naming compounds

When naming a compound, there are some rules to follow.

1. If there is a metal in the compound, it gets named first. For example, $CaCl_2$ is calcium chloride. Calcium is the metal, so it is named first.
2. If there are only two elements in the compound, there are only two words in the name. The second word will usually end in -ide. Again, consider $CaCl_2$. Calcium chloride contains two elements and the second element word ends in -ide.
3. When the name ends in -ate or -ite, it means the compound contains both oxygen and another non-metal. For example, $CaCO_3$ or calcium carbonate contains calcium, which is a metal, and carbon and oxygen, which are both non-metals.
4. When you are working with non-metals, such as oxygen (O) and chlorine (Cl), the start of the second element word changes based on how many atoms there are in the compound. For example, CO_2 contains one carbon atom and two oxygen atoms, and so the second word starts with di- – it is called carbon dioxide. Table 5.6 summarises the prefixes used, depending on how many atoms of the second element there are in the compound.

Number of atoms of second element	Prefix (start) of second element word	Example
1	None or mono-	Chloride
2	Di-	Dichloride
3	Tri-	Trichloride
4	Tetra-	Tetrachloride
5	Penta-	Pentachloride

Table 5.6 Prefix used at the start of the second element when naming compounds

ISBN 978-1-108-61069-8 Cambridge University Press

Practical 5.4: Teacher demonstration

Making a compound

Aim

To make a compound from two elements, and to practise using elemental symbols and naming compounds

Materials

- strip of magnesium ribbon (approximately 5 cm)
- fine sandpaper
- crucible with lid
- pipeclay triangle
- safety glasses
- wooden tongs
- Bunsen burner and matches
- heatproof mat

Be careful

Do not look directly at the reaction. The reaction is very bright and can damage your eyes.

Method

1. Examine the piece of magnesium and record its properties. If it isn't shiny and clean, gently use the sandpaper to remove any imperfections from the surface.
2. Coil the ribbon up and place it in the crucible with the lid. Place the crucible on the pipeclay triangle, as shown in Figure 5.24.

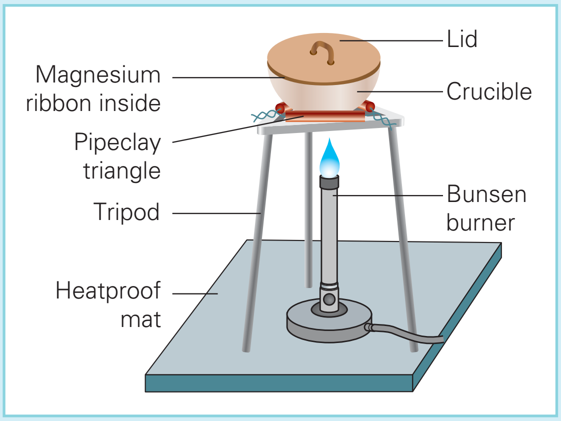


Figure 5.24 Experimental set-up

3. Put on your safety glasses. Heat the crucible with a blue flame, and every so often monitor the reaction by using the tongs to carefully lift the edge of the crucible lid.
4. When the reaction has finished, the magnesium ribbon will no longer be recognisable. Turn off the Bunsen burner and let the crucible cool down.
5. Record what you see in the crucible.

Results

Record your observations.

Evaluation

1. Magnesium is an element. What is its elemental symbol?
2. When magnesium is heated, it reacts with something. What is the other element, and what is its elemental symbol?
3. Describe what you saw in the crucible after heating, and decide whether it is an element or a compound. Explain your answer.
4. Work out the chemical formula for this compound and the name of the substance formed in the crucible.

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Conclusion

1 What claim can be made from this experiment regarding what the two elements were and what compound they formed? Begin your sentence with: 'This experiment suggests that ... '.
2 What evidence did you gather? Refer to your results by beginning a sentence with: 'The results show that ... '.
3 Explain how your observations support your claim. For example, how can you be sure that a new compound was formed? Begin your sentence with: 'This means that ... '.

Quick check 5.7

1 Complete the following table.

Compound	Scientific name	Formula	List of elements	Number of atoms of each element
Natural gas	Methane	CH_4	Carbon Hydrogen	C 1 H 4
Petrol	Octane	C_8H_{18}		
Alcohol	Ethanol	C_2H_6O		
Aspirin	Acetylsalicylic acid	$C_9H_8O_4$		
Eggshells	Calcium carbonate	$CaCO_3$		

2 Write the formula for each of the following compounds:
   a hydrochloric acid – contains one atom of hydrogen and one atom of chlorine
   b glucose – a sugar, contains six carbon atoms, twelve hydrogen atoms and six oxygen atoms
   c rust – contains two atoms of iron and three atoms of oxygen.
3 Work out the names of the following compounds:
   a one carbon atom and four chlorine atoms
   b rust – contains two atoms of iron and three atoms of oxygen
   c one magnesium and one oxygen atom.

Practical 5.5

Breaking down a compound

Aim

To investigate the breakdown of copper carbonate

Be careful

Safety glasses must be worn at all times.

Wash hands thoroughly at the end of the experiment.

Materials

- copper carbonate
- limewater
- straw
- three test tubes
- Bunsen burner
- matches
- heatproof mat
- wooden tongs
- paper towel
- retort stand and clamp
- delivery tube and stopper
- spatula

Method

1 Half fill a test tube with limewater. Using the straw, blow into the limewater so it bubbles. Record your observations when CO_2 from your breath is bubbled through limewater.
2 Use the diagram in Figure 5.25 as a guide to the steps that follow.

continued...

ISBN 978-1-108-61069-8

...continued

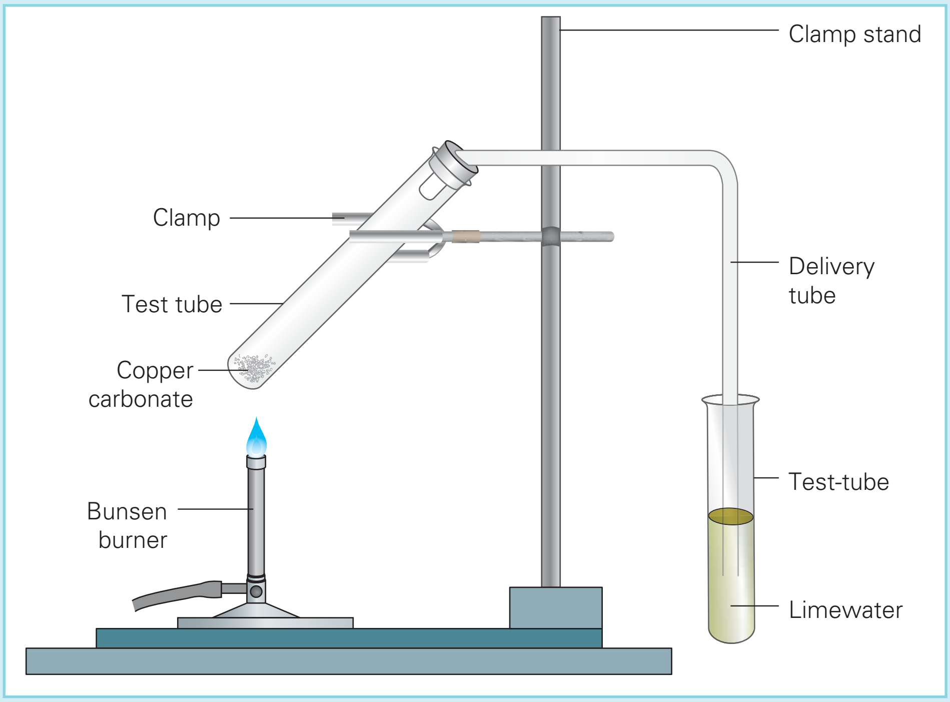


Figure 5.25 Experimental set-up

3 Place a small amount of the copper carbonate in a large test tube and fit it with the gas delivery tube and stopper. Clamp the test tube to a retort stand.
4 Record your observations of the copper carbonate.
5 Half fill another test tube with limewater and place the gas delivery tube in it.
6 Using a small blue flame on the Bunsen burner, gently heat the copper carbonate.
7 Observe and record the changes in the copper carbonate and the limewater.
8 Remove the limewater solution before removing the Bunsen burner.
9 Allow to cool.

Results

Record your observations of the limewater after bubbling, the copper carbonate before heating, and the substance and the limewater after heating.

Evaluation

1 What caused the change in the limewater when you blew into it?
2 What happened to the copper carbonate after heating? Describe what it was like before and what happened after heating. Mention the changes you observed in the limewater.
3 What is the evidence that copper carbonate is a compound and not an element?
4 Why is it important to remove the delivery tube from the limewater as soon as heating is stopped?
5 Why do some gas bubbles pass through limewater when heating is first started?
6 Identify any faults in the method for this experiment and how the experiment could be improved if it were to be carried out again.

Conclusion

1 What claim can be made from this experiment regarding how the substance changed upon heating? Begin your sentence with: 'This experiment suggests that … '.
2 What evidence did you gather? Describe what you observed upon heating the copper carbonate, with a sentence that begins with: 'The results show that … '.
3 Explain how the data supports your claim. Begin your sentence with: 'This means that … '.

ISBN 978-1-108-61069-8 Cambridge University Press

Mixtures

Mixtures are not pure substances like elements and compounds. You may remember from Year 7 that a mixture is a substance made from two or more different pure substances that have been mixed together and can be physically separated. The components of a mixture can be separated, as they are not combined in a chemical way. Some examples of mixtures that you may be familiar with are soft drinks (a mixture of sugar, water, carbon dioxide and colouring), a soothing cup of tea (a mixture of tea leaves and water), refreshing tap water (a mixture of water, fluoride and chlorine) and tasty spaghetti bolognaise (a mixture of tomatoes, beef, garlic, chillies and thyme).

Mixtures have different properties from those of compounds, as there is no chemical bond between the parts of a mixture. Table 5.7 summarises the differences between compounds and mixtures.

	Compound	Mixture
Components	Contains two or more elements	Contains two or more elements or compounds
Bonding between atoms	Elements are chemically bonded together	Elements/compounds are not chemically bonded together
Properties	The compound has properties that are different from the properties of the elements it contains	Each substance in the mixture keeps its own properties
Separation	The compound can be separated into its elements using chemical reactions	Each substance is easily separated out of the mixture
Ratio of different atoms	Elements occur in strict ratios to each other	Substances in the mixture can occur in any ratio

Table 5.7 The differences between a compound and a mixture

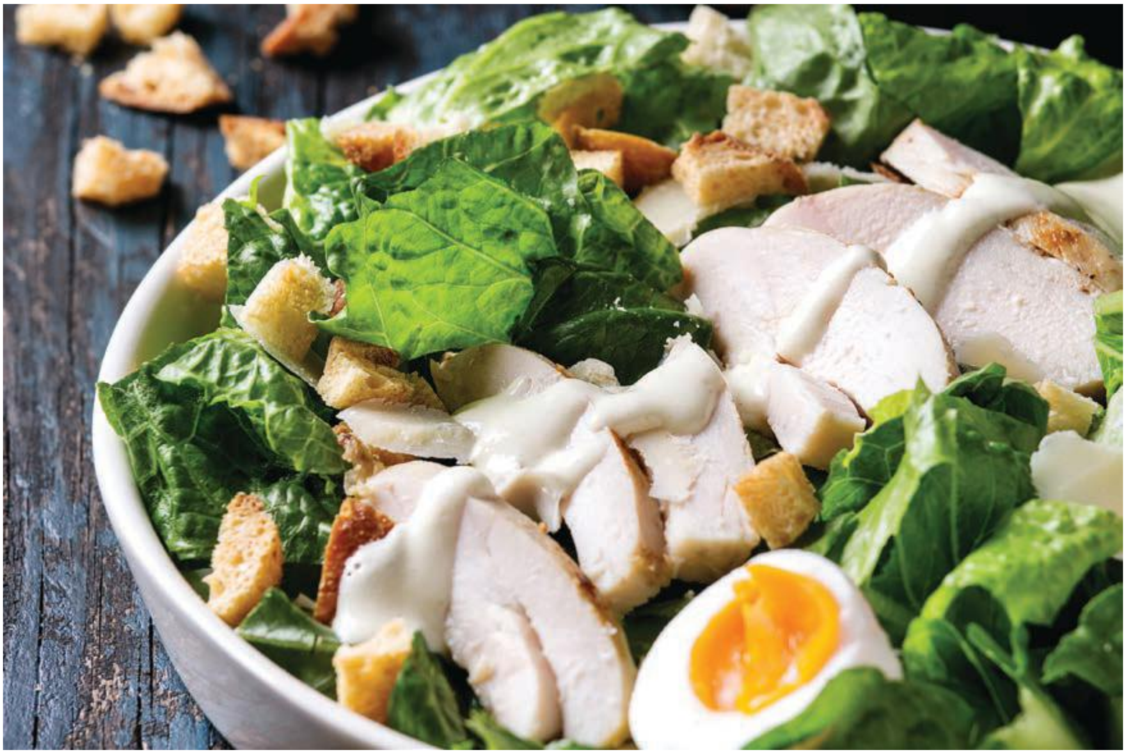


Figure 5.26 This caesar salad is an example of a mixture – the components are not chemically combined, and so they can be separated.

ISBN 978-1-108-61069-8

Mixtures can be broadly classified into two categories: **homogeneous** mixtures and **heterogeneous** mixtures.

homogeneous
describes a mixture of two or more substances that are evenly distributed and do not separate out

heterogeneous
describes a mixture that can be separated into its parts, and the parts retain their original properties; the mixture is not blended evenly

Homogeneous mixture
You cannot tell that two or more substances have been mixed together, as they don't separate out when left to stand. The components of the mixture are all evenly distributed, so the entire mixture has the same properties.
Examples: air, water, chocolate pudding, soft drink.

Figure 5.27 Soft drink is an example of a homogeneous mixture.

Heterogeneous mixture
Can easily be separated into its parts, and those parts retain their original properties. The mixture is not blended together evenly and is not the same consistency throughout, so if you took a sample from different parts of the mixture, the samples would all have different properties.
Examples: trail mix, choc chip cookies, smog, pizza topping.

Figure 5.28 Pizza is an example of a heterogeneous mixture.

Symbols for mixtures

You know about writing symbols for the different elements, and know how to write the symbols for compounds. But what about mixtures? Because mixtures are substances made from two or more different pure substances mixed together that can be physically separated and are not combined in a chemical way, you will never have to write a chemical formula for mixtures. The elements and compounds that make up the mixture retain their own symbols/formulas.

ISBN 978-1-108-61069-8 Cambridge University Press

WIDGET
Elements, compounds and mixtures

Summing up

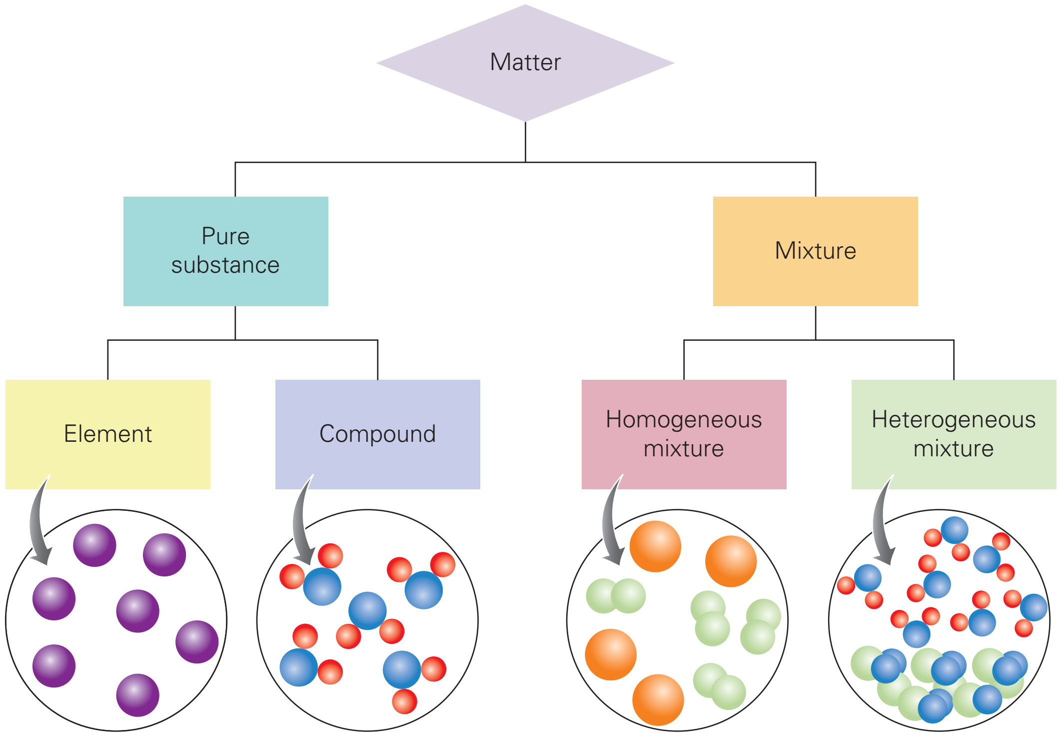


Figure 5.29 Matter consists of pure substances and mixtures. In this chapter, you have learned about both these groups.

Make a revision flip book

Try this 5.6

Using three pieces of white A4 paper, in portrait orientation, cut from the middle of the top to the middle of the bottom of the paper, so you end up with six long, thin rectangles. Stack the rectangles on top of each other, turn the rectangles to landscape orientation, and place three staples, equally distant, across one long edge (see Figure 5.30). Using your scissors, and the picture as a reference, cut the rectangle into thirds.

First, label the three top panels with the words 'element', 'compound' and 'mixture'. Next, decide what key concepts you have learned in this chapter, to add to your flip book. Consider examples, definitions, symbols/formulas, diagrams, organisation and so on. Then hop to it!

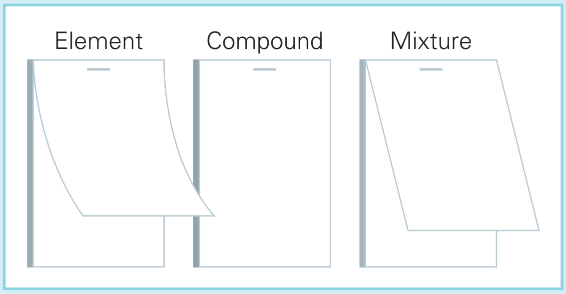


Figure 5.30 Your revision flip book

QUIZ

Section 5.3 questions

Remembering

1 Define the following key terms related to the organisation of compounds: molecule, polymer, lattice.

Understanding

2 Read each of the following statements and decide whether it applies to compounds or mixtures.
   a The substances in it are not chemically bonded.
   b The substances in it are chemically bonded.

continued...

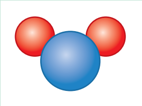
ISBN 978-1-108-61069-8 Cambridge University Press

...continued

- **c** Each substance in the mixture keeps its own properties
- **d** Its properties are not the same as the properties of the elements that make it up.
- **e** The substances can be separated by chemical means only.
- **f** The substances can be separated by physical methods.

Applying

3 Copy and complete the following table.

Name	Diagram	Formula	Number of different elements in the compound	Number of atoms in each molecule
Water		H_2O	2	3
Carbon monoxide		CO		
Sulphuric acid		H_2SO_4		
Nitric oxide		NO		
Nitrous oxide				
Methanol		CH_3OH		

4 Use the information you provided in your answer to the previous question to answer the following questions.
- **a** What is the difference between nitric oxide and nitrous oxide?
- **b** Which is bigger: a molecule of sulphuric acid or a molecule of carbon monoxide? Explain.
- **c** In what ways are nitrous oxide and water similar?

5 Write the formula for the following compounds:
- **a** marble, which contains one calcium atom, one carbon atom and three oxygen atoms
- **b** propane, which contains three carbon atoms and eight hydrogen atoms
- **c** sucrose, which contains 12 carbon atoms, 22 hydrogen atoms and 11 oxygen atoms.

6 Identify the names of the following compounds:
- **a** sand, which contains one silicon atom and two oxygen atoms
- **b** epsom salts, which contain one magnesium atom, one sulphur atom and four oxygen atoms
- **c** one phosphorus atom and three chlorine atoms.

Analysing

7 Draw a Venn diagram and label one circle 'compounds' and the other 'mixtures'. Write statements in each circle to distinguish between the two, and in the middle to identify what they have in common.

8 A tiny sample of quartz contains 1 000 000 atoms of silicon and 2 000 000 atoms of oxygen. Determine what the formula would be, based on this information.

Evaluating

9 Substances A, B and C were tested and were found to have the following chemical compositions:

A: 70% oxygen, 30% carbon

B: 60% hydrogen, 40% carbon

C: 60% oxygen, 40% carbon

Are any two of these substances the same compound? Give reasons for your answer.

10 Compare and contrast a heterogeneous mixture with a homogeneous mixture.

ISBN 978-1-108-61069-8

Cambridge University Press

Review questions

SCORCHER

Remembering

1 What has to happen to separate a compound into its elements?

2 Match the element name with its correct symbol.
Symbols: O, C, He, Br, Au, Zn, H, S, Na, Mg
Names: sodium, hydrogen, oxygen, helium, magnesium, carbon, bromine, sulphur, zinc, gold

3 Baking powder is a common substance in pantries. Its formula is $NaHCO_3$. What does the 3 mean?

Understanding

4 Complete the following sentences by filling in the blanks.
- a Elements are pure substances containing only one kind of ____________.
- b An element ____________ be separated into simpler materials.
- c All existing elements are listed and classified in the ____________.
- d In compounds, the atoms are ____________ combined using bonds.
- e Compounds ____________ be separated by physical means.
- f The properties of a compound are usually ____________ to the properties of the elements it contains.
- g Mixtures are two or more ____________ or ____________ that are not chemically combined.
- h Mixtures can be uniform (called ____________).
- i Mixtures can also be non-uniform (called ____________).
- j The properties of a mixture are ____________ to the properties of its components.

5 Explain how the properties of an element relate to its use. Include examples.

6 Explain why carbon dioxide does not appear in the periodic table.

Applying

7 Distinguish between mixtures and compounds.

8 Copy and complete the following table.

Name of compound	Formula	Number of elements in the compound	Name of the elements in the compound	Number of atoms in the compound
Magnesium oxide	MgO	2	Magnesium Oxygen	2
	FeS			
Potassium oxide	K_2O			
	$FeSO_4$			
Benzene	C_6H_6			
	Al_2O_3			
		2	Sulphur Oxygen	4

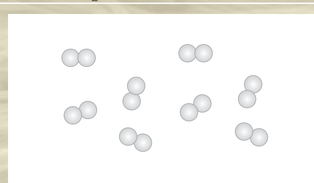
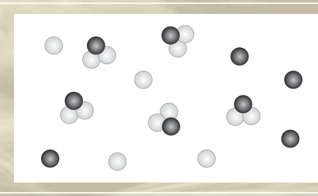
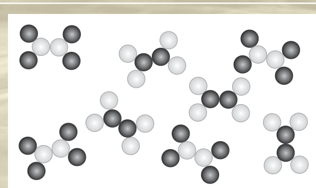
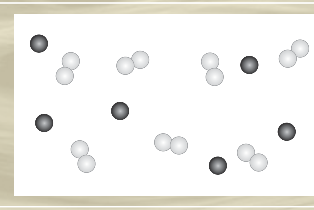
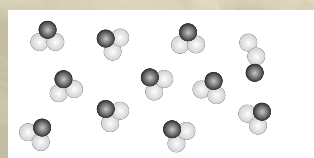
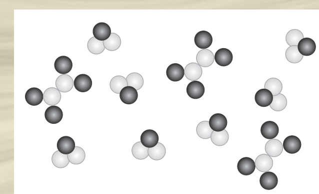
9 Summarise the arrangement of atoms in an element, a compound and a mixture.

10 Methane (natural gas), hexane (glue for shoes) and octane (petrol) are substances that contain only carbon and hydrogen. Identify why they are all so different.

ISBN 978-1-108-61069-8

Analysing

11 Classify each of the following substances as an element, a compound, a mixture of elements, a mixture of compounds, or a mixture of elements and compounds. Some of the substances are named, and some are provided as diagrams.

a	Chicken soup	b	Bismuth (Bi)
c	Dry ice (CO_2)	d	Concrete
e		f	
g		h	
i		j	

12 Compare the properties of metals and non-metals.

13 Marie heated an unknown powder with the Bunsen burner and some gases were released (nitrogen dioxide and oxygen).

- **a** Was the original unknown substance an element or a compound?
- **b** Which elements can you confirm were in the original substance?

Marie then continued to heat the substance and more oxygen gas was released. There was also a silvery residue in the test tube (the element mercury).

- **c** What other element/s can you now confirm were in the original substance?

Evaluating

14 We can use the letters of the alphabet to make up words, sentences, paragraphs and more. Using this analogy, what would best represent compounds, mixtures and elements – letters, words or paragraphs? Justify each of your answers.

15 Give reasons why elements and compounds can be represented by chemical formulas but mixtures cannot.

ISBN 978-1-108-61069-8

STEM activity: To mine or not to mine?

VCSSU097 VCDSTS043 VCMNA285 VCSIS107 VCSIS111 VCSIS113

Background information

You may remember from Year 7 that mining is a process used to extract natural resources from the Earth. Most of these resources are non-renewable, which means that, unless recycled, they can only be used once. This poses a number of challenges for future generations. For example, minerals such as indium and silver might run out within the next 20 years, making the search for a substitute vital for the maintenance of the electronics industry. Mined resources are used for many things, such as making toys, computers and cell phones (copper, iron, nickel, tin), as well as heating homes and generating electricity. Resources that are more accessible can be used up first, while resources that are not as accessible may require further exploration and effort. These resources may be more expensive due to the extra effort required to mine them.

You may not know it, but Australia is a leading producer of minerals for the world. Australia produces 19 minerals from nearly 400 operating mines in every state and territory. We have the world's largest resources of gold, iron ore, lead, nickel, uranium and zinc, as well as the second-largest resources of cobalt, copper and silver. Australia's resources of tungsten, lithium and manganese ore are ranked in the top five in the world.

Mining minerals, and the associated technology and services, is an important part of the Australian economy, accounting for around 15% of gross domestic product (GDP) in 2015/16—that is, about $236.8 billion! The Australian Bureau of Statistics also reports that, in 2017, the mining industry employed around 1.1 million people, which is about 10% of overall employment. The Australian minerals industry is a major contributor to national income, investment, high-wage jobs, exports and government revenue. So why aren't more mines opening in Australia? We have the resources, mining creates jobs and income .... Let us investigate.

Figure 5.31 An open-cut gold mine in Australia

ISBN 978-1-108-61069-8

Design brief: Use digital technologies to create a proposal for opening a mine in country Victoria.

Activity instructions

You are an engineer working for the Elemental Resource Mining Company. Along with a team of other engineers, you have applied for permission to open a new open pit mine in country Victoria, in order to harvest rare earth elements (REE) from the ground. This region is famous for its clean waters, and farmers rely on this water in growing their crops. Also, local tourists visit the region for a weekend away. But, as with many regional areas, local communities experience high levels of unemployment.

Your team must begin by investigating questions such as:

- how open pit mining works
- how REE minerals in such mines are processed
- what properties make these minerals suitable for use
- how mining for REE may affect the environment
- how much money is to be made or lost by mining
- the impact that opening a mine would have on local communities.

Your team will then propose how feasible it is to open a new mine in country Victoria, and present your findings to the local community using a PowerPoint (or equivalent) presentation.

Suggested materials

- Web browser
- PowerPoint

Evaluate and modify

1. Choose an element to be mined, and investigate: its chemical symbol, its properties, what it is used for, the form it is found in, where there are deposits in Australia (including a map), how it is extracted and processed, and the volume currently mined (include a graph demonstrating its change over time).
2. Outline the advantages of the proposed mine: the export value of the element (include a graph demonstrating its change over time), benefits to the national economy, possible jobs created, and other community benefits.
3. Discuss the disadvantages of the proposed mine: the environmental impacts, impacts on the local community including farming and tourism, additional costs such as exploration and wages.
4. Propose and present your team's findings, including your conclusions with regard to the feasibility of opening a mine that harvests your chosen element from the Earth.
5. As a class, evaluate the presentations made by all the teams, and propose which element would be best to mine and which should not be mined.

ISBN 978-1-108-61069-8

Cambridge University Press

Chapter 6 **Chemical change**

Chapter introduction

This chapter introduces you to the physical and chemical changes that occur in our world. You will also learn about how substances react to form new substances, and the evidence that a reaction has occurred. You will look at how glow sticks work, how marshmallows go goopey and delicious over a fire, how fruit ripens, and how fireflies glow in the night.

Curriculum

Chemical change involves substances reacting to form new substances (VCSSU098)	
• identifying the differences between chemical and physical changes	6.1, 6.2
• identifying evidence that a chemical change has taken place	6.2
• investigating simple reactions, for example, combining elements to make a compound	6.3

Victorian Curriculum F–10 © VCAA (2016)

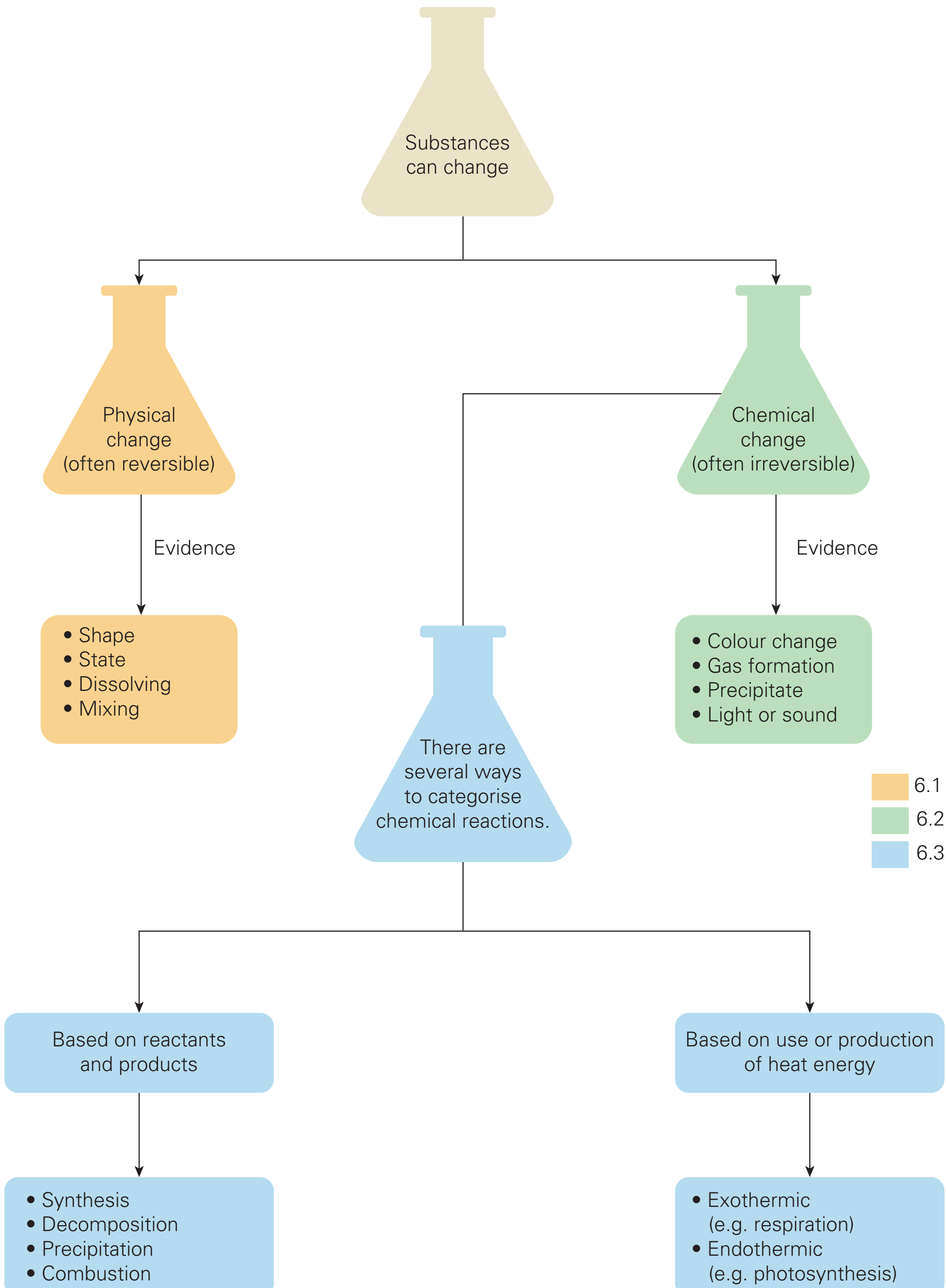
Glossary terms

bioluminescence
chemical change
chemiluminescence
combustion
condensation
contraction
corrosion
decomposition
diffusion
dissolving
endothermic
evaporation
exothermic
expansion
freezing
galvanisation
irreversible
melting
physical change
precipitate
precipitation
products
reactants
reversible
synthesis
thermal decomposition

ISBN 978-1-108-61069-8

Cambridge University Press

Concept map



ISBN 978-1-108-61069-8 Cambridge University Press

6.1 Evidence of physical change

Physical change

physical change
when the physical properties of a substance change in some way, but no new substance is formed; it is reversible; examples are a change in shape, expansion and contraction, change in state, mixing and dissolving

reversible
capable of going in the opposite direction

During a **physical change**, the characteristics of a substance, or its physical properties, change in some way but nothing new is formed. Examples of physical properties are texture, shape, size, colour, odour, volume, mass, weight, pH and density. As the chemical nature of the substance is not altered, physical changes are usually considered to be **reversible**.

When trying to determine whether a physical change has occurred, there are several pieces of evidence to look for, such as:

- a change in shape
- expansion or contraction
- a change in state
- mixing or dissolving occurring
- a non-permanent colour change.

Evidence of physical change

Changing shape

When an object changes shape, we say it has undergone a physical change. For example, when an elastic band is stretched, the physical properties of the elastic band change but not its chemical structure, nothing new has formed and it is reversible. Think about a soft drink can being crushed. Have its physical properties changed? Has its chemical structure changed? Has anything new been made? Is it reversible? So is it a physical change?

WORKSHEET

Figure 6.1 Different types of evidence that a physical change has occurred: change in shape (top left), expansion or contraction (top right), change in state (bottom left), mixing or dissolving (bottom right)

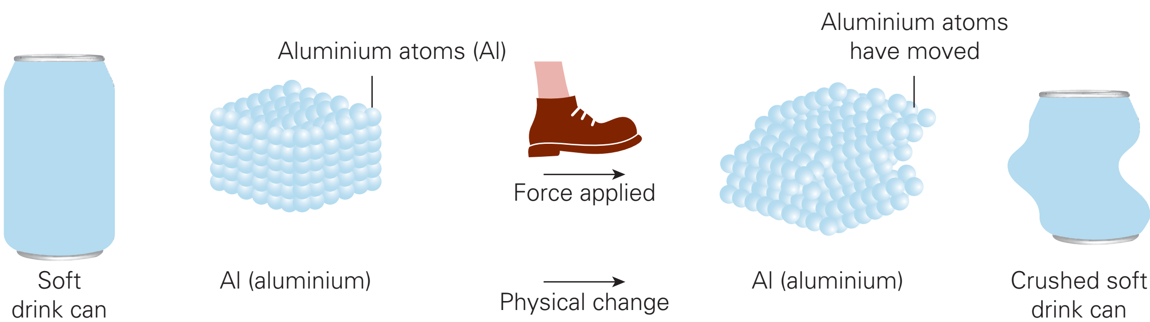


Figure 6.2 When an aluminium can is crushed, the characteristics of the can have changed, but nothing new is formed. Therefore it is a physical change.

ISBN 978-1-108-61069-8

Figure 6.3 An example of a physical change is when glass breaks: its physical characteristics change, but it is still glass.

Breaking glass is another example of physical change. Can you explain why?

Quick check 6.1

1. Write a definition of the term 'physical change'.
2. List the four pieces of evidence to look for when determining whether a physical change has occurred.
3. Explain how changing shape is an example of physical change.

Expansion and contraction

In Year 7 you learned about the particle model and different states of matter. The particle model, which describes the behaviour of atoms in solids, liquids and gases, suggests that if you heat up a substance, the atoms in the substance will also gain energy, move faster and expand if the container allows. This means the atoms will gain energy, move more and increase the distance between each other. This process of getting larger is called **expansion**. Expansion is an example of physical change – the properties of the substance have changed (volume increases and

expansion
the process of getting larger, the atoms in a substance move further apart as they heat up

Figure 6.4 When the air inside a hot air balloon is heated, the atoms in the heated air gain energy, move faster and take up more space. This is an example of a physical change occurring and it results in the air being less dense on the inside of the balloon, so the balloon rises.

density decreases), but no new substance has formed, and it is reversible. Hot air balloons and thermometers are two examples of where we can see evidence of a physical change occurring in this way.

The reverse of expansion is **contraction**, and this is also evidence of a physical change occurring. The substance cools down, the atoms lose energy, they slow down, and the distance between the atoms gets smaller (volume decreases and density increases).

contraction
the process of getting smaller, the atoms in a substance move closer together as they cool

Note that if the gas in inside a container of fixed size, the pressure will change but the volume will not.

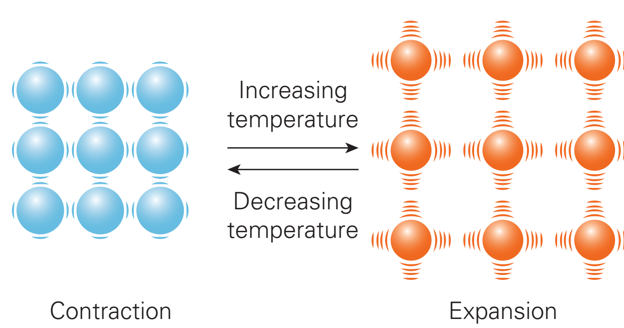


Figure 6.5 The physical changes experienced by atoms during expansion and contraction

ISBN 978-1-108-61069-8

Cambridge University Press

Practical 6.1

Making a model thermometer

Aim
To demonstrate expansion and contraction by making a model thermometer

Materials
- 250 mL conical flask
- glass thermometer
- clear narrow plastic straw
- ice-cream container
- red food colouring
- permanent marker
- modelling clay (or Blu Tack)
- water
- ice

Method
1. Half fill the bottle (conical flask) with water.
2. Add a drop or two of food colouring.
3. Place the straw in the bottle, but do not let it touch the bottom. Use the clay to seal the edges of the bottle's top with the straw in the middle. The clay will hold the straw in place and prevent it from touching the bottom of the bottle.
4. Write a hypothesis: what do you predict will happen as the fluid in the bottle warms up? And when it cools down?
5. On the side of the bottle, use a permanent marker to mark the height of the liquid inside the straw (your thermometer) at room temperature. Record the temperature of the room.
6. Place the bottle into an ice-cream container with ice and allow to cool. Record the temperature of the environment and mark the side of the bottle to document where the liquid level is now.
7. Place the bottle in a different temperature environment. Let the bottle sit there for several minutes. Record the temperature of the environment and mark the side of the bottle to document where the liquid level is.
8. Make a scale on your thermometer, using the temperatures you have recorded and the marks you have made on the bottle. Test your thermometer.

Results
Record your observations and tabulate your results: the temperature of each environment and the height of the fluid in the straw.

Evaluation
1. Did your results support your hypothesis? Explain.
2. Explain your results. Why did the fluid move up/down the straw? Use your knowledge of the particle theory to aid in your explanation.
3. Imagine you repeated your experiment but with a narrower straw. How would you expect the measurements to be different for a narrower straw? Explain whether this new thermometer would be likely to be more or less accurate than your first thermometer.
4. Outline possible faults in this experiment, and explain how each could have affected your results.
5. Suggest improvements for this experiment if you were to carry it out again.

Conclusion
1. What claim can be made from this experiment regarding the behaviour of liquids at different temperatures? Begin your sentence with: 'This experiment suggests that … '.
2. What evidence did you gather? Begin your brief summary with: 'The results show that … ' and remember to include possible faults in the experimental technique.
3. Explain how the data supports your claim. Begin your sentence with: 'This means that … '.

ISBN 978-1-108-61069-8

Changing state

You know that heating up a substance causes an increase in temperature. If enough heat is added, the substance can change its state. When a substances changes state, it is a physical change – it can be reversed, and the actual substance is still chemically the same, it is just its physical properties that have altered.

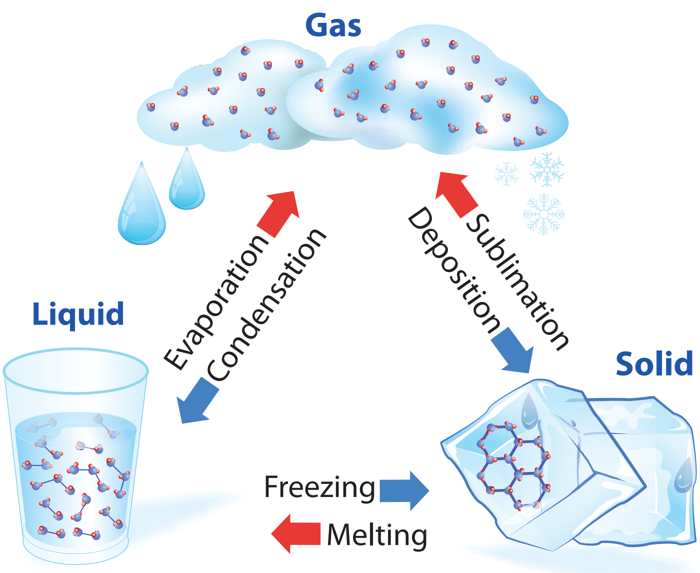


Figure 6.6 When a substance gains or loses heat, it undergoes a physical change: no new substance is produced and the substance changes its physical properties but is still the same substance.

melting
the process in which heat causes a solid to become a liquid

Melting is the process in which heat causes a solid to become a liquid. Remember that heating a substance gives the atoms of that substance more energy, and this makes the atoms move or vibrate faster. If you add enough heat to the atoms, the edge of the solid will eventually jiggle around so much that some of the atoms will break free, and a liquid will form. For example, when a snowman melts, the solid water becomes liquid water. The two forms of water have very different properties (hardness, ability to be poured, shape and so on), but they are both water. The process of melting is reversible, and no new substance has been formed, so melting ticks all the boxes for being an example of physical change.

Figure 6.7 A snowman melting is an example of physical change. Can you explain why?

freezing
the process in which heat is lost, causing a liquid to become a solid

Freezing is the opposite of melting. It is a physical change that occurs when heat is lost, causing a liquid to become a solid. As liquid cools, the atoms lose energy and move or vibrate more slowly. If you remove enough energy, the atoms will end up just vibrating in a fixed position. Because of their closeness, the atoms will form stronger bonds with their neighbours than before, forming a solid.

Figure 6.8 Candle wax undergoes a physical change – it melts or forms a liquid when heated, and freezes or forms a solid when cooled.

ISBN 978-1-108-61069-8

evaporation
the process in which heat causes a liquid to become a gas

Evaporation is another change of state. It occurs when heat causes a liquid to become a gas. Consider the clothes you hang on the line to dry – they dry as the water evaporates from the surface of the clothes. No new substance has formed, and the change is reversible, so it is a physical change.

Figure 6.9 Clothes dry as water evaporates from them.

condensation
the process in which heat is lost, causing a gas to become a liquid

Condensation is the opposite of evaporation. It occurs when heat is lost, causing a gas to become a liquid. An example you are probably familiar with is when you see water vapour from the air cooling and forming condensation on the outside of your cold drink.

Figure 6.10 Condensation is an example of a physical change, as no new substance has formed, it is reversible and it is only the physical properties of the water that have altered, not its chemical make-up.

Science as a human endeavour 6.1

Physical changes have happened on Mars too!

In 2015, scientists used special computer modelling to see if freezing liquid water could have caused the surface features of the Martian landscape. Features like the dried-out river valleys and gigantic outflow channels are clearly visible to orbiting spacecraft. As you know, a change of state is an example of physical change, so physical changes have happened on Mars too.

In 2018, data collected by the European Space Agency's Mars Express spacecraft suggested that there is in fact a pool of liquid water buried under layers of ice and dust in the south of Mars. Orbiters, landers and rovers exploring the Martian landscape have also discovered minerals that can only form in the presence of liquid water.

Figure 6.11 The surface of Mars is thought to have been shaped by physical changes.

Quick check 6.2

1 Explain how expansion and contraction are examples of physical change.
2 Explain how changing state is an example of physical change.

ISBN 978-1-108-61069-8 Cambridge University Press

Mixing and dissolving

dissolving
the process in which a substance (solute) breaks up into small particles that can no longer be seen in a solution

diffusion
the movement of atoms/molecules until they are evenly spread out; occurs in a liquid or a gas

When you mix substances or dissolve one substance in another, a physical change occurs. Think about **dissolving** sugar (solute) in water (solvent) to form a solution. The way the molecules of sugar spread out within the water is called **diffusion**. When the sugar is all spread out in the water, you still have sugar, but the molecules have been separated and surrounded by water molecules. The characteristics of the sugar have changed from a crystalline, solid structure to one where all the sugar particles are free to float around in the water. No new substance has been formed, and the process is reversible if you evaporate the water. It is for this reason that mixing and dissolving are considered evidence of physical change.

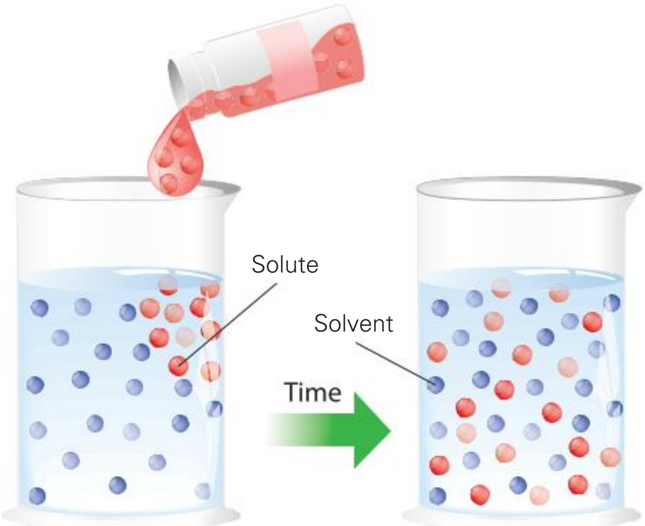


Figure 6.12 Molecules of water (blue) move randomly in a glass. Add molecules of sugar (red) and these new molecules will eventually become distributed uniformly throughout the water. This is diffusion.

Skittles and diffusion

Try this 6.1

Note: This activity uses lollies, which may present a risk if students have food allergies. No food items are to be consumed.

Collect the following materials: Petri dish, stopwatch, filter paper or white paper, five skittles of different colours, and a beaker of water.

Now place the Petri dish on the filter or white paper and place the five skittles equally spaced in the Petri dish. Slowly pour water into the Petri dish to fill it up, and start timing. Record your observations. Explain your observations using the term 'diffusion'.

Repeat, but this time use warm water. Explain the differences you observe.

Figure 6.13 Skittles can help demonstrate diffusion.

Quick check 6.3

1 Explain how mixing and dissolving are examples of physical change.
2 Identify which of the following are physical changes.
   a slicing bread
   b turning on a light
   c breaking an egg
   d mowing grass
   e fireworks
   f breaking glass
   g freezing water
   h cutting hair
   i making a fire
   j drying clothes
   k burning toast
   l melting chocolate
   m colouring hair
   n yoghurt going 'off'
   o popping popcorn
   p squeezing an orange

ISBN 978-1-108-61069-8

Cambridge University Press

Explore! 6.1

More physical changes?

Are there other examples of physical change that you have not investigated, or have you covered them all? Your job is to find out what you can about the following three situations, and provide evidence for each on why it is or is not an example of physical change.

1 the heating of an iron bar until it turns red
2 the magnetising of a piece of iron
3 the glowing filament of a light globe.

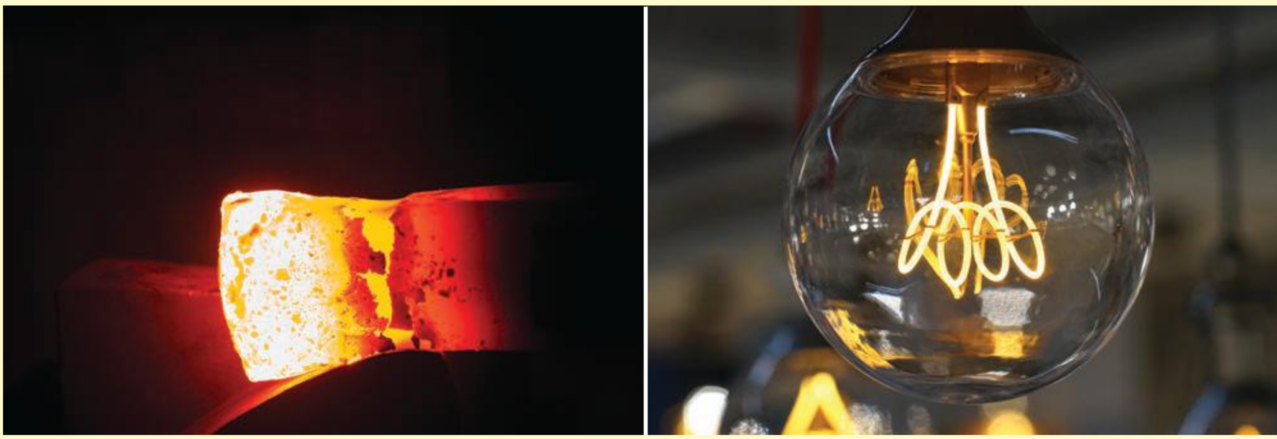


Figure 6.14 An iron bar glows red when heated, and a filament glows in a light globe. Are these examples of physical change?

Practical 6.2

Physical change

Aim

To conduct a series of activities/experiments in order to explore physical change, and be able to identify the evidence of change

Be careful

No food items are to be consumed.

Materials

- small plastic cups
- ice
- Play-Doh
- rehydration powder
- beaker of water

Method

Activity 1

1 In a plastic cup, place one ice cube.
2 Observe and record how the ice looks and feels.
3 Set the cup with ice aside and complete the other activities.
4 Return to your cup with ice, observe and record how the ice now looks and feels.
5 Record what evidence of change you see, in the results table.

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Activity 2

1 Take some Play-Doh in your hands.
2 Observe and record how the Play-Doh looks, feels and smells.
3 Break the Play-Doh into lots of little bits. Observe and record how the Play-Doh looks, feels and smells.
4 Record what evidence of change you see, in the results table.

Activity 3

1 Observe and record how the rehydration powder and water look on their own.
2 Add a teaspoon of the powder to the beaker of water.
3 Observe and record how the water looks and smells.
4 Record what evidence of change you see, in the results table.

Results

Copy and complete the table below, to show the evidence that a physical change has occurred in the three activities.

Activity	Change in shape	Change in state	Expansion/ contraction	Mixing/ diffusion	Other	Observations
1						
2						
3						

Evaluation

1 Define 'physical change'.
2 Outline the different pieces of evidence that a physical change has occurred, and provide an example from your activities.
3 Were there any pieces of evidence that weren't demonstrated during these activities? Write an activity that would allow you to demonstrate this piece of evidence of physical change.

Conclusion

1 What claim can be made from this experiment regarding physical change? Begin your sentence with: 'This experiment suggests that … '.
2 What evidence did you gather? Begin your brief summary with: 'The results show that … '.
3 Explain how the data supports your claim. How did you know a physical change had occurred? Begin your sentence with: 'This means that … '.

QUIZ

Section 6.1 questions

Remembering

1 Identify which of the following are examples of physical properties.

- a blue colour
- b odour
- c density
- d sweet taste
- e flammable
- f reacts with air
- g reacts with water
- h boiling point
- i hardness
- j dissolves in water
- k lustre
- l volume

continued...

ISBN 978-1-108-61069-8

Cambridge University Press

...continued

2 Identify which of the following are physical changes.

- a cutting an apple
- b milk going 'off'
- c digesting food
- d ice melting
- e cooking pikelets
- f wood rotting
- g reacting with vinegar
- h inflating a bike tyre
- i grass growing
- j silver tarnishing
- k mopping up water
- l Milo dissolving in milk

3 Define the following terms: reversible, expansion, contraction, melting, freezing, evaporation, condensation, dissolving, diffusion.

Understanding

4 Write T or F for each of the following statements to demonstrate whether it is true or false. Then rewrite the false statements so that they are true.

- a During a physical change, the chemical make-up of the substance also changes.
- b Melting is a physical change.
- c As particles warm up, expansion can occur and this is a physical change.
- d Physical changes are never reversible.
- e When heat is lost from a substance, the particles can move closer together, and a gas can change to a liquid.
- f Cutting up a cake changes the shape and size of the cake – this is a physical change.
- g Burning wood in a fire forms charcoal and ash – this is a physical change.
- h When a solvent dissolves in a solute, nothing new is formed, so this is a physical change.

5 Identify five physical changes that happen in your home.

Applying

6 Summarise the following physical changes, using your knowledge of the particle theory.

- a why the tyres on your family car seem more deflated on a cold day
- b how a liquid in glass thermometer works
- c why on extremely hot days there are concerns about train tracks not working well

7 Explain the process whereby a strong-smelling deodorant is sprayed in one corner of the room but eventually everyone in the whole room can smell it.

Analysing

8 Examine how you could you reverse the following physical changes.

- a salt dissolving in water
- b inflating a balloon
- c ice melting
- d glass breaking

Evaluating

9 Give reasons why each of the following is an example of a physical change.

- a blow drying your dog's coat after giving him a bath
- b making cordial from a concentrate and water
- c your lilo getting tight and ready to pop after lying in the sun
- d crushing cereal boxes before putting them out for recycling

ISBN 978-1-108-61069-8

Cambridge University Press

6.2 Evidence of chemical change

Chemical change

WORKSHEET

chemical change
when the chemical properties of a substance change and a new substance is formed; irreversible; indicators of chemical change include colour change, change in temperature, gas or precipitate being produced

During a **chemical change**, a new substance is formed. This new substance could be a solid, a liquid or a gas. To help determine whether a new substance has been formed, and therefore a chemical change has occurred, there is evidence you can watch for. Occasionally you will get exceptions to this list, but most of the time, one or more of the following would be observed:

- a permanent colour change
- a gas being given off (as an odour, or smoke or bubbles)
- a solid (called a **precipitate**) forming in a solution
- a change in temperature (up or down)
- energy in the form of light or sound being produced (e.g. an explosion)
- a new substance being formed.

precipitate
the solid that forms when two clear solutions are mixed together and undergo a chemical change

Consider the fireworks that light up the night sky each year on New Year's Eve. The bright explosions of colour that we see are actually metals, like magnesium and copper, that change chemically as they burn, producing fantastic colours. What signs are there that a chemical change has occurred? Referring to the previous list, we see colour, light and smoke, we hear cracking and fizzing, and we know the fireworks are dangerous to get close to, because of the heat they produce.

Chemical changes are also considered to mostly be **irreversible**. 'Irreversible' means that the products cannot easily (if ever) be converted back to the substances that formed them. To reverse a chemical change often requires a chemical reaction to take place, or the input of energy.

irreversible
incapable of going in the opposite direction

Figure 6.15 New Year's Eve fireworks over Melbourne are an example of chemical change

ISBN 978-1-108-61069-8

Quick check 6.4

1 What is the key piece of evidence that a chemical change has occurred?
2 List the five pieces of evidence to look for, to determine whether a chemical change has occurred.
3 What is the evidence that a chemical change has occurred in each of these situations?
   a Leaves turn red in the autumn.
   b Sherbet fizzes in your mouth.
   c Bread is baking in the oven.

Science as a human endeavour 6.2

Chemical reactions caught on film

In March 2017, scientists shared with the world how they had been able to 'film' inter-molecular chemical reactions. They were able to do this using the electron beam from a transmission electron microscope (TEM), like stop-motion or stop-frame filming. This technique can show chemical reactions as they are happening and, among other challenging questions, could help us understand how molecules interact or react with each other at the atomic level. We may also be able to find out why one product results rather than another product.

Evidence of chemical change

It is finally the school holidays and your family is going camping. One cool evening you are all relaxing around the campfire to keep warm. The adults are cooking sausages on the grill over the flames, and damper in the coals beneath them. You toast marshmallows using sticks held over the edge of the fire, letting them get all brown, gooey and delicious. On this lovely evening, chemical changes are happening all around you!

Figure 6.16 Damper bread that has been cooked in the coals of a fire shows evidence of a chemical change occurring.

Colour change

VIDEO Evidence of chemical reactions

Remember: a chemical change is any change that causes a new substance to be formed. For example, when your campfire has burned completely out, ashes are left behind – these are a new substance formed by the burning of wood. This is a chemical change. But what about permanent colour change? This is another indicator that a chemical change has occurred.

Your marshmallows, sausages and damper are all browning on the outside from being exposed to the heat of the campfire flames. Not only is a new substance (charcoal) forming on the outside where the food is burned, but there is also a permanent colour change, indicating that a chemical change has indeed occurred. Generally speaking, the changes caused by cooking food are all chemical changes.

The ripening of fruit and vegetables is another example of a colour change indicating that a chemical change has occurred. For example, when a tomato reaches the green stage of its development, it starts to produce ethylene gas.

ISBN 978-1-108-61069-8 Cambridge University Press

The ethylene then interacts with the tomato fruit to start the ripening process, which involves chemical reactions, and so it is evidence of chemical change.

Figure 6.17 Tomatoes ripening and changing colour is evidence that a chemical change has occurred.

Rusting, a type of **corrosion**, is a slow and usually unwanted chemical change that causes iron and steel to go flaky and brown. This is not desirable in things like buildings, bridges and train tracks, which are made of iron and steel. Rusting occurs when iron reacts with water and with the oxygen in the air to form iron oxide (rust). This is a new substance forming and so, clearly, rusting is a process producing a chemical change.

corrosion
the gradual and natural process of metals breaking down; an example is rusting

Figure 6.18 Screws exposed to water and oxygen will start to corrode or rust, providing evidence of chemical change.

Given the widespread use of iron and steel, we need ways to prevent rusting. The word equation for the process of rusting is:

iron + water + oxygen → iron oxide

This equation means that all three substances on the left of the arrow are required to produce the substance on the right of the arrow. If iron and steel are not exposed to water and/or oxygen, then iron oxide cannot be made and rusting is halted. You may have noticed that, in hardware stores, there are two options for stopping water and oxygen coming into contact with the iron and steel:

- a surface protector can be painted onto the iron or steel surface. This is like the paint we put on cars to prevent the metal panels being exposed to the elements
- **galvanisation**, in which the iron or steel is coated in a layer of zinc. If a corrugated iron roof has been galvanised, the zinc coating will corrode before the iron, and so the iron is protected from rusting.

galvanisation
the process of coating iron or steel in zinc to prevent corrosion

Figure 6.19 A galvanised corrugated iron roof: the zinc coating will corrode before the iron underneath, preventing rusting of the iron.

ISBN 978-1-108-61069-8

Try this 6.2

Steganography

Steganography is the practice of sending hidden messages. For this activity you will need some lemon juice in a small container, white paper, a plastic tray, some cotton buds and access to an iron or a hair dryer. Begin by placing a piece of white paper on your tray. Dip a cotton bud into the lemon juice and write a message on the paper. When your message is dry, take it up to your teacher and they will reveal your message using a heat source (iron or hair dryer). Explain why this is an example of a chemical change.

Practical 6.3: Self-design

To rust or not to rust

Aim

To determine the conditions required for the chemical change of rusting

Materials

- steel wool
- large glass test tubes with stoppers
- vegetable oil
- water

Method

1. You may need to wash the steel wool to remove soap residue.
2. Consider what you learned earlier in the chapter about the conditions that are required for the chemical change of rusting.
3. Design an experiment that will demonstrate that the conditions you believe are required for rusting are indeed required, using steel wool, oil (to prevent air getting access to water or steel wool), stoppers and test tubes. Think about your independent, dependent and controlled variables as you plan. You will need to leave your experiment overnight.
4. Draw a diagram of your method, showing what will be added to each test tube.
5. Draw up a results table.
6. Write a hypothesis or prediction about what conditions are required for rusting.
7. Check your design with your teacher before starting your experiment.

Results

Use your results table to record your results.

Evaluation

1. Did your results support your hypothesis? Explain how they did or did not.
2. Define the terms ‘chemical change’ and ‘rusting’. List any chemical changes you saw in this experiment.
3. Write a word equation for the reaction that occurs when rust is produced.
4. How would you design your experiment differently if you had the opportunity to repeat it? Give details in your answer.
5. For a super challenge, how can you make the steel wool rust faster? You may like to use salt water, vinegar and soft drink in your experiment.

Conclusion

1. What claim can be made from this experiment regarding the conditions required for rusting? Begin your sentence with: ‘This experiment suggests that … ’.
2. What evidence did you gather? Begin your brief summary with: ‘The results show that … ’.
3. Explain how the data supports your claim. Begin your sentence with: ‘This means that … ’.

ISBN 978-1-108-61069-8 Cambridge University Press

Gas is formed

To produce a soft, fluffy loaf of bread or a delicious piece of cake, you need a chemical change to occur. One of the key indicators in this case is a gas being produced. This gas could be in the form of an odour, bubbles or even smoke.

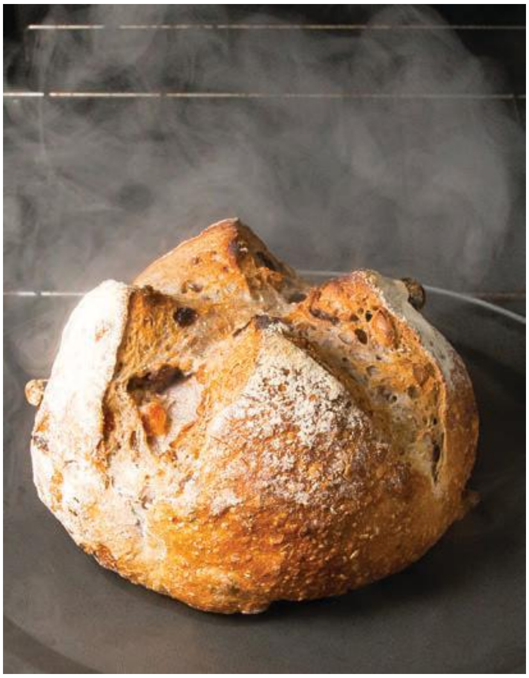


Figure 6.20 Mmmm … hot bread straight out of the oven, a delicious consequence of chemical change.

Bread can be made using a substance known as bicarb soda (or sodium bicarbonate), which is added to the main ingredients – flour, salt, oil and water. The ingredients are mixed together into a dough before baking. When heated, the bicarb soda breaks down and produces carbon dioxide gas. As the carbon dioxide is released into the dough, it expands with the heat (note that this is a physical change). Large bubbles of gas form in the dough, and this is what gives the bread its spongy texture.

Bread can also be made using micro-organisms called yeast. The yeast uses the starch and sugars in the flour to produce alcohol and carbon dioxide. The alcohol escapes during cooking, but the carbon dioxide expands inside the dough, creating bubbles of gas and making the bread rise.

Try this 6.3

Ready, set, bake!

Jump online and find a simple bread recipe. Give it a go at home. Write a word equation for the reaction – that is, write the ingredients that go into the bread, and then an arrow to represent the change, and then write the substances that are formed, to the right of the arrow. What evidence is there that a chemical change has occurred? Also list any physical changes you notice.

Rotting things often produce gas, and again this is a sign that a chemical change is occurring. For example, your vegetable scraps in the compost bin are broken down by micro-organisms in a process called **decomposition**, and this produces carbon dioxide gas.

decomposition a reaction in which one substance (reactant) breaks up into smaller ones (products)

What about the eggs you buy? One of the ways to tell whether an egg is rotten or still good is to use the flotation test. To carry out the test, gently place the egg in a glass of water. A fresh egg will rest at the bottom of the glass. An egg that sinks but rests with the large end facing up may be a bit older but is still okay to cook and eat. If the egg floats, it is old and may be rotten.

Figure 6.21 The flotation test used to determine whether an egg is rotten (left) or fresh (right)

ISBN 978-1-108-61069-8 Cambridge University Press

This test works because, as the egg starts to rot, decomposition occurs and carbon dioxide forms. The more rotting, the more gas. The gas can move through the eggshell, so some of the gas escapes through the eggshell and is lost to the atmosphere. When enough gas is lost, the egg is lighter (less dense) than the water, and so the egg floats.

Precipitate is formed

Another indicator that a chemical change has occurred is the formation of a precipitate. A precipitate is the name given to a solid that forms when two clear solutions are mixed together. The precipitate is unable to dissolve in water and so, when it forms, it makes the solution look cloudy before it settles on the bottom. You will learn more about chemical reactions that produce a precipitate in the next section.

Quick check 6.5

1. Give three examples of where a colour change indicates that a chemical change has occurred.
2. Write the process of rusting as a word equation.
3. Explain some examples of where a gas being formed provides evidence of chemical change.
4. Define the term 'precipitate'.

Change in temperature

You already know that during a chemical change, new products are formed. But did you know that heat energy may also be given off or absorbed during a chemical change? This is another sign that a chemical change has occurred. For example, the burning of natural gas in the kitchen when you are cooking is a chemical change that gives off a great deal of heat. Heat is used in cooking to speed up the many chemical changes that result in a delicious meal. Remember how all matter consists of atoms joined together to form different substances? Heat can help atoms break free of each other and form different substances. For example, when you cook an egg, the heat makes the atoms in egg white break free and recombine in a different way, and this appears to us as cooked egg!

Figure 6.22 When natural gas burns, a lot of heat energy is released, and we use this heat to cook our food.

Essentially, any time you burn something, heat energy is produced, and the increase in temperature indicates that a chemical change has occurred. But the opposite can also happen: heat energy can be absorbed, and the temperature decreases. Chemical ice packs are probably the most common example of this. If you injure yourself, you may be offered an ice pack. You pop a bubble inside the pack and magically the pack starts to absorb heat from the surrounding environment, and this makes the pack feel cold. You will investigate chemical processes that produce heat energy and absorb heat energy, in the next section.

Light or sound produced

Another piece of evidence that a chemical change has occurred is light or sound. Remember the fireworks discussed earlier? During that chemical change, both sound and light are produced. Can you think of other examples where light or sound (or both) are evidence that a chemical change has occurred? The following information may help you.

WIDGET
Physical vs chemical change

ISBN 978-1-108-61069-8

Did you know? 6.1

Fireflies glow because of chemical reactions!

Fireflies produce a chemical reaction inside their abdomens that allows them to produce light. This process is called **bioluminescence** and is shared by many other organisms, mostly sea-dwelling or marine organisms. (Note that boluminescence is a type of **chemiluminescence**.)

bioluminescence a chemical reaction that produces light in living things

chemiluminescence a chemical reaction that produces light

When oxygen combines with calcium, adenosine triphosphate (ATP) and the chemical luciferin, and a bioluminescent enzyme is also present, light is produced. When oxygen is available, the firefly's light organ glows, and when it is not available, the light goes out. The firefly is able to control the beginning and end of the chemical reaction, and thus start and stop the production of light. Unlike a light bulb, which gets hot when it produces light, a firefly's light is cold light, and so very little energy is lost as heat. This is very lucky for the firefly, because it would not survive getting as hot as a light bulb!

Fireflies light up for a number of reasons. The larvae produce short glows that act as a warning to predators that they taste bad. As adults, many fireflies have flash patterns unique to their species, and use them to discriminate between members of the opposite sex. In males, a higher rate and intensity of flashing has been shown to be most attractive to females in several firefly species.

Figure 6.23 The tail of a firefly produces light through a chemical reaction known as bioluminescence.

Explore! 6.2

Glow sticks

Have you ever played minigolf in the dark with glow-in-the-dark balls? Have you ever celebrated New Year's Eve with glow sticks? It all comes down to chemical reactions.

1 Define the following key terms: fluorescence, chemiluminescence, bioluminescence.
2 Find out about the structure of glow sticks and explain what is involved in the chemical reaction that produces the light. Summarise your findings and include a picture/diagram.

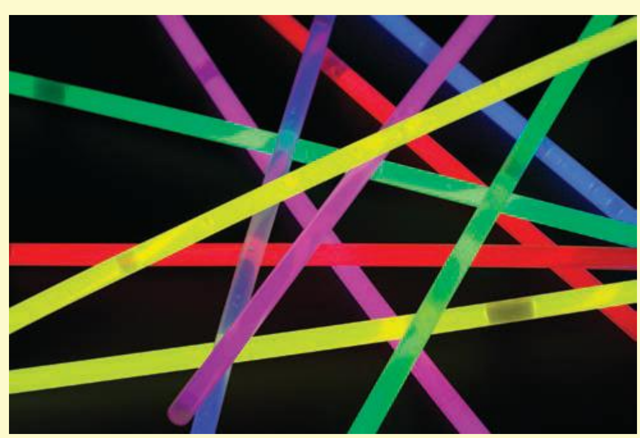


Figure 6.24 Glow sticks work because of chemiluminescence, a chemical reaction that produces light.

Quick check 6.6

1 List some examples of where a change in temperature provides evidence of chemical change.
2 List some examples of where light or sound being formed provides evidence of chemical change.

ISBN 978-1-108-61069-8 Cambridge University Press

Practical 6.4

Chemical change

Be careful
Personal protective equipment is to be worn. All waste is to be collected and disposed of appropriately.

Aim
To conduct a series of activities/experiments in order to explore chemical change and be able to identify the evidence of change

Materials
- Bunsen burner
- matches
- wooden skewer
- strontium chloride solution
- copper II sulfate solution
- ammonium hydroxide solution
- test tubes and test tube rack
- 2 cm strip of magnesium ribbon
- 1 M hydrochloric acid
- thermometer
- 100 mL glass beaker
- lemon juice
- baking soda

Method
Activity 1
1. Light the Bunsen burner.
2. Take a wooden skewer and break it in half.
3. Dip the broken-off end of the skewer into the strontium chloride solution.
4. Place the wet end of the skewer into the flame.
5. Record your observations for Activity 1 in your results table and tick which of the pieces of evidence show that a chemical change has occurred.
6. Repeat the above steps with the copper II sulfate solution.

Activity 2
1. Place three eye droppers full of ammonium hydroxide into a test tube in a rack.
2. Add the copper sulfate solution, drop by drop, no more than 10 drops, into the ammonium hydroxide.
3. Record your observations for Activity 2 in your results table and tick which of the pieces of evidence show that a chemical change has occurred.

Activity 3
1. Place a 2 cm strip of magnesium ribbon into a test tube in a rack.
2. Gently stand a thermometer in the test tube also.
3. Add approximately 2 cm of dilute hydrochloric acid to the test tube.
4. Record your observations for Activity 3 in your results table and tick which of the pieces of evidence show that a chemical change has occurred.

Activity 4
1. Put approximately 40 mL of lemon juice in a 100 mL glass beaker.
2. Gently stand a thermometer in the beaker.
3. Add 1 teaspoon of baking soda to the lemon juice.
4. Record your observations for Activity 4 in your results table and tick which of the pieces of evidence show that a chemical change has occurred.

continued…

ISBN 978-1-108-61069-8

...continued

Results

Copy and complete the table to show the evidence that a chemical change has occurred.

Activity	Change in colour	Change in temperature	Gas produced	Light produced	Precipitate produced	Observations
1						
2						
3						
4						

Evaluation

1 Define 'chemical change'.
2 Outline the different pieces of evidence that a chemical change has occurred, and provide an example from your activities.
3 Were there any pieces of evidence that were not demonstrated during these activities? Write an activity that would allow you to demonstrate this piece of evidence of chemical change. You may need to do some online research first.

Conclusion

1 What claim can be made from this experiment regarding chemical change? Begin your sentence with: 'This experiment suggests that … '.
2 What evidence did you gather? Begin your brief summary with: 'The results show that … '.
3 Explain how the data supports your claim. How did you know a chemical change had occurred? Begin your sentence with: 'This means that … '.

Try this 6.4

Physical and chemical changes are all around us. Figure 6.25 shows some photos from a family holiday. List the physical and chemical changes you can see in the photos. For every change you notice, state the evidence that a change has occurred or is occurring – for example, colour change, a gas being produced or a new product being formed.

Figure 6.25 Can you spot the physical and chemical changes in these photos from a family holiday?

ISBN 978-1-108-61069-8

Did you know? 6.2

Digestion is all about change!

Thousands of physical and chemical changes take place during the digestion of your food … yes, thousands!

Part of the body	Type of change	Details
Mouth	Physical	Food is chewed by teeth to break it down into smaller pieces, so that the chemical processes have more surface to work on.
	Chemical	An enzyme in saliva (called amylase) starts to break down sugars and carbohydrates into simpler forms that your body can absorb.
Oesophagus	Physical	As the oesophagus moves food from the mouth to the stomach, the muscles squeeze, pushing the food along, in a process called peristalsis.
Stomach	Physical	The stomach muscles squeeze and churn the food to break it into smaller pieces so that the chemical processes have more surface to work on.
	Chemical	Hydrochloric acid in the stomach reacts with food to break it down even further, so your body can absorb it. More digestive enzymes are released here.
Small intestine	Physical	As the small intestine moves food along towards the large intestine, the muscles squish the food to help break it down further.
	Chemical	Enzymes break down proteins and fats even further, so they can be absorbed into your bloodstream through the walls of the intestine.

Table 6.1 Some of the many physical and chemical changes that occur in the digestive system

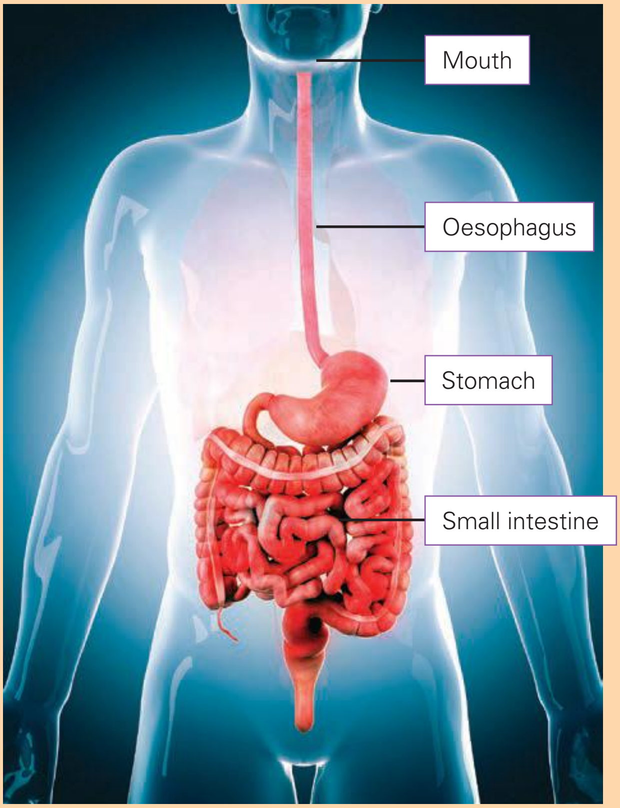


Figure 6.26 The digestive system uses physical change and chemical change to break down your food for absorption.

ISBN 978-1-108-61069-8

Cambridge University Press

Quick check 6.7

1 Copy and complete the following table.

Physical change	Chemical change
Reversible	
No new products are formed	
Change in shape	
Expansion/contraction	
Change in state	
Mixing/dissolving	

Science as a human endeavour 6.3

Forensic detection of fingerprints

In 2015, an Australian scientist's home was broken into. This inspired him to develop a new technique for fingerprint detection at a crime scene. Fingerprints can be used as an identification tool for suspects as each pattern is unique to each individual. However, while some fingerprints may be visible such as those from a dirty hand, often they are invisible on surfaces.

Dr Liang from the CSIRO found that by adding a drop of liquid containing crystals to surfaces, investigators using a UV light are able to see latent (invisible) fingerprints 'glow' in about 30 seconds. The benefits of the crystals are that they are cheap, react quickly and can emit a bright light. The chemical reaction doesn't create dust or fumes, reducing waste and the risk of inhaling dangerous gases.

Figure 6.27 Detecting latent (invisible) prints left at a crime scene is now easier, with new detection methods involving chemical reactions.

QUIZ

Section 6.2 questions

Remembering

1 Rewrite the following, matching each term from the left column with its correct definition from the right column.

Term	Definition
Physical property	a new substance is formed and the process is irreversible
Physical change	the way substances look and act, e.g. colour, melting point, hardness, boiling point, density
Chemical property	nothing new has formed and the process is reversible
Chemical change	the behaviour of a substance when it reacts with another substance

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

2 State some examples of physical properties.
3 State some examples of chemical properties.
4 List the five common signs that a chemical change has occurred.

Understanding

5 Outline three examples of chemical change occurring in your home.
6 Explain the process of rusting and why it is an example of chemical change.
7 A stoppered test tube of yellow liquid is left on the window sill of a science lab over the weekend. When the students come back to class, they observe that there is condensation on the inside of the tube, the liquid has gone green, and the stopper has popped out. Explain whether these observations indicate physical or chemical changes, and how you know.

Applying

8 Distinguish between bioluminescence and chemiluminescence.
9 Classify each of the following as physical or chemical change.
   a vegetable scraps breaking down in the compost bin
   b separating sand from gravel
   c cutting fingernails
   d drilling a screw into wood
   e mulching tree branches
   f a stock cube dissolving in hot water
   g fruit on the ground going mouldy
   h crushing a can
   i trees growing new leaves in spring
   j breakfast cereal going soggy
   k rain making the ground muddy
   l dropping and breaking a plate
   m baking a quiche
10 Identify the types of changes occurring in the following situations. (There may be more than one type.)
   a Pastry is defrosted and then used to make a pie.
   b To make honeycomb, sugar is mixed with water and honey, heated, and then bicarbonate of soda is added.
   c A candle burns and wax drips down the side.

Analysing

11 For each of the following situations, summarise the signs of chemical change you would observe.
   a Birthday candles are burning.
   b Glow sticks work when you break them.
   c Sandwiches go mouldy.
   d Baking soda and vinegar are mixed together.
12 Determine the reasons why galvanised iron does not rust.

Evaluating

13 Give reasons why rusting occurs faster on door hinges of boat sheds compared to door hinges a kilometre inland from the beach.
14 For each of the following situations, identify whether a physical change, a chemical change, or both, has occurred. Give reasons for your answers.
   a biting, chewing and swallowing noodles
   b ice cubes melting in your iced chocolate drink
   c petrol burning in a car
   d bread dough being kneaded, then rising
   e a steel spoon being left out after being washed and little red spots forming on it

ISBN 978-1-108-61069-8 Cambridge University Press

6.3 Investigating reactions

WORKSHEET

You now know what evidence to look for when a physical change occurs, and when a chemical change occurs. And you know the difference between physical and chemical change. In this section, you will investigate what happens when a chemical change occurs – that is, a chemical reaction.

Reactants and products

reactants
the substances that are present at the beginning of a chemical reaction

products
the substances that are present at the end of a chemical reaction

In a chemical reaction, the substances you start with are called **reactants**, and the substances you finish with are called **products**. A chemical reaction can be represented in different ways, such as a word equation or a chemical equation.

An example of a chemical reaction is when light hits photographic film coated with silver chloride. Tiny crystals of the compound silver chloride are attached to film. When the film is exposed to light, a chemical reaction occurs, and this darkens the film to produce an image. This reaction can be represented by a word equation and by a chemical equation.

Figure 6.28 Photographic film works because of chemical reactions.

Word equation:
silver chloride → silver + chlorine

Chemical equation:
$2AgCl \rightarrow 2Ag + Cl_2$

The reactants or, in this case reactant, is on the left of the arrow – silver chloride. Note that the formula for silver chloride is AgCl, one atom of silver joined to one atom of chlorine.

The products are on the right of the arrow – silver and chlorine. Note that chlorine has the formula Cl_2 as it is exists as a molecule, never as an atom on its own.

You may have noticed that in front of the AgCl is the number 2, and there is also a number 2 in front of the Ag. Why are these extra numbers in the equation when they are not part of the formula of the compound AgCl? This is part of the process of balancing equations, which you will learn more about in Years 9 and 10. To put it simply, atoms cannot be destroyed or made, they just move around during chemical reactions. So this means the number of silver atoms in the reactants must be the same as the number in the products, and the number of chlorine atoms in the reactants must be the same as in the products. The extra numbers you see in the equation are there to balance the numbers of atoms on each side of the equation.

ISBN 978-1-108-61069-8 Cambridge University Press

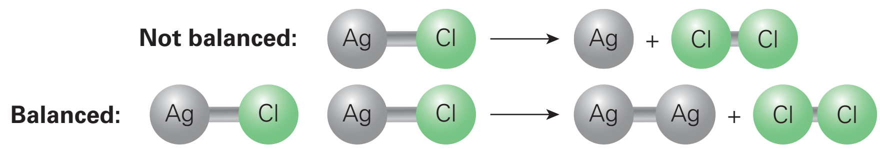


Figure 6.29 Keeping it simple: balancing equations is like working out whether you need one or two cups of flour to make bread. The top equation is not balanced, because the number of chlorine atoms is not the same on both sides of the reaction.

Quick check 6.8

1. a Do chemical reactions involve physical change or chemical change?
   b Give examples of what evidence there would be if a chemical reaction occurred.
2. Define the terms 'reactants' and 'products'.
3. Name and give examples of two different ways we can represent chemical equations.

Four types of chemical reactions

There are four basic types of chemical reactions:

- synthesis reactions (sometimes called combination)
- decomposition reactions (sometimes called breaking down)
- precipitation reactions
- combustion reactions.

Synthesis

Synthesis reactions are when two (or more) elements or reactants combine to form one new substance or product. Synthesis reactions can be represented in this way:

synthesis
a reaction in which two (or more) elements or reactants combine to form one new substance or product

$$A + B \rightarrow AB$$

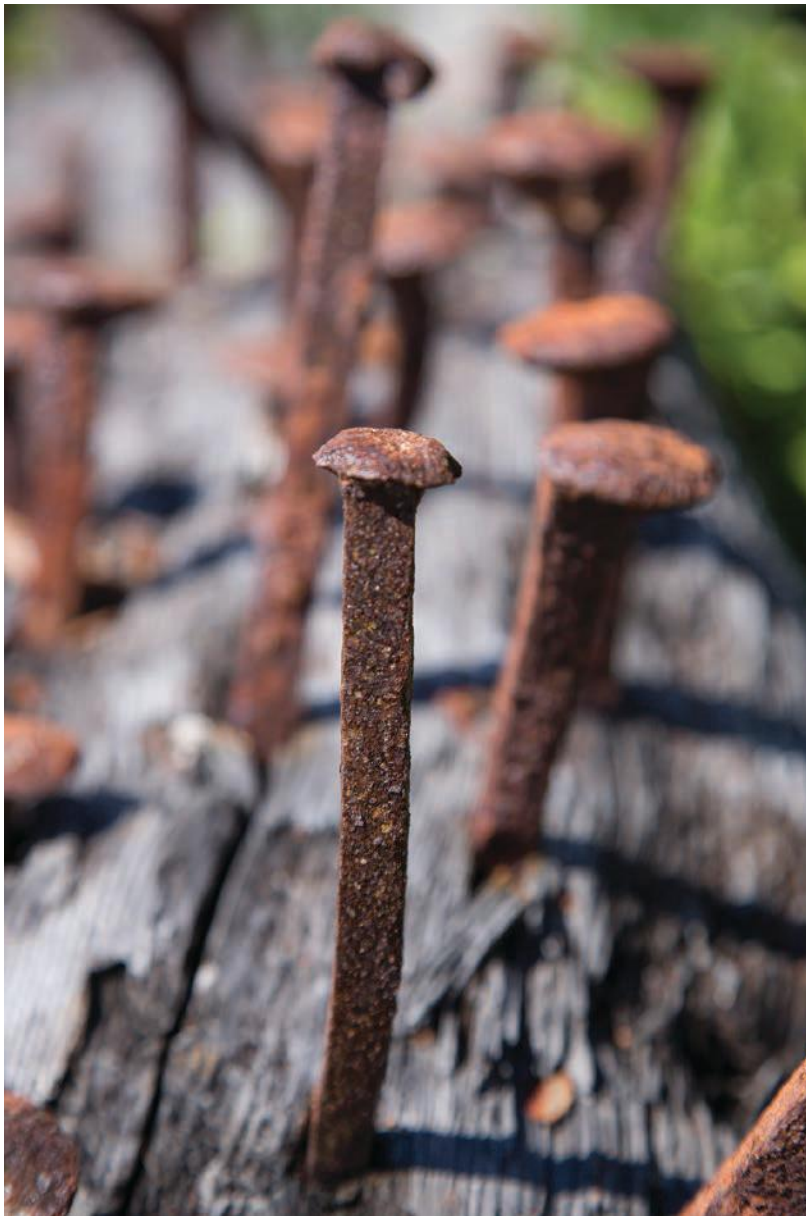
where A and B are the reactants and AB is the product.

You have already read about many synthesis reactions in this chapter, such as the rusting of iron. Iron reacts with oxygen gas in the air, to form rust.

Word equation:
iron + oxygen gas → iron oxide

Chemical equation:
$2Fe + O_2 \rightarrow Fe_2O_3$

Figure 6.30 A nail rusting is an example of a synthesis chemical reaction



ISBN 978-1-108-61069-8 Cambridge University Press

Try this 6.5

The Hulk's hand

You are probably familiar with the Hulk and know that he has large hands when he takes on his green form. You are going to make the Hulk's hand using a chemical reaction! Put on safety glasses and move over to the sink, as this can get messy. Take a disposable latex glove (preferably green) and, working with a partner, place 10 g of sodium bicarbonate into the thumb of the glove. Then pour 50 mL of vinegar into the three fingers of the glove furthest from the thumb. Carefully seal the wrist of the glove, ensuring the different fingers don't mix. When you are ready, shake the glove and watch what happens. Can you guess what is being synthesised in this chemical reaction? What are the signs that this is a chemical reaction and chemical changes are occurring?

Figure 6.31 You too can have a hand like the Hulk's.

Decomposition

Reactions where one substance (reactant) breaks up into smaller ones (products) is called a decomposition reaction. Some compounds break down when heated – in this case, the reaction is called **thermal decomposition**. Decomposition reactions are essentially the opposite of synthesis reactions and can be represented in this way:

thermal decomposition decomposition that occurs when a substance is heated

$$AB \rightarrow A + B$$

where AB is the reactant and A and B are the products.

Figure 6.32 The foaming and spraying that occurs when you open a can of soft drink is an example of a decomposition chemical reaction.

For example, carbonic acid (H_2CO_3) is an ingredient in soft drinks. When you open a can of soft drink, a decomposition reaction takes place.

Word equation:

carbonic acid → water + carbon dioxide

Chemical equation:

$$H_2CO_3 \rightarrow H_2O + CO_2$$

ISBN 978-1-108-61069-8

Try this 6.6

Thermal decomposition

Many metal carbonates can take part in thermal decomposition reactions. For example, copper carbonate breaks down easily when it is heated:

Word equation: copper carbonate → copper oxide + carbon dioxide

Chemical equation: $CuCO_3 \rightarrow CuO + CO_2$

Your teacher may demonstrate this. Wearing safety glasses, add two spatulas of copper carbonate to a test tube. Then, using tongs, gently heat the base of the test tube. Make sure the mouth of the test tube is pointing towards a wall. You may like to hold a flame or a lit match over the mouth of the test tube. What do you observe? What evidence is there of a chemical change? What happened to the flame? What gas was produced?

Calcium carbonate ($CaCO_3$) behaves in the same way. Can you write both a word equation and a chemical equation?

Did you know? 6.3

Airbags use a decomposition chemical reaction

We all know airbags are essential in cars for safety reasons, but how do they work? Airbags are not inflated from some gas source but rather from the products of a decomposition chemical reaction. The chemical responsible for the airbag reaction is called sodium azide, NaN_3. An electronic sensor in the car detects a sudden change of speed and/or direction of the car, and sends a signal to an ignitor, which provides heat. This causes the sodium azide to break down rapidly into sodium and nitrogen gas, and it is this gas that causes the airbags to inflate. Amazingly, a handful of sodium azide will produce 67 litres of nitrogen gas! What is even more amazing is that from the time the sensor detects the collision to the time the airbag is fully inflated is only 0.03 second!

It is important to know that the sodium produced from the decomposition is dangerous, and so manufacturers of airbags must add other chemicals into the mix so that the sodium quickly binds with something else to make it less dangerous.

Figure 6.33 Deflated airbags after an accident. Airbags inflate because of a decomposition chemical reaction.

Quick check 6.9

1 Name the four different types of chemical reactions.
2 Explain how you would identify that a chemical reaction was a synthesis reaction.
3 Explain how you would identify that a chemical reaction was a decomposition reaction.

ISBN 978-1-108-61069-8 Cambridge University Press

Precipitation

Chemical reactions that involve the mixing of two clear solutions to produce a solid are called **precipitation** reactions. This is because the solid that is formed is a called a *precipitate*. These solids are insoluble, which means they are unable to dissolve in water. The beautiful news is that precipitates are often very colourful and some are even used as pigments in paint.

precipitation
a reaction that involves the mixing of two clear solutions to produce a solid called a precipitate

For example, when colourless lead nitrate and colourless potassium iodide are added together, a canary yellow precipitate forms (lead iodide).

Word equation:

lead nitrate + potassium iodide → lead iodide + potassium nitrate

Chemical equation:

$$Pb(NO_3)_2 + 2KI \rightarrow PbI_2 + 2KNO_3$$

Figure 6.34 When two clear solutions are mixed together and a solid forms, this a precipitation reaction.

Practical 6.5: Teacher demonstration

Precipitation reactions

Be careful
Ensure appropriate personal protective equipment is worn.

Aim

To demonstrate and observe how to mix two clear solutions in order to produce an insoluble, and often coloured, solid called a precipitate, and to name the precipitates formed.

Materials

- 0.1 M solutions of the following chemicals in dropper bottles: sodium carbonate, silver nitrate, lead nitrate, potassium iodide, sodium hydroxide and potassium chromate
- micro test tubes
- micro test tube rack
- safety glasses

Method

1. Place approximately 10 drops of silver nitrate in six micro test tubes standing in a rack.
2. Add 10 drops of lead nitrate to the first micro test tube containing silver nitrate.

continued...

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

3 Observe whether there is reaction and record your observations in the results table.
4 Repeat steps **2–3** with each of the other solutions in the top row of the results table.
5 Now test lead nitrate with each of the other solutions in the same way.
6 Name the precipitates that were formed. To do this, take the first name of the first solution and add it to the last name of the second solution. For example,

Lead nitrate and potassium iodide react to form lead iodide (the product).

Follow this rule for the rest of the precipitates formed in this experiment.

Results

Draw up a table like the one shown here, to record the results of mixing two clear solutions to produce a precipitate.

Chemical	Silver nitrate	Lead nitrate	Copper sulphate	Potassium iodide	Sodium carbonate	Sodium hydroxide	Potassium chromate
Silver nitrate							
Lead nitrate				Yellow precipitate			
Copper sulfate							
Potassium iodide		Yellow precipitate					
Sodium carbonate							
Sodium hydroxide							
Potassium chromate							

Evaluation

1 Define the terms 'chemical change' and 'precipitate'.
2 What observations did you make that suggest a chemical change has taken place?
3 Write word equations for each of the pairs of solutions that reacted to form a precipitate.
4 Challenge: Use formulas to write a chemical equation for each of the pairs of solutions that reacted to form a precipitate.
5 Suggest some possible faults in the experimental method used and how these would be resolved if the experiment were to be carried out again.

Conclusion

1 What claim can be made from this experiment regarding precipitate formation? Begin your sentence with: 'This experiment suggests that … '.
2 What evidence did you gather? Begin your brief summary with: 'The results show that … '.
3 Explain how the data supports your claim. How did you know a precipitate had been formed and how did you name them? Begin your sentence with: 'This means that … '.

ISBN 978-1-108-61069-8

Cambridge University Press

Combustion

Chemical reactions that involve the burning or exploding of something are called **combustion** reactions. In this case, there is a substance that reacts with oxygen, a chemical reaction occurs, and heat and light are released.

combustion
a reaction that involves the burning or exploding of a substance, usually in the presence of oxygen

For example, methane is the gas that comes out of your school Bunsen burner. It reacts with oxygen to produce carbon dioxide, water, light and heat.

Word equation:
methane + oxygen → carbon dioxide + water

Chemical equation:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2\,H_2O$$

Another example is octane, the fuel you use to power your family car. It reacts with oxygen to produce carbon dioxide, water, light and heat.

Word equation:
octane + oxygen → carbon dioxide + water

Chemical equation:

$$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$$

Figure 6.35 A lit Bunsen burner is an example of a combustion reaction.

Practical 6.6: Teacher demonstration

Sugar snake

Aim

To investigate a combustion reaction

Materials

- fumehood or well-ventilated area (outdoors recommended)
- teaspoons
- aluminium pie tin
- sand
- mixing bowl
- lighter fluid (or isopropyl alcohol)
- matches
- powdered sugar
- baking soda

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Method

1 In a bowl, combine 4 teaspoons of powdered sugar with 1 teaspoon of baking soda.
2 Fill the pie tin with sand and create a small mound in the centre. Then use your hand to make an indent in the middle of the mound.
3 Pour lighter fluid on the mound and in the indentation. Make sure the sand is well soaked.
4 Spoon the sugar and baking soda mixture into the centre of the mound.
5 Carefully light the sand near the sugar mixture.

Results

Take photos of each stage of the method and record the chemical reaction using a phone or video camera.

Evaluation

1 Define the terms 'chemical change' and 'combustion'. What evidence do you see that a chemical change has occurred?
2 What ingredient do you think is undergoing combustion? What gas is being made?
3 Can you explain why the snake goes black? Why does it keep growing?
4 Explain the purpose of the sand.
5 Why is it recommended that this experiment is done wearing safety glasses, in a well-ventilated area or fumehood?

Conclusion

1 What claim can be made from this experiment regarding the types of reactions that have occurred? Begin your sentence with: 'This experiment suggests that … '.
2 What evidence did you gather? Begin your brief summary with: 'The results show that … '.
3 Explain how the data supports your claim. How did you know that certain types of reactions had occurred? Begin your sentence with: 'This means that … '.

Quick check 6.10

1 Explain how you would identify that a chemical reaction was a precipitation reaction.
2 Explain how you would identify that a chemical reaction was a combustion reaction.

Exothermic and endothermic reactions

Another way of categorising or describing chemical reactions is by identifying whether they use or produce heat energy.

Exothermic reactions

exothermic describes a chemical reaction in which heat or another form of energy is released

Combustion, the chemical reaction where something burns in the air to produce heat and light, is said to be **exothermic**.

'Exo' means 'releases' and 'thermic' means 'heat', and so exothermic is a way of describing chemical reactions where heat is released. In fact, when chemists use the term 'exothermic', they are referring to the release of any form of energy as a consequence of a chemical reaction, so this could be heat, light or sound and so on.

VIDEO Exothermic and endothermic chemical reactions

Remember the glow sticks you investigated in Section 6.2? You learned that they work because when you break the inner glass layer, the solution inside the glass mixes with the chemicals around it, causing a chemical reaction. It is an exothermic reaction, because the fluorescent dye gives off light, a form of energy.

Another example of an exothermic reaction is when you light a sparkler.

ISBN 978-1-108-61069-8

Cambridge University Press

A sparkler consists of a chemical mixture that is moulded onto a rigid wire. When you light it, a chemical reaction occurs and the result is heat, light and sound being released.

Figure 6.36 Sparklers burning are an example of an exothermic reaction.

Practical 6.7: Teacher demonstration

Elephant's toothpaste

Aim

To observe the evidence that shows the decomposition of hydrogen peroxide is an exothermic reaction

Materials

- empty 500 mL plastic soft drink bottle
- ½ cup hydrogen peroxide (6% for a big reaction or 3% for a smaller reaction)
- 1 packet of dried yeast
- warm water
- dishwashing detergent
- dishwashing gloves
- cup
- food colouring
- funnel
- large plastic tray

Method

1. Pour the peroxide into the bottle using a funnel.
2. Add a large squirt of detergent to the bottle and swirl to mix.
3. Add some food colouring.
4. In the cup, mix about 4 tablespoons of warm water and the dry yeast, and stir to combine.
5. Pour the yeast into the bottle with the peroxide using a funnel. Quickly stand back and observe what happens. Record your observations.

Results

1. Take photos of each stage of the method, and record the chemical reaction using a phone or video camera.
2. Once the reaction is complete, touch the foam and the edge of the bottle, and record your observations of the temperature.

Evaluation

1. Define the terms 'chemical change' and 'exothermic'.
2. What evidence was there that a chemical change had occurred?
3. How do you think the foam was formed? Why do you think it is called 'elephant's toothpaste'?
4. How was the heat made?
5. Write a word equation for the decomposition of hydrogen peroxide (H_2O_2).
6. Write the chemical equation for the decomposition of hydrogen peroxide.
7. Investigate yeast and find out why it is included as an ingredient in this reaction.

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Conclusion

1 What claim can be made from this experiment regarding what type of reaction the decomposition of hydrogen peroxide is? Begin your sentence with: 'This experiment suggests that … '.
2 What evidence did you gather? Begin your brief summary with: 'The results show that … ' and remember to include possible faults in the experimental method.
3 Explain how the data supports your claim. Begin your sentence with: 'This means that … '.

Explore! 6.3

Keeping warm

Portable hand warmers are used in many different situations. How do they work? It must be an exothermic reaction, as heat is the energy released from the reaction. But what are the substances needed to make this happen?

1 Investigate the chemical reaction involved in disposable portable hand warmers. Record what you find out by writing a word equation and a chemical equation.
2 How are disposable and reusable hand warmers different? Explain in terms of the substances involved and the chemical reactions that occur.

Figure 6.37 How do portable hand warmers work?

Endothermic reactions

endothermic describes a chemical reaction in which energy is absorbed from the surroundings

An **endothermic** reaction is a reaction that needs some type of energy to make it start. 'Endo' means 'within' and 'thermic' means heat, and so 'endothermic' is a way of describing chemical reactions in which energy is absorbed from the surroundings.

Many of the reactions that occur in cooking are endothermic, because you have to supply heat to make them proceed. Examples are cooking an egg and baking bread.

Try this 6.7

How low can you go?

Your task is to achieve the lowest temperature by adding powdered citric acid, bicarbonate powder and water, in different amounts. You may like to draw up a table like the one shown here and begin with the suggested amounts. Record the temperature and then begin mixing.

Amount of citric acid (spatula)	Amount of bicarb soda (spatula)	Amount of water (mL)	Temperature (°C)
1	2	2	

Table 6.2 Mix the chemicals in different amounts to get the lowest possible temperature.

Explore! 6.4

Keeping cool

Portable ice packs are used in many different situations. How do they work? It must be an endothermic process, as there is no energy released. In fact, energy is needed to start this process, but what are the other substances needed to make this happen?

1 Investigate the chemical process involved in ice packs. Record what you find out by writing a word equation and a chemical equation.
2 Find out why athletes use ice packs when they are injured. Explain how the ice packs help.

Figure 6.38 An ice pack uses an endothermic chemical process to help athletes treat an injury. This process is not a chemical reaction, as no new substance is formed.

ISBN 978-1-108-61069-8

Photosynthesis is endothermic and respiration is exothermic

Photosynthesis is the process that green plants use to make a sugar, called glucose. They use the Sun's light energy, water from the soil, and carbon dioxide from the air, to make the glucose. They also produce oxygen during this process, which is great for us! Because energy from the Sun is absorbed during photosynthesis, this chemical reaction is considered to be endothermic.

Respiration is a chemical reaction that plants and animals use to burn up the sugar glucose, to make energy. This energy is used for growth and repair, movement and keeping warm. Because respiration produces energy, this chemical reaction is considered to be exothermic. Now you know why you feel so hot after running to catch the tram – your muscles create heat as they move, because respiration is happening faster to provide you with the energy to move quickly.

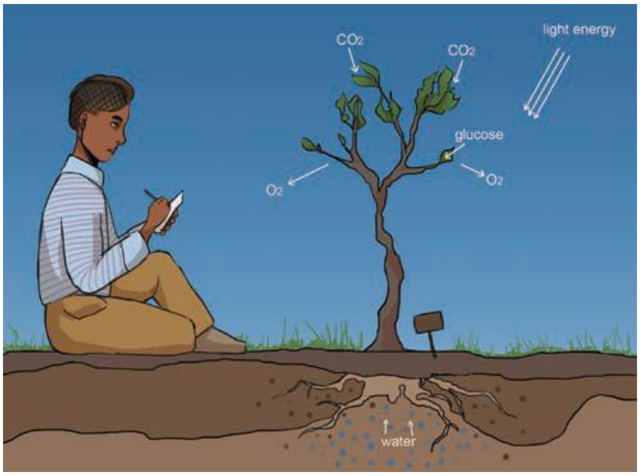


Figure 6.39 Photosynthesis is an endothermic reaction, as energy from the Sun is absorbed by the plant.

Figure 6.40 Respiration produces energy and this can make you feel hot when exercising, because of the exothermic chemical reaction occurring in your cells.

Quick check 6.11

1 Define the terms 'exothermic reaction' and 'endothermic reaction'. Include examples.
2 Decide which of these processes are exothermic and which are endothermic.
  a When two compounds are mixed, the temperature increases.
  b Plants take in the Sun's energy for photosynthesis.
  c A solid burns brightly and releases heat, light and sound.
  d When two substances in an ice pack are mixed, their temperature drops.
  e Two chemicals will only undergo a chemical reaction if you heat them continually.

ISBN 978-1-108-61069-8

Cambridge University Press

QUIZ

Section 6.3 questions

Remembering

1 What are the characteristics of a precipitation reaction?
2 What are the products of a typical combustion reaction?
3 What are the reactants and products of respiration and photosynthesis?
4 Define the term 'precipitate'.

Understanding

5 Explain what gas is necessary for a combustion reaction.
6 Explain the following:
  a how a synthesis reaction is different than a decomposition reaction
  b how you could tell whether a precipitation reaction is occurring
  c what is some evidence you would look for when an endothermic reaction is occurring.
7 Demonstrate how a reaction might fit into more than one category. Use an example.

Applying

8 Summarise the four types of reactions in a table like the one below.

Reaction type	Definition	Example

9 Write word equations for each of the following reactions.
  a Hydrogen gas and oxygen gas explode to form water.
  b When fruit ripens, fructose (a sugar) is formed from starch and water.
  c Solid iron is combined with sulfur and forms iron sulfide.
10 Identify the reactants and products in the following reactions.
  a $2Mg + O_2 \rightarrow 2MgO + heat$
  b In fermentation, sugar decomposes to form ethanol + carbon dioxide + energy.
11 A chemical reaction occurs between two clear solutions: baking soda and calcium chloride. Calcium carbonate is the solid that forms, along with sodium chloride and carbon dioxide dissolved in water. Chemical equation: $2NaHCO_3 + CaCl_2 \rightarrow CaCO_3 + 2NaCl + CO_2 + H_2O$
  a Write the word equation for this reaction.
  b Identify the reactants and the products in the reaction.
  c Identify the type of reaction.

Analysing

12 Label each of the following reactions as synthesis, decomposition, precipitation or combustion.
  a $A + B \rightarrow C$
  b methane + oxygen → carbon dioxide and water
  c $Fe + S \rightarrow FeS$
  d $C_6H_{12}O_6 \rightarrow C + H_2O$
  e $2Mg + O_2 \rightarrow 2MgO + heat$
  f carbon dioxide → carbon + oxygen
  g sodium chloride + silver nitrate → silver chloride $_{(solid)}$ + sodium nitrate
13 Distinguish between exothermic and endothermic reactions. Include examples.

Evaluating

14 You and your partner are carrying out a chemical reaction in class and observe that condensation appears on the inside of the test tube. Is this evidence of a physical change or a chemical change? Has heat energy been absorbed or released? Give reasons for each of your answers.
15 Respiration is considered to be a combustion reaction. Give reasons why this is the case.

ISBN 978-1-108-61069-8

Cambridge University Press

Review questions

SCORCHER

Remembering

1 Define the following key terms: physical property, chemical property, physical change, chemical change, reactant, product.

2 List the possible evidence that a physical change has occurred.

3 Name the products released when a typical combustion reaction occurs.

4 State whether each of the following processes is a physical or chemical change.

- a moth balls evaporating in a cupboard
- b building a sand castle
- c hydrogen burning in chlorine gas
- d fogging up a mirror by breathing on it
- e breaking a bone
- f a broken bone mending
- g slicing potatoes for making chips
- h hand sanitiser evaporating
- i mixing sugar with coffee
- j making a paper aeroplane
- k pan frying dumplings
- l copper turning green when exposed to the air
- m paper ripping

5 For each of the following statements, write T for true or F for false. Rewrite the false statements so they are true.

- a Synthesis reactions are when two (or more) elements or reactants combine to form one new substance or product.
- b Precipitation reactions involve the creation of a colourful and soluble solid that can settle.
- c Decomposition reactions are those in which several reactants break up into even smaller products.
- d Combustion occurs anytime there is oxygen.

Understanding

6 a Explain why baking cookies is not an example of physical change.
  b Explain why bending metal in half is not an example of chemical change.

7 Summarise the observations you could make if a chemical change had occurred.

8 What is the only real proof that a chemical reaction has occurred?

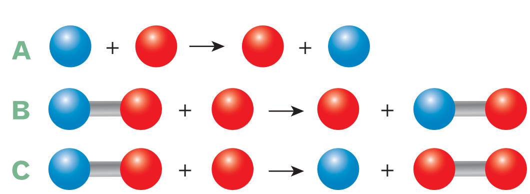
9 When Tori reacts a lump of calcium carbonate with sulfuric acid, she sees water, carbon dioxide and calcium sulfate form.

- a Write a word equation representing the information given.
- b Outline the reactants and the products, and how you know.

10 Write the following as word equations.

- a Dean mixed together eggs, flour and milk. He then heated the mixture and *ta daa*! Delicious pikelets!
- b Suzi dropped a chunk of magnesium into a test tube containing hydrochloric acid, and magnesium chloride was formed. She also noticed a gas forming and when she held a glowing splint nearby, it went *pop*, just like hydrogen gas does when it burns.

11 Which of the following are examples of chemical reactions?



ISBN 978-1-108-61069-8

Cambridge University Press

Applying

12 Photosynthesis is a process that green plants use to make the sugar glucose. It is this sugar that we need to consume to survive. Summarise the reactants and products of photosynthesis, and where plants get the reactants from.

13 Explain why a colour change occurring is not always a sign that a chemical change has occurred.

14 Use word equations to demonstrate why some people say respiration and photosynthesis are the opposite of each other.

15 Write word equations for the following chemical reactions.

- **a** Maisie used some nitric acid from science class to mix with iron oxide and produce iron nitrate and some water.
- **b** Edward put some copper scraps with some sulfur powder in a test tube and heated it over a Bunsen burner. At the end of the reaction, he observed a greenish colour on the copper – a sulfide.

Analysing

16 Contrast endothermic and exothermic reactions.

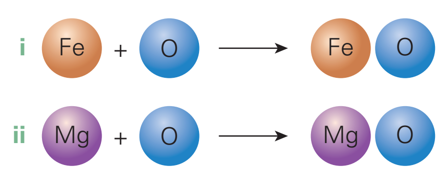
17 Can atoms that are not in the reactants end up in the products of a chemical reaction? Why or why not?

18 Barium sulfate, $BaSO_4$, is used in medical imaging of the gastrointestinal tract, because it absorbs X-rays and can show up in an imaging scan. It is formed when the two clear solutions, barium chloride and sodium sulfate, react together. Sodium chloride is also formed.

- **a** List the reactants of this chemical reaction.
- **b** List the products of this reaction.
- **c** Barium sulfate is a solid produced during this chemical reaction. What type of chemical reaction is this an example of?
- **d** What evidence do you have that your answer to part **c** is correct?

19 When a substance burns, it reacts with a gas in the air and forms an oxide.

- **a** What is the name of this gas?
- **b** What type of chemical reaction is this?
- **c** Write word equations for the two examples shown at right. You will need to refer to a periodic table to determine the names of the elements involved.



Evaluating

20 **a** When you combine bicarb soda and buttermilk, a gas is produced. Why is the gas considered evidence that a chemical reaction occurred?

- **b** Can you continue to add more and more of one reactant and expect to get more and more product? Give reasons why or why not.

21 Determine whether each of the particle diagrams below indicates a chemical or physical change. Justify your answer.

a

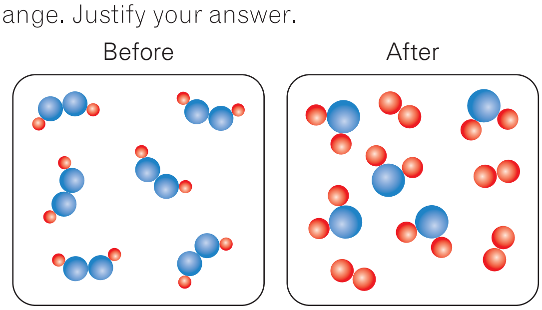


Figure 6.41

b

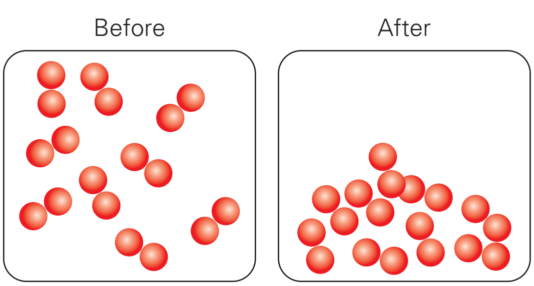


Figure 6.42

ISBN 978-1-108-61069-8

Cambridge University Press

STEM activity: Building a rocket

Background information

VCSSU098 VCMNA283 VCMNA285 VCDSTC048 VCDSCD050 VCDSCD052 VCSIS108 VCSIS109 VCSIS110 VCSIS111 VCSIS112

Rockets are exciting machines that are designed by engineers and used to explore space. It is amazing to think that someone has worked out how to get these heavy vehicles into space! Rockets depend on a combustion reaction to provide the thrust they need to overcome the force of gravity and shoot up into orbit. Combustion is a fast, exothermic reaction between a fuel and oxygen, in which the fuel burns and heat is produced. As you know, during a chemical reaction, new compounds are made – in this case, these compounds are the rocket's exhaust. The exhaust is pushed out from the bottom of the rocket at high pressure, and this pushes the rocket upward.

In a process known as the engineering design cycle, aerospace engineers design small-scale models to learn from and experiment with. By testing small-scale models, the engineers make sure the rockets will work, without wasting time and money on testing full-size rockets. They can test the thrust and stability and make modifications, in order to design the best rocket they can.

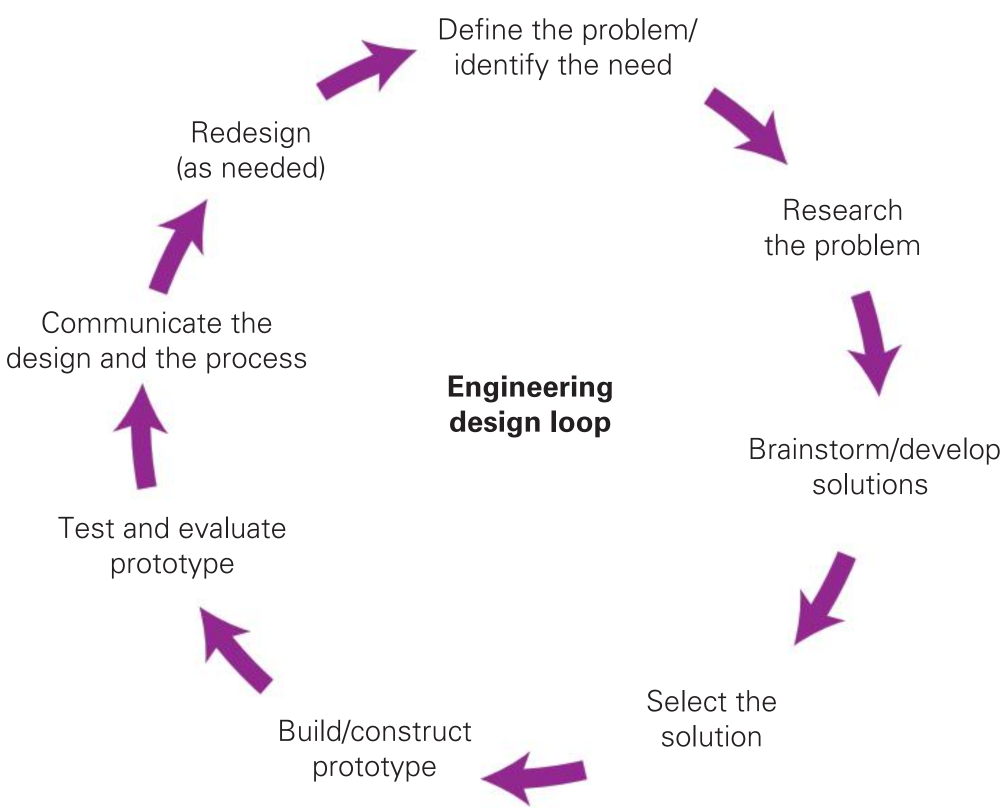


Figure 6.43 Designing and testing of a model comes before construction of the real thing.

ISBN 978-1-108-61069-8

Figure 6.44 Space launch

Design brief: Design, build, test and evaluate a rocket that will launch in exactly 10 seconds.

Activity instructions

In teams, you will take on the role of aerospace engineers. The Super Fast Rocket Company has hired your team to design, build, test and evaluate a rocket that will launch in exactly 10 seconds. You will begin investigating the chemical change that occurs when half an antacid tablet (containing stored chemical energy) and water are put into a film canister. With the lid snapped on, the production of carbon dioxide gas inside the canister causes pressure to build up until the lid pops off, propelling the rocket into the air.

To launch your rocket at exactly 10 seconds, your team will need to consider what factors affect the rate or speed of the chemical change that occurs. For example, you will need to investigate whether it is affected by the temperature of the water, the surface area of the tablet, the mass of the tablet, or other factors. Your team will continue to evaluate and refine your prototype until it launches at exactly 10 seconds.

Suggested materials

- 35 mm film canister with an internal snapping lid
- an antacid tablet, such as Alka-Seltzer®
- water
- scissors, sticky tape, textas, paper
- chopping board, mortar and pestle, knife, spoon
- safety glasses

Evaluate and modify

1. Use Microsoft Excel or other graphing tools (such as Desmos) to graph your data. For example, create a scatter plot of mass (x-axis) versus time to launch (y-axis), or temperature versus time to launch. Identify a line of best fit and determine the equation for the line of best fit.
2. Discuss the different conditions you investigated and what you found out about the effect of temperature, surface area and mass on the rocket launch times.
3. Draw a flow chart to show your original design for a 10-second launch and the modifications that followed, ending with your rocket launching at exactly 10 seconds. Highlight the change/improvement you made at each step along the way.
4. Consider both your rocket and the other rockets you observed being launched. Identify and describe the characteristics that make one rocket perform better than another.
5. Discuss what challenges you faced while designing and testing your rocket, and how you overcame these challenges.

ISBN 978-1-108-61069-8

Cambridge University Press

Chapter 7 Rocks

Chapter introduction

In this chapter, you will learn about the Earth's crust and the rocks it is formed from. You will learn about the three types of rock – igneous, metamorphic and sedimentary – and how rocks can change from one form to another, according to the rock cycle. You will also learn about the mining industry and how resources contained in the rocks are extracted to make useful materials, such as metals for technology, and glass and cement for building.

Curriculum

Sedimentary, igneous and metamorphic rocks contain minerals and are formed by processes that occur within Earth over a variety of timescales (VCSSU102)	
• recognising that rocks are a collection of different minerals	7.1
• considering the role of forces and energy in the formation of different types of rocks and minerals	7.1, 7.2
• identifying a range of common rock types using keys based on observable physical and chemical properties	7.1, 7.2, 7.3

Victorian Curriculum F–10 © VCAA (2016)

ISBN 978-1-108-61069-8

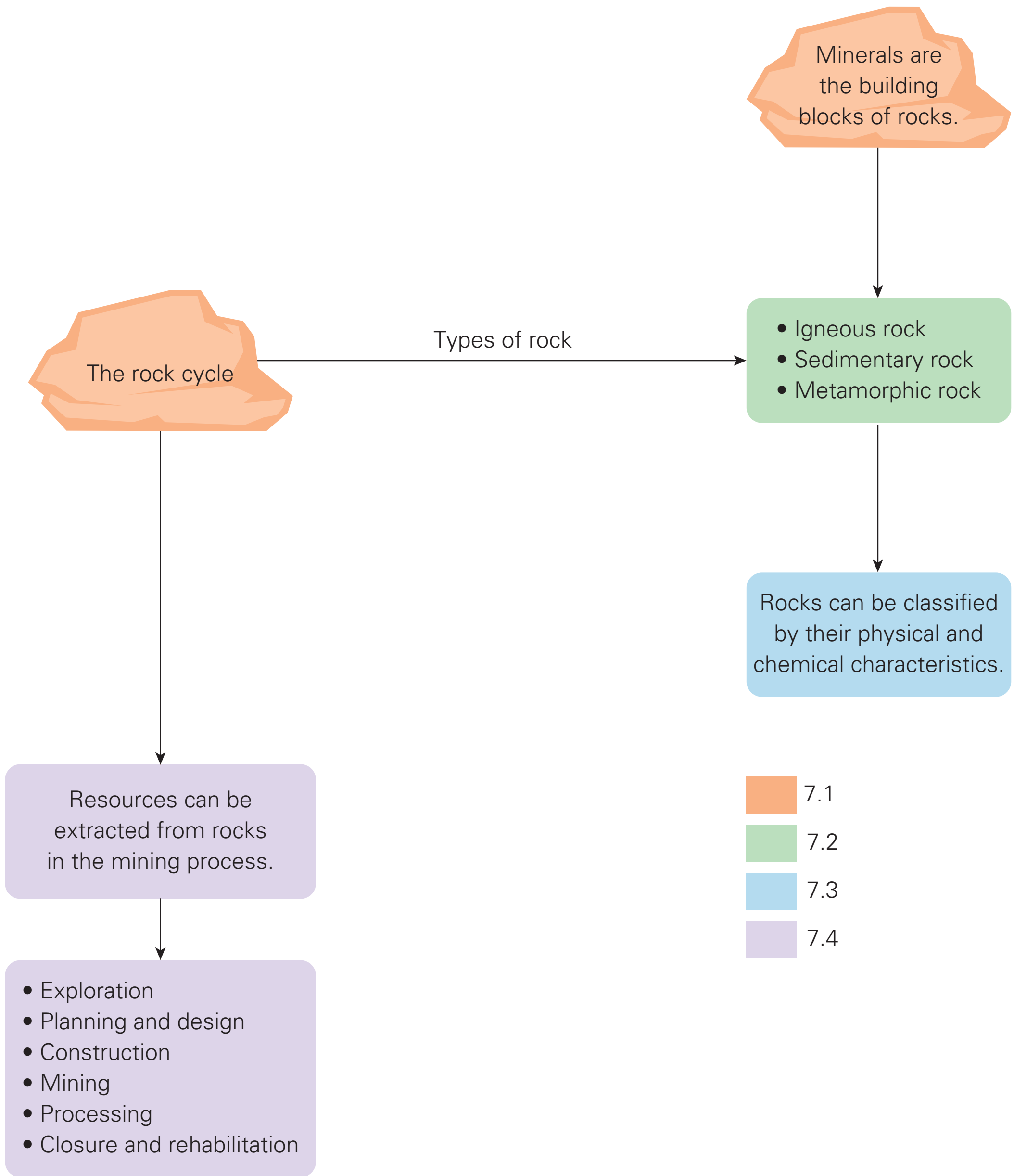
Glossary terms

- biological weathering
- breccia
- cementation
- central core
- chemical weathering
- cleavage
- compaction
- conglomerate
- crust
- crystal
- deep time
- deposition
- electrolysis
- erosion
- extrusive
- fossil
- geology
- igneous
- intrusive
- karst
- lava
- lithosphere
- magma
- mantle
- metamorphic
- meteorite
- mineral
- Mohs scale
- opaque
- ore
- outer core
- physical weathering
- radioactivity
- rock
- rock cycle
- sedimentary
- sediments
- seismology
- smelting
- streak test
- surface mining
- translucent
- transparent
- underground mining

ISBN 978-1-108-61069-8

Cambridge University Press

Concept map



ISBN 978-1-108-61069-8 Cambridge University Press

7.1 Rock formation

Rocks and minerals

rock
solid material forming the Earth's crust; rocks are formed as part of the rock cycle

mineral
a valuable or useful chemical substance that is formed naturally in the ground

igneous
describes rocks made from lava on the surface or magma below the surface

sedimentary
describes rocks made from deposited materials that are the products of weathering and erosion

metamorphic
describes rocks that are changed by being exposed to high temperature, pressure or both

Rocks are a naturally occurring substance made up of one or more **minerals**. Minerals are considered to be the building blocks of rocks, and each mineral has a specific chemical structure. Rocks can be:

- **igneous** – formed from molten rock
- **sedimentary** – formed from the products of erosion
- **metamorphic** – altered by heat and pressure.

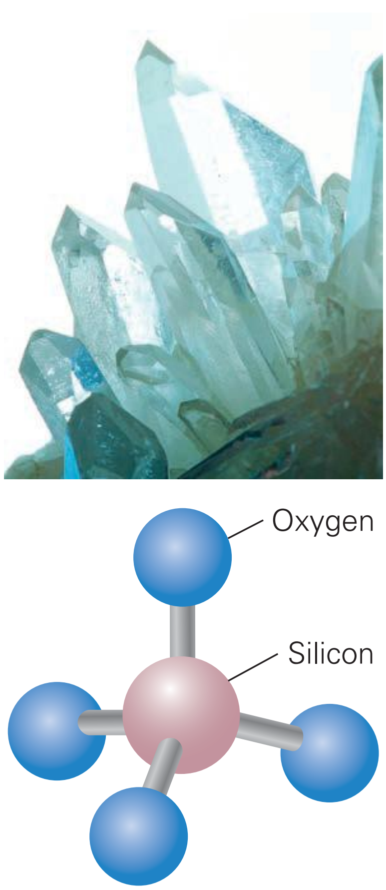


Figure 7.1 Quartz (shown at top) is a mineral made of silicon and oxygen atoms arranged in a continuous framework.

A mineralogist is a person who studies minerals. It is a difficult job, because there are over 5000 minerals to study. Some minerals are found in the form of **crystals** and this can be an easy way to identify them.

WORKSHEET

crystal
a mineral in which the atoms are arranged in an ordered way to form a geometric shape

Figure 7.2 Red granite is an igneous rock consisting of two minerals. The large crystal size in the rock indicates that the rock cooled slowly, probably underground.

Did you know? 7.1

Minerals include gemstones that are used in jewellery. Most gemstones are brightly coloured or transparent crystals. Diamond, for example, is a crystal made from carbon. Carbon is the same chemical element that is in graphite, which is used to make pencil leads.

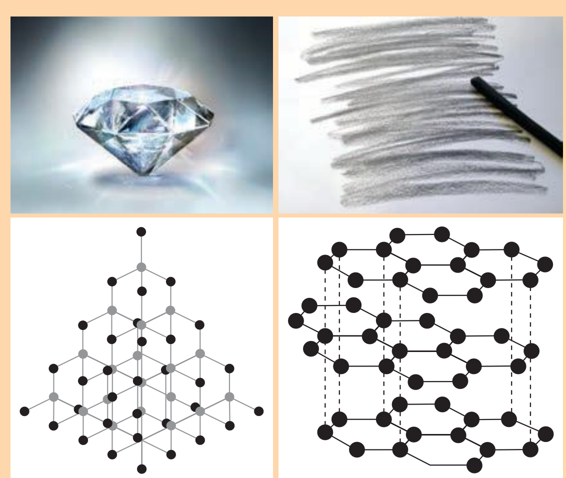


Figure 7.3 Diamond (shown at left) and graphite (shown at right) are both made of carbon atoms. However, the arrangement of the atoms makes a big difference to their properties.

ISBN 978-1-108-61069-8 Cambridge University Press

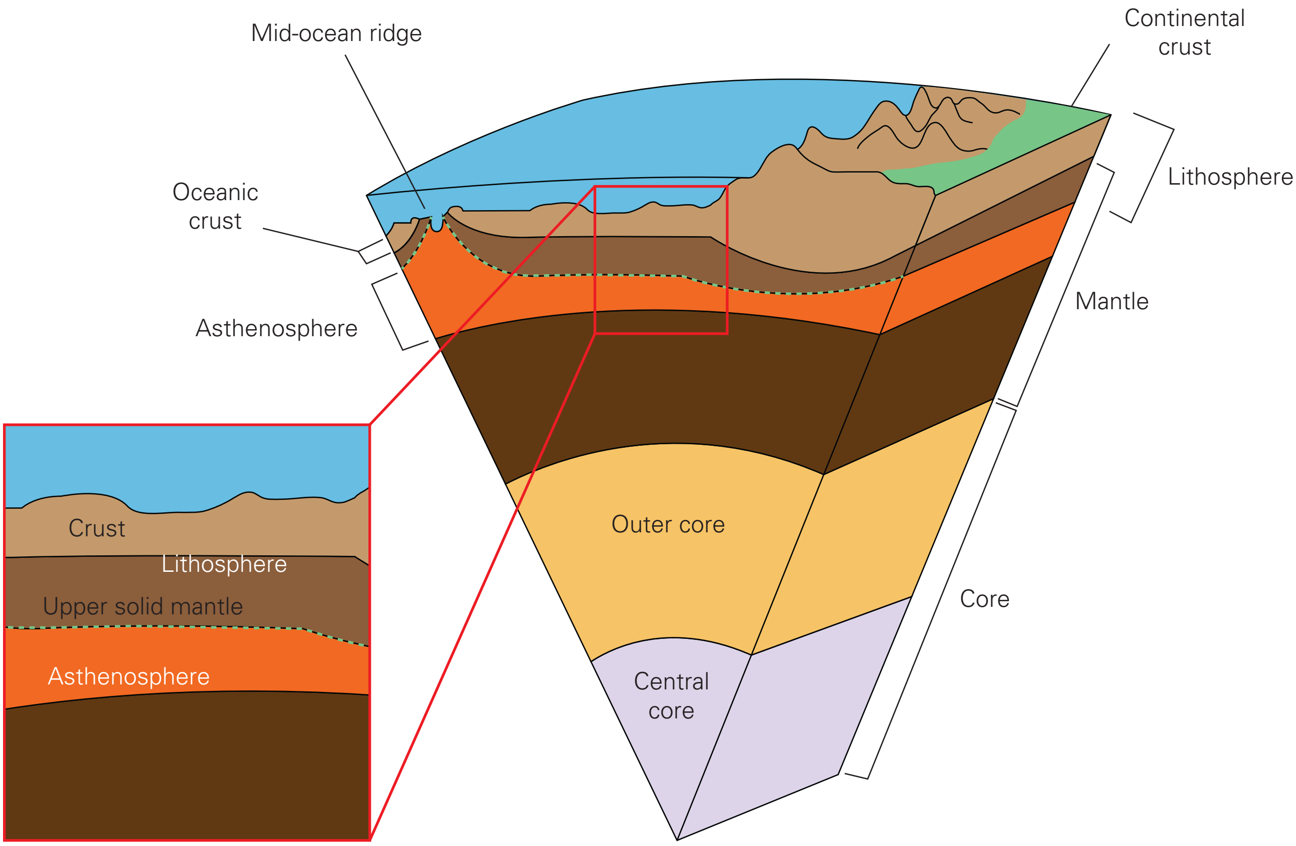


Figure 7.4 The Earth is composed of several layers.

Rocks and the Earth

central core
the solid centre of the Earth, probably made of iron

outer core
the liquid layer surrounding the central core, also probably made of iron

mantle
the layer of solid and semi-molten rock that surrounds the outer core and extends up to the Earth's crust

crust
the solid outer layer of the Earth; continental crust is on average 50 km thick and the average thickness of oceanic crust is 20 km

lithosphere
the solid outer layer of the Earth; includes the crust and uppermost mantle

The **central core** of the Earth is currently thought to be mostly solid iron, while the **outer core** is made of liquid iron and nickel. Surrounding the outer core is the **mantle**, comprising mostly solid and semi-molten rock. Earth's outer layer is the solid **crust**. Rocks are formed and reformed in the **lithosphere**, which includes the crust and the uppermost mantle.

The Earth's mass is predominantly made up of iron, then oxygen, silicon and magnesium. Small amounts of all the other elements can also be found. This is what makes geology (the study of the rocks and similar substances that make up the Earth's surface) fascinating, as each type of rock contains different components and has different properties.

Element	% of Earth's mass
Iron	35
Oxygen	30
Silicon	15
Magnesium	13

Table 7.1 These four elements make up most of the Earth's mass.

Quick check 7.1

1. Define and distinguish between rocks and minerals.
2. Where are rocks formed in the Earth?
3. What elements make up most of the Earth's mass?

ISBN 978-1-108-61069-8

The rock cycle

The Moon has stayed unchanged for millions of years, but the **geology** of the Earth is very different. James Hutton, the father of modern geology, tried to explain why the surface of the Earth is so complex. He came up with two conclusions.

- The Earth is very old – Hutton called this **deep time**.
- The Earth's surface has been constantly changing throughout its history. The rock component changes constantly due to some key processes, which together are called the **rock cycle**.

Melting and cooling

As you can see in Figure 7.5, the melting of rock to form magma (molten rock), and then the cooling of that magma, result in the formation of igneous rock. The process of melting takes place beneath the Earth's crust at temperatures that can be as low as 500°C and as high as 1600°C. The process of cooling can happen below or above the Earth's surface. An interesting characteristic of igneous rocks is that the minerals in them may form crystals. This is because, when **magma** cools, crystallisation occurs. Below the Earth's surface, magma takes a long time to cool, and the crystals formed in it are large. Magma that reaches the Earth's surface is called **lava**. Because lava cools more quickly, the crystals formed are small and may even be microscopic. You will learn more about igneous rocks in the next section of this chapter.

geology
the study of the rocks that make up the surface of the Earth

deep time
the idea first suggested by James Hutton that the Earth is very old

rock cycle
the constant process of change that rocks go through, between igneous, metamorphic and sedimentary forms

magma
molten rock under the Earth's surface

lava
molten rock from inside the Earth (called magma) that has reached the surface

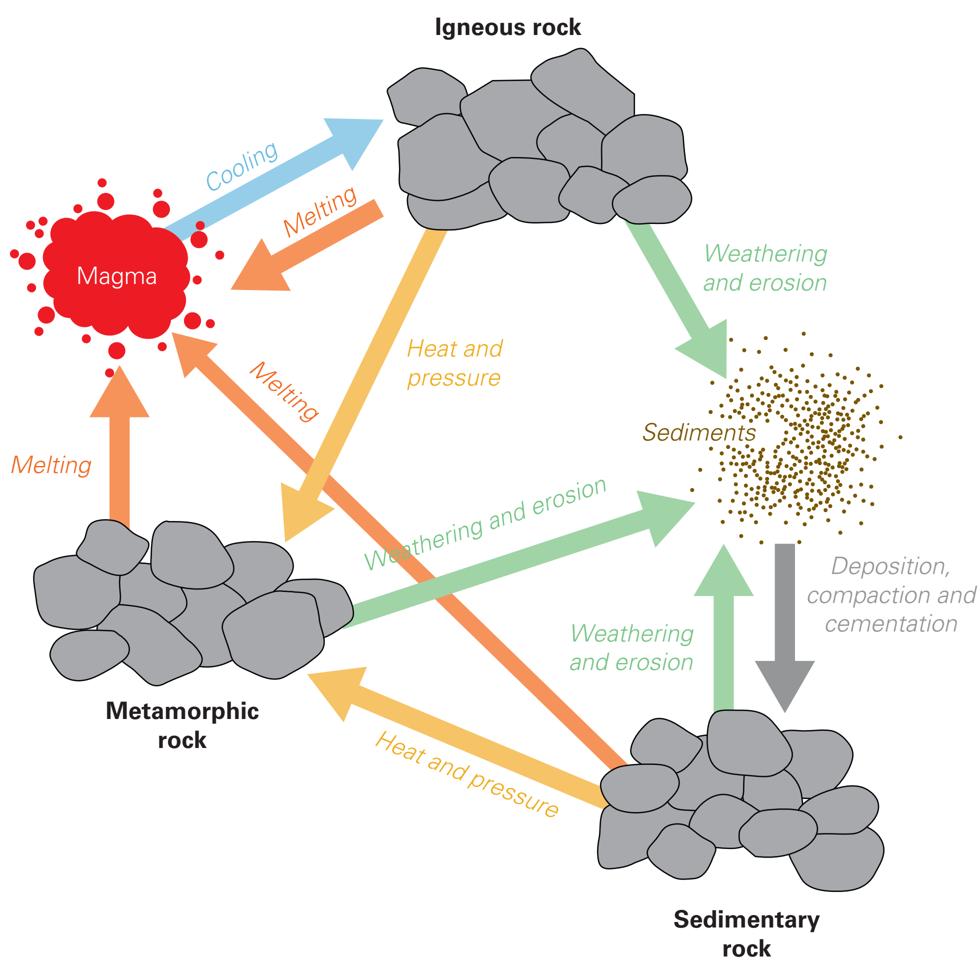


Figure 7.5 In the rock cycle, the three types of rock can change through the action of weathering and erosion, deposition, compaction and cementation, melting and cooling, heat and pressure.

ISBN 978-1-108-61069-8

Cambridge University Press

Did you know? 7.2

'Igneous' and 'ignite' come from the same Latin word, *ignis*, which means 'fire'. This is an easy way to remember that igneous rocks are formed from hot magma.

Figure 7.6 'Igneous' comes from a Latin word meaning 'fire'.

Explore! 7.1

What is a meteorite?

From time to time, rocks arrive on Earth from space, in the form of **meteorites** that land on the surface. Use your preferred search engine to answer the following questions.

meteorite
a rock from space (meteor) that has entered the atmosphere as a 'shooting star' and reached the ground

Figure 7.7 An iron meteorite that landed on Earth from space

1 What is the composition of meteorites?
2 How does a meteorite end up on Earth?
3 Propose whether or not meteorites pose a threat to life on Earth. Justify your argument using examples of meteorites that have landed on Earth, and their impact.

Try this 7.1

Making crystals

You will need the following materials:

- soluble crystals such as copper sulphate, sugar or salt
- beaker
- warm water
- two Petri dishes.

Figure 7.8 Copper sulphate crystals

Stir the crystals in the water until they dissolve. Keep adding crystals until no more can be dissolved – this will give you a concentrated solution. Filter the solution to remove any solids. Put the resulting liquid into two Petri dishes and place one in a hot sunny place and the other in a dark cupboard at room temperature. Leave for a few days. The water will evaporate and you should see crystals form. The liquid placed in direct sunlight will evaporate quickly, leading to small crystals being formed. The liquid placed in the cupboard will evaporate more slowly and the crystals should be larger. This same process takes place if a liquid solidifies to form crystals – the slower the rate at which it cools, the larger the crystals formed.

Use your observations to explain how melting and cooling form rocks. Draw on the similarities between this activity and the process of rock formation.

ISBN 978-1-108-61069-8 Cambridge University Press

Quick check 7.2

1 What are the three types of rocks formed in the rock cycle?
2 What roles do melting and cooling play in the rock cycle?

Weathering

Weathering occurs when exposed rocks are broken down – for example, by ocean waves hitting a cliff face. Weathering breaks up large rocks into small particles called **sediments**. It includes physical weathering, chemical weathering and biological weathering.

sediments
sand, stones, etc. that slowly form a layer of rock

physical weathering
the breaking down of rocks into smaller particles by contact with other rocks, wind, water or ice

Physical weathering is the breaking down of rocks into smaller particles by temperature, pressure or weather – for example, by extreme temperatures, high wind, snow, hail, rain and flooding. Ice is a very powerful agent in the weathering process, because of a process known as 'freeze–thaw action'. In this process, water enters a crack in a rock and freezes. As it freezes, it expands with great force and widens the crack. This can happen many times, widening the crack slowly until eventually the rock breaks apart.

Figure 7.9 A rock split in two by freeze–thaw action

Practical 7.1

Water breaks rock

Aim
To observe how freezing water can break rock

Materials
- milk carton
- ice-cream container
- balloon
- 1 cup of plaster of Paris
- water

Method
1 Fill the balloon with water until it is about 5 cm in diameter, and tie it off. Ensure it can sit in the milk carton with some space on the sides.
2 Place the plaster of Paris into the ice-cream container and mix while adding water, until it is the consistency of yoghurt.
3 Add some plaster to the milk carton until it is about 1 cm deep.
4 Hold the water-filled balloon just on top of the plaster so it is touching the surface.

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

5. Add more plaster until the balloon is just covered. Keep holding it in position until the plaster is firm enough for the balloon to be let go.
6. Stop holding the balloon and cover about 1 cm above the top of the balloon.
7. Wait for the plaster to set and take a picture of the surface you can see.
8. Place it in the freezer overnight. Think about what you predict will happen.
9. The next day, observe what has happened, and take another picture.

Results

Draw a diagram to represent the before and after pictures.

Evaluation

1. Describe your observations of the plaster before and after it was put in the freezer.
2. Deduce what you think happened overnight.

Conclusion

1. Make a claim regarding water and rocks. Start your sentence with: 'This experiment suggests that water … '.
2. Support your claim by using what you observed of the water and plaster. Start your sentence with: 'It was observed that … '.
3. Explain how the data supports your claim. Start your sentence with: 'This means that … '.

chemical weathering the disintegration of rocks caused by substances dissolving in water

Chemical weathering occurs when rocks are slowly dissolved by substances in rainwater. It is more effective on limestone and silicon compounds, as these are slightly soluble in water. Rainwater that seeps underground in a limestone area can slowly create vast underground caves over millions of years, as well as long underground rivers. Limestone caves often contain stalactites hanging from the roof and stalagmites on the ground; when these meet, they form columns. Limestone caves such as the Jenolan Caves (see Figure 7.10) are often developed as tourist attractions because of the beautiful limestone features they contain.

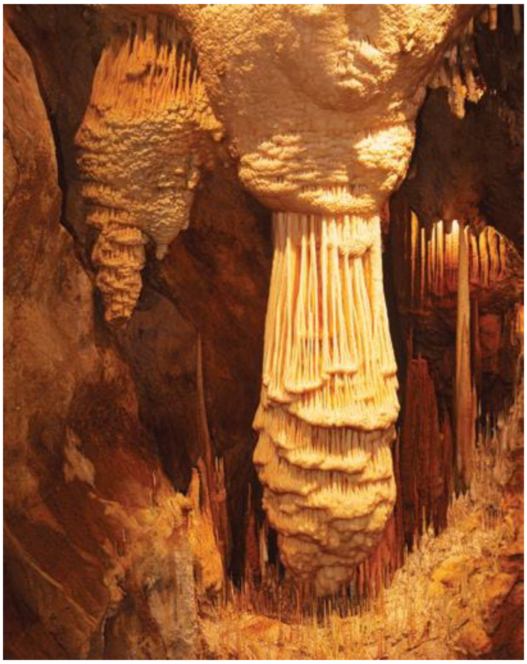


Figure 7.10 A pillar in the Jenolan Caves in New South Wales

karst an area of land formed of rock such as limestone that is worn away by water to make caves and other formations

When limestone contains underground rivers it can give a very characteristic landform called a **karst** landscape (see Figure 7.11), which has caves, sinkholes, limestone outcrops and dry valleys with no water because the river that formed them has gone underground. The Nullarbor Plain between South Australia and Western Australia is the world's largest karst landscape.

ISBN 978-1-108-61069-8 Cambridge University Press

Figure 7.11 The entrance to a cave in a typical karst landscape. Rainwater enters the cave and can travel underground for many kilometres.

Did you know? 7.3

A person who studies caves scientifically is called a 'speleologist', but a person who explores caves as a pastime is called a 'caver' or a 'spelunker'.

Figure 7.12 Cavers explore underground cave systems, looking for amazing rock formations like this.

ISBN 978-1-108-61069-8

Cambridge University Press

Science as a human endeavour 7.1

Saving limestone buildings

Researchers from the University of Iowa and Cardiff University have found that statues and buildings made of limestone can be protected from chemical weathering. A water-resistant coating can be applied in a thin, single layer, and this will protect the limestone from weathering. The coating contains fatty acids from olive oil and substances with fluorine additions.

Figure 7.13 This church in Pella, Victoria, was built of limestone from a nearby quarry.

Practical 7.2

Oxidation and salt

Rocks that are iron-rich are susceptible to oxidation, which is the formation of rust. Rocks in fresh water undergo oxidation at a different rate than those in a salt lake, because of the presence of salt.

Aim

To investigate the effect of salt on the oxidation process

Materials

- steel wool
- three plastic Petri dishes
- water
- salt
- beaker
- marker

Method

1. Label the Petri dishes 'Control', 'Fresh water' and 'Salt water'.
2. Cut three pieces of steel wool. Ensure all the pieces are the same size.
3. Place one piece of steel wool in each Petri dish.
4. Fill the beaker with water and submerge half of the 'Fresh water' steel wool in water.
5. Add water and salt to a beaker and submerge half of the 'Salt water' steel wool in salt water.
6. Observe the results after three days, and describe what happened, in the results table.

continued...

ISBN 978-1-108-61069-8

...continued

Results

Copy and complete the following table.

	Control	Fresh water	Salt water
Observation			

Evaluation

1 What is the purpose of the control dish?
2 Compare what happened in the fresh water and salt water dishes.

Conclusion

1 Make a claim regarding oxidation and salt water. Start your sentence with: 'This experiment suggests that salt water … '.
2 Support your claim by using what you observed about the steel wool. Start your sentence with: 'It was observed that … '
3 Explain how the data supports your claim. Start your sentence with: 'This means that … '.

biological weathering the disintegration of rocks by living things

Biological weathering occurs when rock is broken down into smaller particles by living things. For example, human feet can wear dips into the tops of stone steps (see Figure 7.14), plant roots grow into small cracks in rocks and make the cracks bigger, and people who do not stay on pathways in national parks damage the vegetation, which can eventually lead to erosion.

Figure 7.14 These steps have been 'weathered' by people walking on them. The particles of stone have been washed away or eroded by the rain.

Quick check 7.3

Distinguish between the three types of weathering: physical, chemical and biological.

Erosion

erosion the transport of rocks from one place to another as a result of weathering

Erosion occurs when rock that has been broken loose by weathering is transported or moved to a new location. It includes rocks or rock particles falling due to gravity, being carried away in the wind, or moved by waves, ocean currents, running water or even ice in a glacier.

Figure 7.15 The Twelve Apostles, off the shore of the Port Campbell National Park. These limestone stacks were formed on the seabed. Today the seabed has been raised and the limestone is being weathered and eroded by the ocean waves.

ISBN 978-1-108-61069-8 Cambridge University Press

The size of particle that can be carried is highly dependent on the way it is transported. Only small particles, such as sand, can be blown by the wind, but pebbles and even boulders can be transported in rivers and oceans. The size of particle that can be moved depends on the speed of the wind or water – for example, mud can be carried by slow-moving rivers, sand requires faster water, and stones and boulders can only be transported by a river in flood. Glaciers can carry giant boulders trapped in the ice, for many kilometres. They are also powerful weathering agents, because the ice leaves a smooth surface as it passes over the bedrock.

During the ice age, the world, including Australia, was very different. Large quantities of water were trapped in giant ice sheets that spread out from the poles and covered much of Europe and North America. Because of this, the sea level was much lower and it was possible to walk on land from Victoria to Tasmania and from Queensland to Papua New Guinea. Although neither Australia nor Tasmania was covered in an ice sheet, glaciers formed on Cradle Mountain in Tasmania and the surrounding areas. The landscape was transformed by the ice moving over the rocks, leaving a characteristic smooth surface.

Figure 7.16 Dove lake on Cradle Mountain in Tasmania. The smooth appearance of the rocks is due to the action of glaciers twenty thousand years ago.

The profile of Wave Rock in Western Australia (see Figure 7.17) demonstrates the erosive power of wind. Sand grains carried by wind have worn down this rock and carried away the debris. Initially it was chemical weathering (vegetation breaking down) that weakened the rock, and then the wind-borne sand started its work at the weakened lower levels of rock. Eventually a wave-like shape formed.

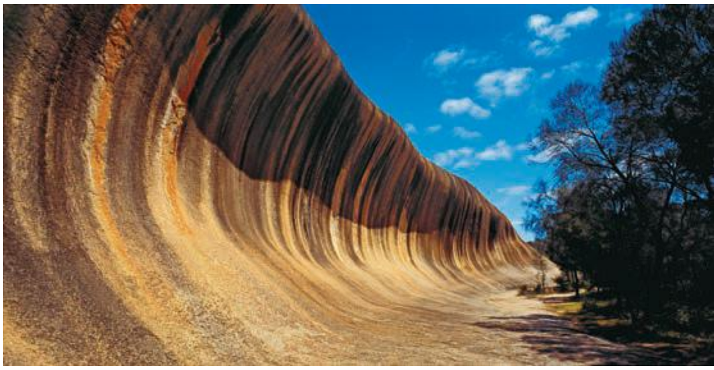


Figure 7.17 Wave Rock in Western Australia is made of granite that is over two billion years old.

Try this 7.2

Erosion by wind

You will need the following materials:

- Petri dish
- water
- dry sand
- pebbles of various sizes
- drinking straw
- newspaper.

Place the Petri dish on the edge of the newspaper. Moisten the bottom of the Petri dish with just a little bit of water, before filling it with sand. Place five pebbles on top of the sand and spread them out evenly. Gently blow through the straw, away from the edge of the newspaper, so the sand lands on the newspaper and does not make a mess.

What do you observe? Does the sand blow away more from under the pebbles or around the pebbles?

ISBN 978-1-108-61069-8 Cambridge University Press

Deposition, compaction and cementation

Particles or sediments that are eroded come to rest when the wind or water moves more slowly or the ice melts. When the particles reach their destination, they are dropped, in a process called **deposition**. Often deposition occurs on ocean beds or lake beds. The particles are often deposited in visible layers, which become **compacted** or compressed by the weight of the layers above, and **cemented** together. These processes finally form sedimentary rocks. Sometimes animal and plant remains are mixed in with the sediments and preserved as **fossils**. On the seabed, this process can continue in the same place for millions of years and can create layers of sediment many metres high.

deposition process that occurs when eroded particles stop moving and build up to form sedimentary rocks

compaction the process of parts becoming closely positioned together, using very little space

cementation the sticking together of sediment

fossil the shape of a bone, shell, plant or animal that has been preserved in rock for a very long time

Figure 7.18 Sedimentary rocks are very common, covering over 70% of the Earth's surface. Some contain fossils that are billions of years old. Note the different layers of sediment, all cemented together.

Quick check 7.4

1 Distinguish between weathering and erosion.
2 In your own words, explain the processes of deposition, compaction and cementation.

Practical 7.3

Deposits on a riverbed

Aim

To model and observe how sediments are deposited on a river bed

Materials

- soil
- sand
- gravel
- water
- jar with lid

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Method

1 Add soil, sand and gravel to a jar, and mix them. Fill the jar to halfway.
2 Add water. Fill the jar ¾ full and put the lid on.
3 Make sure the lid is tight, and shake the jar for one minute. How do you predict the particles will settle?
4 Observe how the particles settle. Time how long it takes for each layer to form.

Results

Draw a diagram representing the different layers, and label them.

Evaluation

1 Do the larger particles end up on the top layer or the bottom layer?
2 How long does each layer take to settle? Can you explain why this occurred?

Conclusion

1 Make a claim regarding the particle size in a layer and how it settles in a river bed. Start your sentence with: 'This experiment suggests that in a river bed … '.
2 Support your claim by using what you observed of the particles settling. Start your sentence with: 'It was observed that … '.
3 Explain how the data supports your claim. Start your sentence with: 'This means that … '.

Heat and pressure

Rocks that are deep underground may be exposed to extreme pressure, high temperature or both. This can change the nature of the rock, often making it harder and denser. These processes create metamorphic rocks. Mudstone is a sedimentary rock made from mud. When it is exposed to high pressure and temperature it turns into slate, a metamorphic rock. If the temperature and pressure are increased again, it turns into schist, another type of metamorphic rock.

Figure 7.19 Slate is a metamorphic rock formed when mudstone is subjected to high pressure and temperature.

Figure 7.20 Pieces of schist, formed when slate is subjected to high temperature and pressure.

ISBN 978-1-108-61069-8 Cambridge University Press

Try this 7.3

Metamorphic pasta

You will need the following materials:

- 2 textbooks
- penne pasta (or any long type of pasta).

Scatter the pasta around in a random manner on a flat surface, between the two books, as shown in Figure 7.21. Keeping the book spines parallel to each other, slowly bring the spines together, with the pasta pieces in between. As the pasta pieces are compressed, they should align. How does this demonstrate the way in which metamorphic rock is formed?

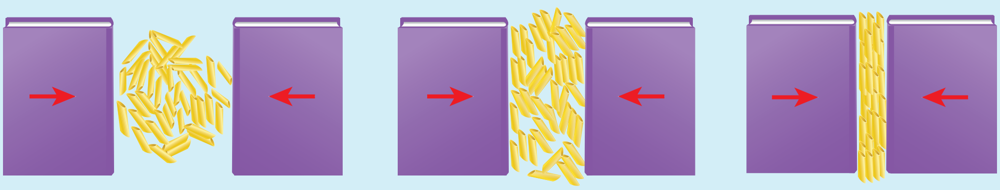


Figure 7.21 As you compress the pasta, the pieces align.

Quick check 7.5

1. List the three different types of rock.
2. Distinguish between the three kinds of rock in terms of how they are formed.

Energy sources for the rock cycle

It takes a lot of energy to move rocks around, break them up, heat them until they melt or change them physically or chemically.

Type of rock	Source of energy	Details
Igneous Metamorphic	Earth's formation and elements that are **radioactive**	When the Earth was formed, it contained radioactive atoms left over from a supernova. This radioactive energy has been released ever since and is what keeps the centre of the Earth at a high temperature.
Sedimentary	Sun	The energy of the Sun causes weathering through rain, wind, waves and ice formation. It also causes rocks to heat up during the day and cool down at night.

radioactivity energy released from the nucleus of an atom when the atom decays; the age of rocks can be determined by measuring their radioactivity

Table 7.2 The energy required for the formation of the different rock types comes from different sources.

Did you know? 7.4

Radiometric dating

Scientists can measure the radioactivity of an old sample of metamorphic or igneous rock and compare it with a sample that is more recent. Older rocks are less radioactive than newer rocks, and this enables the age of a piece of rock to be established. So far, the oldest rock to be discovered is a piece of gneiss from Canada that is estimated to be between 3.8 and 4.3 billion years old. It was formed long before there was life on Earth, and it is almost as old as the Earth itself.

Figure 7.22 This piece of rock is a sample of Acasta gneiss, the oldest rock yet discovered on Earth.

ISBN 978-1-108-61069-8 Cambridge University Press

Try this 7.4

Rock cycle poster

Make a poster of the rock cycle and annotate it with details of the different processes you have learned about in this section. You are going to add to this poster in the next section, so make sure you leave space around the outside for extra information about the types of rocks.

QUIZ

Section 7.1 questions

Remembering

1 Recall the name of the layer on Earth in which rocks are formed and reformed.

2 In Scotland, James Hutton saw igneous rock with millions of years' worth of sedimentary rock lying on top of it. Outline two observations that Hutton published after seeing this.

3 Name the most common type of rock on the Earth's surface.

Understanding

4 Contrast rocks, minerals and crystals.

5 Copy this image of the rock cycle and label the missing processes. Then explain each of the processes.

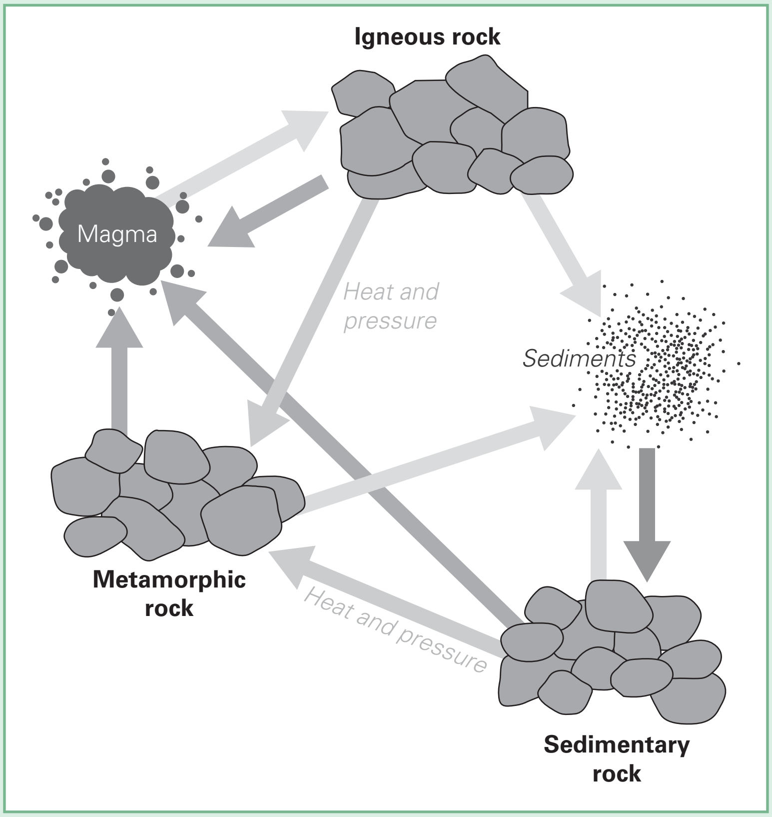


Figure 7.23 The rock cycle

6 Outline how the different types of rock from the previous question are formed.

Applying

7 Make use of what you have learned about weathering to identify one reason why weathering is important to the rock cycle, and one reason why we might want to stop weathering.

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

8 Imagine that the Earth's core suddenly lost its thermal energy. Apart from the effect this would have on life on Earth, which type(s) of rock formation would be affected and why?

Analysing

9 Examine Figure 7.24 and decide whether it is a mineral or a rock. Justify your answer.

Figure 7.24

Evaluating

10 'Once igneous rocks are formed, the only physical change they can experience is being broken down into smaller pieces until they are melted again.' Assess whether you agree with this statement and provide your reasoning.

7.2 Types of rocks

Igneous rocks

WORKSHEET

Beneath the Earth's thin outer crust is molten and semi-molten rock, called magma. When the surface crust becomes fractured, thin or weakened, molten magma can reach the surface and a volcano is formed. You may recall from the previous section that igneous rocks are formed when lava cools quickly following a volcanic eruption, sometimes within minutes, or cools and solidifies slowly underground in a magma chamber after it has been pushed close to the surface.

Figure 7.25 Igneous rock and lava in Hawaii

ISBN 978-1-108-61069-8

Cambridge University Press

The crystals within igneous rocks can be used to identify them. The crystals may be anything from several centimetres long to visible only with a microscope. The size of the crystal gives a clue to how long the igneous rock took to cool and, hence, how close to the surface the rock was formed. When magma breaks through the crust and flows on the surface, it is called lava. The lava solidifies to form **extrusive** igneous rocks. Basalt, an igneous rock, has the interesting property of forming large hexagonal structures as it cools. Pumice, also an extrusive igneous rock, floats on water!

extrusive
describes rocks formed on the Earth's surface; also called volcanic rocks

Figure 7.26 The hexagonal pillars of basalt found at the Giant's Causeway in Ireland are an example of magma flowing onto the surface, solidifying and forming igneous rock.

Another way for molten magma to form rocks is if it stops and cools before it gets to the surface, and solidifies underground. This rock will cool more slowly and so there is more time for crystals to grow, which means the individual crystals are bigger. Igneous rock formed in this way is called **intrusive** or plutonic. Although this rock is hidden when it is formed, it can be exposed later when the layers above have been eroded. Granite is an example of a plutonic igneous rock formed beneath the surface of a volcano. This stone is often used to make kitchen benchtops.

intrusive
describes igneous rocks formed underground; also called plutonic rocks

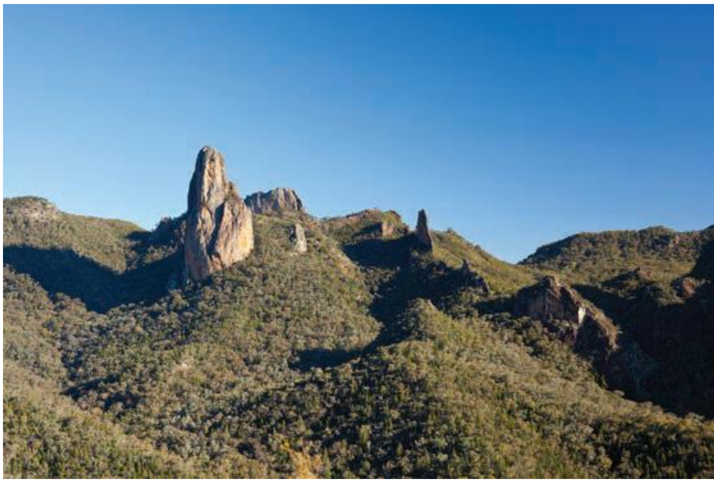


Figure 7.27 An example of intrusive igneous rock. This unusual landform in New South Wales contains the remains of an ancient volcano. Belougery Spire, on the left, was the magma chamber. The Breadknife, running along the right, was a crack in the volcano that filled with magma.

Figure 7.28 Granite has a distinctive mosaic of crystals of different colours.

Quick check 7.6

1 List some examples of igneous rocks.
2 Describe in your own words how intrusive and extrusive igneous rocks are formed.
3 Describe the relationship between crystal size and the time the crystal takes to form.

ISBN 978-1-108-61069-8 Cambridge University Press

Practical 7.4: Self-design

Crystals and cooling rate

Aim

To determine the effect that cooling rate has on crystal size formation

Materials

- saturated potassium nitrate or magnesium sulfate
- water
- test tubes
- beakers
- ice
- hand lens

Method

Using the materials above, design an experiment to investigate how cooling rate affects the size of crystals of saturated potassium nitrate or magnesium sulfate.

Hint: To create crystals, you need to use a saturated solution of potassium nitrate or magnesium sulfate.

Results

Record your observations.

Evaluation

1. Which test tube produced smaller crystals? Which produced larger crystals? Link this to the cooling rate.
2. Evaluate whether your results support what you have learned so far about crystals.

Conclusion

1. Make a claim regarding cooling rate and the crystal size of rocks. Start your sentence with: 'This experiment suggests that cooling rate … '.
2. Support your claim by using what you observed of the crystal sizes. Start your sentence with: 'It was observed that … '.
3. Explain how the data supports your claim. Start your sentence with: 'This means that … '.

Sedimentary rocks

The Earth's surface is covered partly by water and partly by land. As you saw in the previous section, weathering from waves, flowing water, wind, frost, rain, ice, chemicals and even living organisms, can break down the surface of exposed rocks. The particles of weathered rock are eroded: carried away by water, gravity, wind or ice. Eventually the particles can no longer be carried, and sedimentary rocks are formed when these particles or sediments are deposited, compacted and cemented together. Sedimentary rocks take thousands to millions of years to form.

Uluru is an example of sedimentary rock that you are probably very familiar with. Uluru is made of sandstone, but the sedimentary layers are almost vertical. This is evidence that the Earth is very old indeed. The rock that forms Uluru would originally have been horizontal, but over time the movement of the Earth's crust tilted it. The top of the rock has been weathered and eroded, until today just the end is showing.

The type of sedimentary rock formed depends on the particles that are deposited. Chalk is a common sedimentary rock and

ISBN 978-1-108-61069-8 Cambridge University Press

Figure 7.29 Uluru is an ancient sedimentary rock turned through 90° by the movement of the Earth's crust.

is formed from the remains of sea creatures whose bodies fell to the ocean floor. Chalk is made of calcium carbonate and can be identified by a simple test: when acid is placed on the surface, bubbles form. Chalk often contains fossils, and the age of the chalk can be determined from the fossils it contains.

Sea creatures that had tiny skeletons made of carbonates formed beds of chalk. Any gaps in the chalk filled with dissolved silica (also from sea creatures) and formed flint nodules. Flint is a type of chert and was one of the first substances used to make tools.

Sand made of quartz is another familiar material that forms sedimentary rocks. Sand is commonly found all over the world on beaches, and at the bottom of rivers, lakes and the sea. The sedimentary rock formed from sand is called sandstone. It is a common building material because it is relatively easy to cut and is strong. Parliament House in Melbourne was originally built from sandstone mined in the Grampians National Park.

Mud sediment forms mudstone and shale. It is not used extensively for building because it breaks easily. However, mudstone turns into slate at high temperature and pressure, and slate is used as a roofing

Figure 7.30 A chert nodule, found in chalk. Chert is also a sedimentary rock.

Figure 7.31 Parliament House in Melbourne is one of many buildings in Australia made from sandstone.

ISBN 978-1-108-61069-8 Cambridge University Press

material in some parts of the world. Half of the sedimentary rocks on Earth are made of mudstone or similar.

Figure 7.32 Fossilised leaves in mudstone

conglomerate
sedimentary rock composed of rounded rock fragments larger than 2 millimetres

breccia
sedimentary rock composed of angular broken pieces of rock larger than 2 millimetres

Sedimentary rock formed from small stones is called either **conglomerate** or **breccia**. Conglomerate is formed from rounded stones, whereas breccia consists of angular stones.

Figure 7.33 Sedimentary rock made from rounded pebbles is called conglomerate.

How coal is made

Explore! 7.2

Organic material from living creatures can also form sedimentary layers. Layers of plant material form coal, while bacteria decomposes to form oil. Although oil is a liquid, it is still sedimentary.

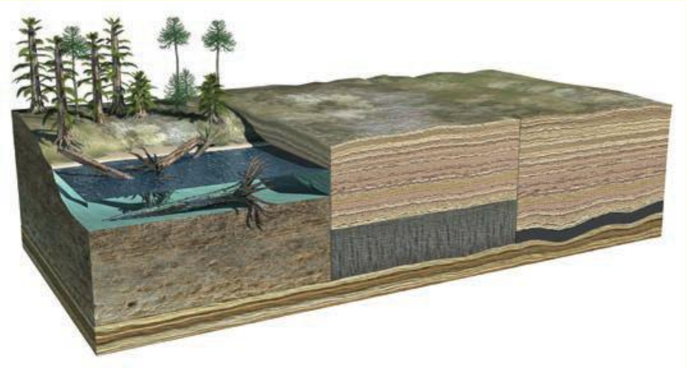


Figure 7.34 How coal is formed. Left: In the Carboniferous Period, trees die and form a layer of wood. Middle: The wood is compressed by the layers of sediment above. Right: The compressed wood is transformed by heat and pressure into coal.

Use your preferred browser to research the following questions.

1. List three different uses for coal.
2. Coal is a non-renewable resource. Are there any alternatives to coal for the uses you listed in the previous question?

Did you know? 7.5

While most beaches are made of quartz sand, some beaches near coral reefs are entirely composed of tiny fragments of coral made of calcium carbonate.

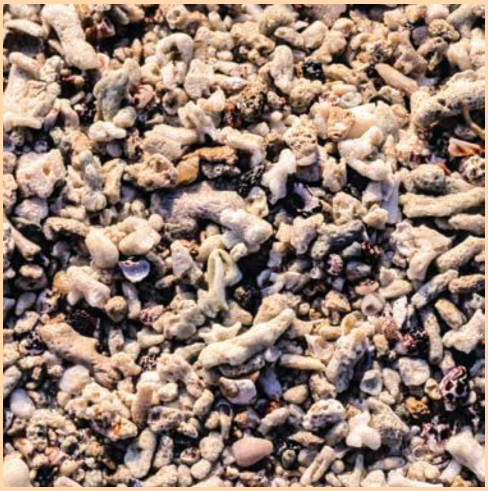


Figure 7.35 Fragments of coral found on a coral beach

ISBN 978-1-108-61069-8 Cambridge University Press

Fossils

The bodies of different organisms may be deposited in sediment and form part of the sedimentary rock – this is how they become fossils. Generally, fossils are only formed in rocks that start as sedimentary rocks. But, as we know from the rock cycle, rocks are always changing and so it is possible that the rock may later change its nature and become metamorphic without the fossil being destroyed.

Fossils can be used to trace the history of life on Earth. Because sedimentary rocks form slowly, the passage of time is traced in their layers, with the oldest rocks at the bottom. Fossils found in the same layer must have lived at the same time in the same location, and so were part of the same ecosystem. Fossils found in different layers must have lived at different times, with newer fossils being found above older fossils. Evidence of extinction events can be seen, when a certain type of fossil suddenly disappears. For example, by studying sedimentary rocks, it is known that all the dinosaurs became extinct at the same time, about 60 million years ago.

Fossil formation **Explore! 7.3**

Use your preferred search engine to find out about the process of fossilisation.

1. Not all living things become fossils. Describe the conditions necessary for fossils to form.
2. Evaluate some things that scientists have learned from fossils.

Types of fossils

There are various types of fossils, depending on how the impression was formed. Some common types are listed in Table 7.3.

Fossil type	Details	Image
Mould	When a plant or animal decays in sediment, it may leave a hollow impression of itself.	 **Figure 7.36** The mould of an ammonite
Cast	When an animal or plant dies, its body creates a space in the sediment. This gap fills with minerals, such as silica, over time and the shape of the animal is preserved as rock.	 **Figure 7.37** A fossilised trilobite, extinct creatures that once dominated life on Earth

Table 7.3 Five common types of fossils

ISBN 978-1-108-61069-8

Fossil type	Details	Image
Imprint	These fossils leave behind a two-dimensional (flat) print.	 **Figure 7.38** Leaves are pressed flat by the pressure in the sedimentary layers and all that is left is a dark area, like a shadow.
Whole body	This is the most common type of fossil. It consists of parts of the remains of living things, mainly the hard parts, e.g. teeth, shells, bones.	 **Figure 7.39** Whole body fossils are also found intact in a medium such as amber (tree resin that has become fossilised).
Indirect or trace	These fossils do not consist of part of the organism. They are indirect records of biological activities, such as footprints, teeth marks or burrow marks.	 **Figure 7.40** From a set of footprints, scientists can tell how fast the animal was moving, whether it was solitary or moved in groups, and how heavy it was.

Table 7.3 *(continued)*

Quick check 7.7

1 Recall how sedimentary rocks are formed.
2 List some examples of sedimentary rocks.
3 Distinguish between the five types of fossils discussed in this section.

ISBN 978-1-108-61069-8 Cambridge University Press

Science as a human endeavour 7.2

How did it become extinct?

The fossil record is the history of life as it is seen from fossils. It can tell us about groups of animals that are extinct, such as dinosaurs, and how animals and plants relate to each other. Unfortunately, the fossil record is incomplete because, as you investigated in *Explore! 7.3*, specific conditions are required for fossilisation to take place. Not all dead things become fossils.

Interpretation of the fossil record has always presented difficulties for paleontologists (scientists who study fossils). For example, for many years it was believed that the extinction of dinosaurs was gradual, but in 1980 evidence was found of a meteor impact that is now thought to have caused the mass extinction. Disappearance from the fossil record also does not always mean that a species is extinct; there may be many other reasons for its absence from the record.

Paleontologists Steven Holland and Mark Patzkowsky designed computer models to aid the study of mass extinction, and are using the models to more accurately decipher the fossil record. Their work is still in progress; however, it provides an initial guideline for analysis and assessment of extinction events.

Figure 7.41 Computer models can aid research in various fields, including the study of fossils.

Metamorphic rocks

The third type of rock in the rock cycle is metamorphic rock. Recall that metamorphic rocks are either igneous or sedimentary rocks that have been irreversibly changed by being subjected to high temperature or pressure. The Earth's crust is very thin in proportion to its size, and rocks that lie beneath the surface can be subject to high pressure and temperature. The crystals inside these rocks may become deformed and the chemical nature of the rock may change. Rocks that have been changed into metamorphic rock tend to be denser and harder than before. Layers may become twisted when rocks are metamorphosed.

Over millions of years, these rocks can eventually make their way to the surface again. These rocks are found all over the world and they constitute about

Figure 7.42 Folded layers are a feature of metamorphic rock.

10% of the Earth's surface. Because of their toughness, they are often used for building materials. For example, chalk (sedimentary) is a very soft rock but when it is exposed to high temperature and pressure, it turns into limestone (sedimentary). If limestone is then

ISBN 978-1-108-61069-8 Cambridge University Press

subjected to even higher temperature and pressure, it turns into marble (metamorphic). Can you think of what marble is used for? Other common metamorphic rocks are slate, which is metamorphosed shale (sedimentary), and quartzite, which is metamorphosed sandstone (sedimentary).

VIDEO
Describe the three rock types

Figure 7.43 Chalk (left) is a sedimentary rock made from the skeletons of sea creatures. Limestone (middle) is a metamorphic form of chalk. Marble (right) is a metamorphic form of limestone.

Try this 7.5

Heat, changes and pizza

The same level of heat affects different foods to various extents. For example, in the pizza shown below, the bread mostly appears the same before and after heating. The meat is caramelised. The grated cheese has undergone major physical and chemical change, as it has melted and joined. What does this tell you about the effects of heat on different materials? How can this apply to rock formation?

Figure 7.44 The same level of heat affects different substances differently.

Quick check 7.8

1 In your own words, describe how metamorphic rock is formed.
2 List some examples of metamorphic rock and what they are made of.

Try this 7.6

Summing up

Using the poster you began in Section 7.1, annotate it with information about the three different rock types you have learned about, and their characteristics and examples.

ISBN 978-1-108-61069-8

Explore! 7.4

Rocks and their uses

You encounter different types of rocks every day. Copy and complete the table below by investigating some of these rocks and how they are formed.

Material	Common uses	Rock type and formation process
Granite	Kitchens, bathrooms	Igneous –
Pumice	Removing dead skin	Igneous –
Sandstone	Ornamental decorations	Sedimentary –
Slate	Roofing, flooring	Metamorphic –

QUIZ

Section 7.2 questions

Remembering

1 What name is given to rocks formed during a volcanic eruption?

2 What is the name given to rocks formed when sedimentary rocks change due to high temperature and pressure?

3 Recall what sedimentary rocks formed from small rounded rocks are called.

4 Name five common fossil types.

Understanding

5 Outline how marble is formed and determine what type of rocks are involved.

6 Explain how the vertical layering of the rock forming Uluru indicates that the Earth is old.

Applying

7 Figure 7.45 shows the Organ Pipes rock formation at the Organ Pipes National Park in Victoria. Use what you have learned about igneous rocks to explain how this formation came to be.

Figure 7.45 A set of basalt columns at Organ Pipes National Park in Victoria

continued…

ISBN 978-1-108-61069-8

Cambridge University Press

...continued

Analysing

8 Examine the following igneous rocks. Decide which one is intrusive and which is extrusive. Explain your reasoning by first recalling the difference between intrusive and extrusive.

Figure 7.46 Which one is intrusive and which is extrusive?

9 Analyse and classify the types of fossils shown in Figure 7.47.

Figure 7.47

Evaluating

10 Evaluate why the water in the Yarra River is brown (see Figure 7.48). Use the following terms in your explanation: particles, sediment, weathering, erosion, deposit, rock.

Figure 7.48 Why is the water brown?

11 'A rock is clearly seen to be made of distinct and different layers. Therefore it must be a rock, not mineral.' Evaluate this statement and explain your reasoning.

ISBN 978-1-108-61069-8 Cambridge University Press

7.3 Classifying rocks

WORKSHEET

Classifying rocks is a skilled job, but it can be simplified by knowing some of the key characteristics of the different rock types, as well as the tests that can be done on rocks, and by using a dichotomous key.

Figure 7.49 Painite, the world's rarest gem

Figure 7.50 Asbestos is a dangerous mineral and should not be handled.

Are all rocks harmless?

Most rocks are harmless. However, because the minerals in them are made of chemicals, some can pose a hazard and need to be handled with care. Beware of handling some metal **ores**, especially those containing mercury, lead or copper, and always wash your hands after handling rocks. Asbestos, which contains crystals in the form of fibres, is dangerous and should be avoided.

ore
a rock that can be mined and smelted to produce a metal

Characteristics of the different rock types

Recall that rocks are made of one or more minerals and can be classified into three groups according to how they have been formed.

1 Igneous rocks – formed from cooling magma. They can differ in colour and texture. Some have holes because of gas that is trapped as the lava cools. Some are characterised by visible crystals.

Figure 7.51 Examples of igneous rock are pumice (left) and diorite (right).

ISBN 978-1-108-61069-8 Cambridge University Press

2 Sedimentary rocks – formed from layers of sediment being compacted and cemented together. They often appear grainy, and may contain fossils. They may be easy to crumble.

Figure 7.52 Examples of sedimentary rock are rock salt (left) and limestone (right).

3 Metamorphic rocks – igneous or sedimentary rocks that have been subjected to high pressure. They often appear layered, and may have crystals arranged in bands.

Figure 7.53 Examples of metamorphic rock are gneiss (left) and granulite (right).

Explore! 7.5

Classifying rocks

You now know that rocks are made of minerals, there are three groups of rocks, and that rocks come in various shapes, sizes, colours and other characteristics. Conduct some research and find out how a rock's characteristics can be used to determine whether the rock is igneous, sedimentary or metamorphic.

1 What are the characteristics of igneous rock?
2 What are the characteristics of sedimentary rock?
3 What are the characteristics of metamorphic rock?

Try this 7.7

Describing rocks

In groups of three or four, take a careful look at the rocks your teacher has supplied, and try to separate the rocks into groups. Some characteristics by which you may want to classify your rocks are size, colour, hardness, crystal size and shape.

What tests can help us classify rocks?

Some common types of rocks are easy to identify, but others can be challenging. There are many different tests geologists use to help classify a rock. Each test allows you to identify the presence or absence of a chemical or the physical property of the substance, and this then allows you to classify the rock and name it.

Crystal size and shape

Does the rock contain crystals? Crystals are a feature of rocks, especially igneous rocks. Some rocks, such as quartz or diamond, are one giant crystal. These are known as crystalline rocks. Other rocks are made of tiny crystals or have crystals that can only be seen with a microscope. The shape and size of the crystals can help in identifying the rock. Earlier you learned that fast-cooling magma can produce small crystals in extrusive igneous rock, while slow-cooling magma can produce larger crystals in intrusive igneous rock.

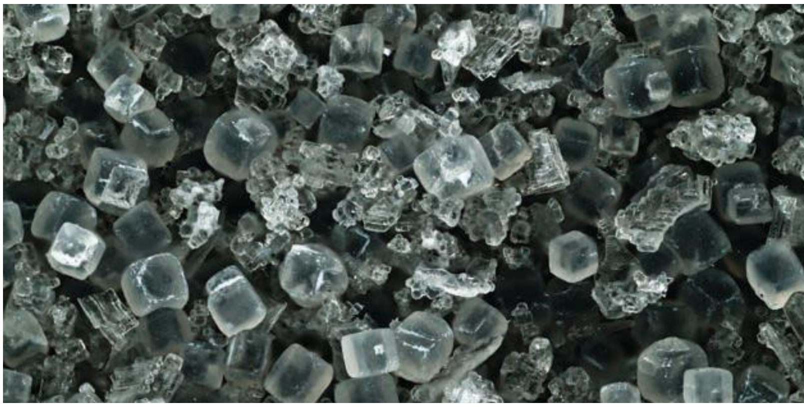


Figure 7.54 Table salt contains tiny crystals that are cubic in shape.

ISBN 978-1-108-61069-8 Cambridge University Press

Hardness

How hard is the rock? A useful method to help identify rocks is to determine how hard the rock surface is. In 1812, Friedrich Mohs classified all minerals according to their ability to scratch each other, on a scale from 1 to 10. Any mineral with a high **Mohs scale** number can scratch any mineral with a lower number. The softest mineral, with a 1 on the Mohs scale, is talc (metamorphic), and the hardest is diamond (metamorphic) with a 10. Your fingernail is about 2.5 and a steel knife is about 5.5. A set of tools called *Mohs picks* can be used to determine where on the Mohs scale a mineral in an unknown rock lies. For example, if a mineral can be scratched by pick number 7 and not by pick number 6, then it has a hardness of 6.

Mohs scale
a scale from 1 to 10 that indicates the hardness of a rock

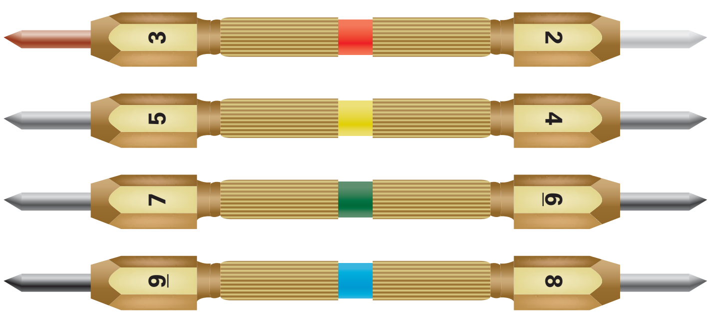


Figure 7.55 A set of Mohs hardness picks, which can be used to help identify a rock by its hardness

Behaviour in light

Most rocks are **opaque**, which means no light can pass through them. Some are **translucent**, which means light can pass through the rock but no clear image is visible through it.

opaque
blocking light completely

translucent
allowing some light through, but no clear image can be seen through the substance

Figure 7.56 Amethyst (mineral) is a translucent crystal and can be found inside igneous, metamorphic or even sedimentary rocks.

Transparent rock, such as diamond (metamorphic) and quartz (igneous), allow light to pass through and images are visible through them.

transparent
allowing light to pass through, and a clear image can be seen through the substance

Behaviour in acid

Weak hydrochloric acid can be used to test for carbonates. Bubbles form on the surface of marble (metamorphic), limestone (sedimentary) and chalk (sedimentary) when acid is dropped onto their surface. Rocks that do not contain carbonates will not fizz or bubble in acid.

Behaviour when struck

Some rocks break more easily in some directions than others. This feature is called **cleavage** and can help identify rock (such as slate, which is a metamorphic rock containing mica).

cleavage
the tendency of a mineral or a rock to break in a particular way because of its structure

Figure 7.57 Slate (left) can be split into thin sheets for building. Slate is composed mostly of quartz and mica (middle). Galena (right) is another mineral which, like mica, has an identifiable cleavage plane.

ISBN 978-1-108-61069-8 Cambridge University Press

Behaviour with magnets

Some iron-bearing rocks are attracted by a magnet, and others are naturally occurring magnets themselves. One of the most common magnetic minerals found in rocks is magnetite, named for its magnetic properties.

Figure 7.58 Magnetite is a mineral found in igneous, metamorphic and sedimentary rocks. It is also found in meteorites.

The streak test

When a rock is scratched onto a hard, ceramic surface, it can leave behind a coloured streak, which is a more reliable indicator of its colour than the colour of its surface. For example, gold and chalcopyrite have a similar surface colour, so a **streak test** is useful to distinguish between them.

streak test
a test used to help identify a mineral by scratching a rock on a hard ceramic tile

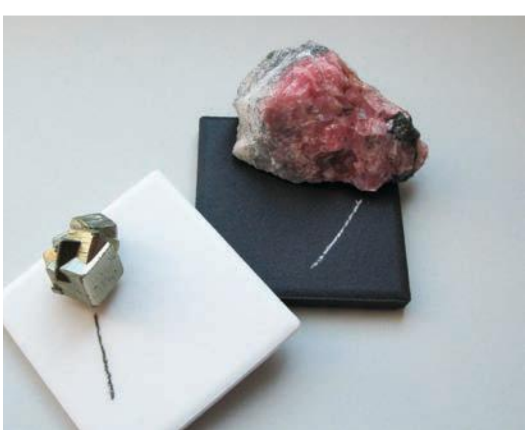


Figure 7.59 Examples of a streak test

Figure 7.60 The streak test for gold (left) shows up as gold, while the streak test for chalcopyrite (right) – also known as 'fool's gold' – shows up as dark green-grey.

Quick check 7.9

1. What are ores? Why are some ores harmful?
2. List seven characteristics that can be used to help classify rocks, and explain each characteristic.
3. Which of the characteristics from the previous question involves a chemical property?

Classifying and identifying rocks

WIDGET
A key to identify rocks

In order to classify and identify types of sedimentary, igneous and metamorphic rocks, you need to use a magnifying glass and work your way through the different tests. A dichotomous key, like the ones you used in Year 7, will also help.

Table 7.4 gives the general characteristics of the three different rock types.

Igneous rock	Sedimentary rock	Metamorphic rock
• May contain holes • Crystals can be small or large • Usually hard	• Grains are cemented together • Can be soft	• Sometimes has a layered look • Can often be cleaved to a straight plane • Ranges from soft to hard

Table 7.4 Some characteristics of rocks

ISBN 978-1-108-61069-8

Practical 7.5

Identifying 12 common rocks

Aim

To practise identifying and finding patterns, by classifying 12 of the most common rocks found in the Earth's crust

Materials

- hydrochloric acid 0.1 M
- dropper
- beaker of water
- hand lens
- disposable gloves
- 12 Petri dishes for the hydrochloric acid test
- two of each of the following rocks: basalt, chalk, gneiss, granite, limestone, mica, pumice, quartz, quartzite, sandstone, schist, slate

Figure 7.61 Twelve common rocks found on the Earth's crust, in random order

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Method

1 Use this dichotomous chart to identify the rock and the rock type. You can work in 12 groups, each group being responsible for one rock (each group will hold two rocks: one for the general test, and one for the hydrochloric acid test).
Rocks are composed of one or more minerals. For this practical, if a rock is made up of only one type of mineral, identify the rock as a 'mineral'.

1	Is the rock composed of crystals?	Yes	Go to 2
		No	Go to 5
2	Are the crystals flat and silvery?	Yes	Mica (igneous, metamorphic)
		No	Go to 3
3	Are the crystals large and transparent?	Yes	Quartz (igneous)
		No	Go to 4
4	Are the crystals small, easily removed by rubbing, and layered?	Yes	Sandstone (sedimentary)
		No	Granite (igneous)
5	Do bubbles appear when acid is placed on the rock? You will need to place the rock in the Petri dish and use the dropper to place 1–2 drops of hydrochloric acid on the rock. Do not handle the rock after hydrochloric acid has been added to it.	Yes	Go to 6
		No	Go to 7
6	Using a fresh rock, can the rock be scratched easily with a nail?	Yes	Chalk (sedimentary)
		No	Limestone (sedimentary)
7	Place the rock in a beaker of water. Does the rock float on the water?	Yes	Pumice (igneous)
		No	Go to 8
8	Is the rock translucent (allows some light to pass through)?	Yes	Quartzite (metamorphic)
		No	Go to 9
9	Does the rock have visible layers that may be curved or bent?	Yes	Gneiss (metamorphic)
		No	Go to 10
10	Does the surface of the rock appear to be made up of plates?	Yes	Schist (metamorphic)
		No	Go to 11
11	Does the rock break to form layers with a flat surface?	Yes	Slate (metamorphic)
		No	Basalt (igneous)

Figure 7.62 Dichotomous key for rock identification

2 Once you have identified your rock, label it. When all the rocks have been identified, sort them into the four groups: igneous rocks, metamorphic rocks, sedimentary rocks and rocks made up of only one type of mineral. Copy and complete the results table.

Results

Copy and complete this table to identify common characteristics of the different types of rocks.

	Rocks made up of only one type of mineral	Igneous rocks	Metamorphic rocks	Sedimentary rocks
Common characteristics				

continued...

ISBN 978-1-108-61069-8 © Roberts et al. 2019 Cambridge University Press

...continued

Evaluation

1 Recall what the hydrochloric acid test reveals about the rock material.
2 Discuss why you think pumice floats in water.
3 Design some rules and a different dichotomous key or chart to classify rocks as minerals, or igneous, sedimentary or metamorphic rocks. Identify any difficulties you encounter in doing this.

Conclusion

1 Make a claim regarding the difference between the different types of rocks. Start your sentence with: 'This experiment suggests that it is possible/not possible to identify rock type based on … '.
2 Support your claim by using what you observed of the characteristics of rock types. Start your sentence with: 'It was observed that … '.
3 Explain how the data supports your claim. Start your sentence with: 'This means that … '.

Science as a human endeavour 7.3

It used to be hotter

Studying the first billion years of the Earth's evolution has always been uncertain. It is difficult to compare ancient rocks with modern rocks, as the original rocks have often been destroyed or changed over time. Researchers at Louisiana State University have shown that komatiites (three billion year old volcanic rocks) were formed from the hottest lava that ever erupted on Earth. Temperatures were close to 1600°C, which is about 400°C hotter than the volcanic eruptions in modern-day Hawaii!

Figure 7.63 Komatiite

ISBN 978-1-108-61069-8 Cambridge University Press

Section 7.3 questions

QUIZ

Remembering

1 List seven characteristics that can be used to help classify rocks.

Understanding

2 Igneous rocks may contain holes. Explain why this is the case.
3 Sedimentary rocks often look like the grains are cemented together, and they are often soft. Explain why this is the case.
4 Metamorphic rocks sometimes have a layered look. Explain why this is the case.

Applying

5 Identify the following rocks, using the dichotomous key in *Practical 7.5*.

a The rock in Figure 7.64 does not bubble when acid is placed on it.

Figure 7.64

b The rock in Figure 7.65 does not bubble when acid is placed on it.

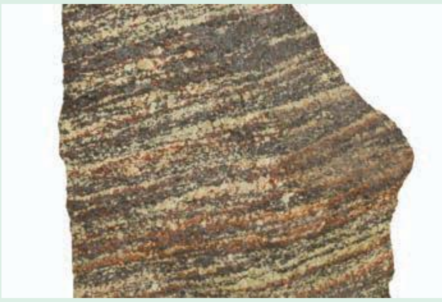


Figure 7.65

c The rock in Figure 7.66 bubbles when acid is placed on it. It cannot be scratched with a nail.

Figure 7.66

d The rock in Figure 7.67 does not bubble when acid is placed on it. The crystals are not easily removed.

Figure 7.67

Analysing

6 Using the rocks in Question **5** and the dichotomous key in *Practical 7.5*, determine the rock type of each rock, and explain how the appearance of each rock links to the rock type.

Evaluating

7 'All types of rock can be classified according to their physical characteristics only'. Assess whether or not you agree with this statement.

ISBN 978-1-108-61069-8

7.4 The mining process

WORKSHEET

VIDEO The mining process

Some minerals are useful to humans and can be mined. Mining is the process by which minerals and other useful materials are extracted from the Earth. Salt, slate, gold, marble and coal can be used as they are found. Others need to be processed to make useful products such as metals, or building materials such as cement.

The mining process has several stages: exploration, planning and design, construction, mining, processing and closure.

1 Exploration

Before any mining project begins, mining companies enlist the expertise of geologists to scout areas and search for mineral deposits. It is important that they find out the quality of the mineral and the size of the site in which the mineral is deposited. This is to determine whether it would be cost effective for the mineral to be mined, as a mining project is extremely expensive once it has started.

Figure 7.68 Geologists sampling rocks during iron ore exploration in the outback (Pilbara, Australia)

ISBN 978-1-108-61069-8

Science as a human endeavour 7.4

PMI guns

In modern mining, new technology is available to confirm a geologist's identification of a rock, in just a few seconds. A positive material identification (PMI) gun uses high-energy radiation (X-rays) to excite the material in a rock, and records the response. Each different material has a unique response, like a fingerprint. By analysing the signal given out by the rock, the percentage of each element can be found.

Geologists use a technique called **seismology** to determine the structure of the rocks that lie beneath the surface. An explosive charge is detonated at a location and, as the sound travels down, it is reflected from the layers beneath the surface. Once an area has been identified, a thin cylinder of rock, called a core sample, is extracted to positively identify any minerals found.

seismology
the use of shockwaves to investigate the structure of rocks underground

Figure 7.69 Miners can use a PMI gun to determine the composition of a rock.

Figure 7.70 Core samples taken from a diamond mine

2 Planning and design

If the results of the exploration strongly suggest that mining in a certain area would yield good results, then the project moves into the planning stage. Collaboration occurs among project managers, mining engineers, finance consultants and other experts to design safe, sound, economically viable and socially responsible plans.

Figure 7.71 Social responsibility in planning includes considering how a new mine will affect society and the natural environment.

ISBN 978-1-108-61069-8 Cambridge University Press

3 Construction

After research, planning and permits are approved, the project moves to the construction stage. This may involve building roads, mining facilities and housing.

Figure 7.72 Constructing a mining site involves many people, such as construction workers, builders, landscape architects and engineers.

4 Mining

Mining is the process by which the minerals are recovered, using various tools and machines. When you think of mining, most people imagine an underground tunnel, which is a technique of mining that goes back to Roman times.

Figure 7.73 An underground coal mine

Underground mining is highly skilled and can also be dangerous. The advantages of underground mining are that there is generally little impact on the environment, and minerals can be extracted from deep underground.

underground mining traditional method of mining by digging tunnels underground to extract ore

Another method of mining is called **surface mining,** or open-cut mining. Large quantities of a mineral can be extracted using this technique. Surface mining can only be used if the mineral is close to the surface. This method has become much more common in recent years, especially for the extraction of metal ores. It is relatively safe compared with underground mining, but there is a significant impact on the environment. Coal and iron ore are usually mined in this way in Australia.

surface mining method of mining that extracts a mineral by digging an open pit

Figure 7.74 An open-cut coal mine in New South Wales. Australia supplies about 20% of the world's coal and about 40% of the world's iron ore.

ISBN 978-1-108-61069-8 Cambridge University Press

Explore! 7.6

Mining extraction processes

There are four main types of mining. Underground mining and surface mining are two of these; the other two are *placer mining* and *in-situ leach* mining. Research these methods and answer the following questions.

1 What is involved in placer mining and in-situ leach mining?
2 List some advantages and disadvantages of all four types of mining.
3 Which of the mining types are most environmentally friendly? Justify your answer.
4 Describe some of the ethical issues that need to be considered with regards to mining.

Explore! 7.7

World's first fully automated mine

Use your preferred web browser to search for 'Syama automated mine'. Do some research with regards to advances in mining technology and automation, and answer the following questions.

1 Identify the advantages of fully automated mining technology.
2 Assess the concerns that fully automated mining may present. Do you think these concerns are justified?

Quick check 7.10

Copy and complete the following table to summarise what you have learned about the mining process so far. Remember, there are still two stages to go, so leave space in your table for these stages.

Mining process	Details	Examples of people involved
1 Exploration		
2 Planning and designing		
3 Construction		
4 Mining		
5		
6		

5 Processing

Recall that ore is rock that contains the metal being mined. There are several ways to process the ore so that only the intended metal is extracted.

Grinding

The ore is usually first crushed so that the pieces are smaller and easier to process.

Smelting

smelting
the process of getting a metal from rock by heating it to a very high temperature

The process of extracting the metal from its ore is called **smelting**. Basically, the metal ore consists of the metal combined with oxygen in the rock. The ore is heated in the presence of carbon (charcoal) and a chemical reaction takes place.

$$\text{metal oxide + carbon} \xrightarrow{\textit{yields}} \text{metal + carbon dioxide}$$

The extraction of metals, ores and other materials from the earth has a very long history. Archaeologists have named two periods of human history, the Bronze Age and the Iron Age, according to the metals that people were producing at that time.

ISBN 978-1-108-61069-8

Purifying

Electricity can be used to purify an impure sample of metal, in a process called **electrolysis**. The sample is connected to a positive terminal, and a pure piece of the metal is connected to the negative terminal. The terminals are placed in a solution containing the metal and, when the circuit is connected, the metal slowly moves through the solution from positive to negative. Any impurities are deposited near the positive terminal. When this is done with copper, the impurities may contain valuable metals such as gold.

electrolysis
a method of extracting a metal from its ore or purifying it using electricity

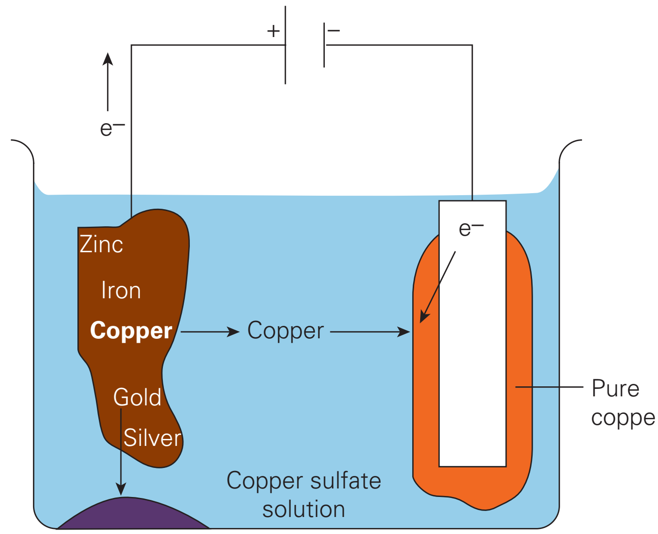


Figure 7.75 Electrolysis in purifying copper

Practical 7.6

Electrolysis of copper

Aim

To see how metals can be purified using electricity, and to demonstrate electroplating

Materials

- 2 copper plates to act as electrodes
- 2 alligator leads
- an old metal fork or spoon
- copper sulfate solution, 0.5 M
- beaker
- 3 V DC power supply

Be careful

Ensure personal protective equipment is worn. All materials and solutions are to be collected. Electrical shocks may occur. Ensure the voltage output is not exceeded. Turn off the power supply when changing the circuit.

Method

Part 1

1. Place two copper electrodes in a beaker containing a solution of copper sulphate.
2. Connect the electrodes to a battery or low-power direct current supply (make sure it is switched off when you do this) using alligator leads.
3. Switch it on and leave it for a while. The cathode will slowly grow, and the anode will become smaller.
4. Switch the power supply off.

Part 2

1. Replace the copper plate connected to the negative terminal with a fork.
2. Switch the power supply on. Copper will move from the other plate to the fork. When it reaches the fork, it will be deposited on the surface and a thin layer of copper will appear. This is called electroplating.

Results

Record your observations for each part of the experiment.

continued…

ISBN 978-1-108-61069-8

...continued

Evaluation

1 Describe what you think happened when the power supply was switched on in Part 1 of the experiment.
2 Deduce some uses for electroplating, which you saw in Part 2 of the experiment.
3 Distinguish between electrolysis and electroplating.

Conclusion

1 Make a claim regarding electrolysis and purifying metals. Start your sentence with: 'This experiment suggests that the process of electrolysis … '.
2 Support your claim by using what you observed of the crystal sizes. Start your sentence with: 'It was observed that … '.
3 Explain how the data supports your claim. Start your sentence with: 'This means that … '.

6 Closure and rehabilitation

The final step in mining is closure and rehabilitation. When the resources in a mining site have been exhausted, the site closes down, all facilities are packed up and a rehabilitation plan is developed. The purpose of this is to return the land to the state it was in before the mine was built. For example, if it was agricultural land, then the plan would involve trying to restore the land to its original level of productivity. Rehabilitation involves scientists, government personnel, bush regenerators and local wildlife experts, among others.

Did you know? 7.6

Rehabilitation and biodiversity

Rehabilitation of the land also takes into consideration the native plants and animals that were in the site before it was mined. Disturbed areas are reshaped to reflect their original state as closely as possible, and care is taken to preserve plant species. An example of mining rehabilitation is the Woodcutters lead–zinc mine in the Northern Territory, which was closed in 1999. In 2002 it was acquired by Newmont, a mining corporation, which has rehabilitated and monitored the site as part of its commitment to sustainable business, in partnership with the Kungarakan and Warai people, who are the traditional owners of the land. The rehabilitation process has several stages, and the latest stage started in 2018, with the planting of wetland vegetation. The final goal is to hand back the land to the traditional owners.

Figure 7.76 Another example of rehabilitation is the Westside Mine, a coal mine near Lake Macquarie in New South Wales The rehabilitation was completed in 2012, two months after operations stopped.

ISBN 978-1-108-61069-8 Cambridge University Press

The mining industry in Australia

The mining industry is one of the most important industries in Australia. Table 7.5 shows a summary of some of the metal resources mined in this country.

It is not just metals that are mined or quarried. Stones are used to make roads. Coal (sedimentary) is mined as a source of energy; Australia is ranked fourth in the world in terms of coal supply. Limestone (sedimentary) is used to make cement; and when sand is combined with small amounts of limestone and sodium carbonate, heated until it melts and allowed to cool, it becomes glass.

Gemstones such as diamonds and opals are mined in Australia, and gemstone mining is a major source of income for some Australian towns. Coober Pedy, for example, is the largest opal mining area in the world.

Resource	Details
Iron	Australia is the world's largest exporter of iron ore.
Uranium	The worldwide nuclear power industry needs uranium ore as fuel. There are no nuclear power stations in Australia, but 10% of the world's uranium is mined here.
Gold	Australia's early history was highly influenced by gold, as many immigrants came during the gold rush days. Gold mining is still a large industry and ore containing even a small amount of gold is mined, because it is so valuable. Gold mines in Australia account for 9% of the world's production and some of these mines are huge operations, occupying many hectares.

Table 7.5 Some important metals mined in Australia

Figure 7.77 An Australian opal. Australia produces 80% of the world's opals.

Figure 7.78 A gold mine in Western Australia

ISBN 978-1-108-61069-8 Cambridge University Press

Figure 7.79 Coober Pedy is an opal mining town in South Australia.

Quick check 7.11

1 Add the last two mining processes to your table from *Quick check 7.10*.

Mining process	Details	Examples of people involved
5 Processing		
6 Closure and rehabilitation		

2 List some of the metals, rocks and minerals mined in Australia.

Section 7.4 questions

QUIZ

Remembering

1 Recall the steps of the mining process, in chronological order.

2 Name three processes that can be used in the processing stage of mining to obtain the intended metal.

3 List some metals and resources that are significant for the Australian mining industry.

Understanding

4 Explain the importance of performing the exploration stage before designing a mine.

5 Outline how geologists determine the content and structure of the rocks under the surface.

Applying

6 List an example of technological progress in the mining industry and explain how it helps the mining process.

Analysing

7 Give at least two advantages and disadvantages of open-cut or surface mining compared with underground mining.

Evaluating

8 Evaluate why electroplating with silver or gold is a very popular technique in jewellery making.

ISBN 978-1-108-61069-8

Review questions

SCORCHER

Remembering

1 Why is the centre of the Earth still hot, despite the fact that the Earth is very old?
2 Name the two types of igneous rock.
3 Name the process of extracting metals from their ores.
4 Recall the stages in the formation of sedimentary rock.
5 Name the two conditions that are required for metamorphic rocks to form.

Understanding

6 Distinguish between rocks and minerals.
7 Propose how you can physically distinguish between a rock and a mineral.

Applying

8 Figure 7.80 shows limestone in the Naracoorte caves of South Australia.
   a Identify the property of the limestone that allows the caves to form.
   b What is the geological name for this type of weathering?

Figure 7.80 Naracoorte caves, South Australia

Analysing

9 Examine the image in Figure 7.81 and determine whether it is a rock or a mineral.

Figure 7.81

ISBN 978-1-108-61069-8

10 **a** Infer the geological process that occurred to produce the formation shown in Figure 7.82.

Figure 7.82

b One feature of metamorphic rock is that it can appear layered. The rock shown in Figure 7.83 is layered. However, it is sedimentary rock. Evaluate why this might be the case.

Figure 7.83

Evaluating

11 A rock is made of a single crystal. Evaluate whether or not this rock is a mineral, and explain your reasoning.

12 **a** The sedimentary rocks in Figure 7.84 are lying at an angle. Determine the geological event that might have caused this to happen.

Figure 7.84

b Figure 7.85 shows a fossil lying on a beach. Deduce where the sedimentary rock would have come from.

Figure 7.85

ISBN 978-1-108-61069-8 Cambridge University Press

STEM activity: Underground bunkers and asteroids

VCSSU102 VCDSTC048 VCDSCD049 VCDSCD051 VCSIS113

Background information

A bunker is a structure built underground for people to shelter or live in, protecting them from dangers on the surface of the Earth. For example, many homes in parts of the world that are prone to tornados have a bunker to protect the home owners. During the Second World War, many major cities had huge bunkers built beneath them, to protect residents from bombs.

When designing a bunker, engineers need to think about how people live and what requirements exist for people to be able to live underground for a period of time. They obviously do not need to take creature comforts into account, but people will still need to have access to food, fresh water and toilets, and somewhere to sleep. Engineers calculate the amount of space that will be required for the number of people intending to use the bunker.

Engineers also need to consider the type of rock and soil that the bunker will be built beneath. They work alongside geologists to determine suitable locations, with rock that is not too soft, so it will support the structure of the bunker, and not too hard, so it is not too difficult to cut into.

Figure 7.86 A bunker provides protection from dangers above.

ISBN 978-1-108-61069-8 Cambridge University Press

Design brief: Design an underground bunker to survive the imminent impact of an asteroid!

Activity instructions

BREAKING NEWS: AN ASTEROID IS HEADING FOR EARTH!

Scientists have calculated that the asteroid will collide with Earth in 20 days. The impact will be so destructive that all humans will need to stay in bunkers underground for at least three months. Your team of engineers has been tasked with building an underground bunker for the people in your local area. There are several factors that you will need to take into consideration before designing and constructing your bunker.

- How many people live in your local area, and who need to be housed?
- What volume does the bunker need to be? Consider that each person will need a bed (can be double or triple bunks) plus some extra communal space for a kitchen and a bathroom area. Decide how high the ceilings need to be, and calculate the volume required using length × width × height.
- You will need to research the most common types of rock that are found in your area, and their rating on the hardness scale. Decide on a location for your bunker, based on the rock types you have found in your research.

You will need to test your bunker for impact resistance by building a scale model. Using layers of rocks and soil in a large container, place your model bunker in the middle and test its strength by dropping several different masses from the same height. Record the largest mass that your bunker can withstand before being damaged.

Suggested materials/presentation formats

- large plastic container
- soil and crushed rock
- cardboard
- icy pole sticks
- scissors
- sticky tape
- glue
- masses

Evaluate and modify

1. Describe some of the difficulties you encountered while calculating and estimating the amount of space people will need to live in.
2. Did you need to make compromises about quality of life for the people living in your bunker, to save space? Explain how you came to your decisions.
3. Describe some modifications you could make to your bunker to withstand more force.
4. Evaluate the feasibility of constructing a bunker located within the rock type you have chosen.

Figure 7.87 Only 20 days to find cover!

ISBN 978-1-108-61069-8

Cambridge University Press

Chapter 8 **Energy**

Chapter introduction

This chapter provides an introduction to the different forms of energy that we encounter in our everyday lives.

The idea of energy is already familiar to you. Your senses can detect several types of energy – your eyes detect light, your ears detect sound, and your skin can feel hot and cold. You use your muscles to move, gaining kinetic energy, or to lift things, giving them gravitational potential energy. The food you eat contains chemical energy, which allows you to move and keep warm. The cells in your brain are constantly exchanging electrical energy, and your nervous system uses electrical energy to send messages between your brain and the rest of your body.

Our homes are full of machines that use energy for lighting, cooking, cleaning, heating, cooling and entertainment. You will learn about how energy can be converted from one form to another, always leaving the total amount of energy the same. This is because energy cannot be created or destroyed; it can only be only changed from one form to another. It is also true that mass can be transformed into energy. In the final section you will learn how the energy we use in our homes is generated, and investigate whether the methods used are renewable and sustainable.

Curriculum

Energy appears in different forms including movement (kinetic energy), heat, light, chemical energy and potential energy; devices can change energy from one form to another (VCSSU104)	
• recognising that kinetic energy is the energy possessed by moving bodies	8.1
• recognising that potential energy is stored energy, for example, gravitational, chemical and elastic energy	8.1
• using flow diagrams to illustrate changes between different forms of energy	8.2, 8.3
• investigating the energy transformations in devices, for example, a catapult or a water wheel	8.2, 8.3

Victorian Curriculum F–10 © VCAA (2016)

ISBN 978-1-108-61069-8

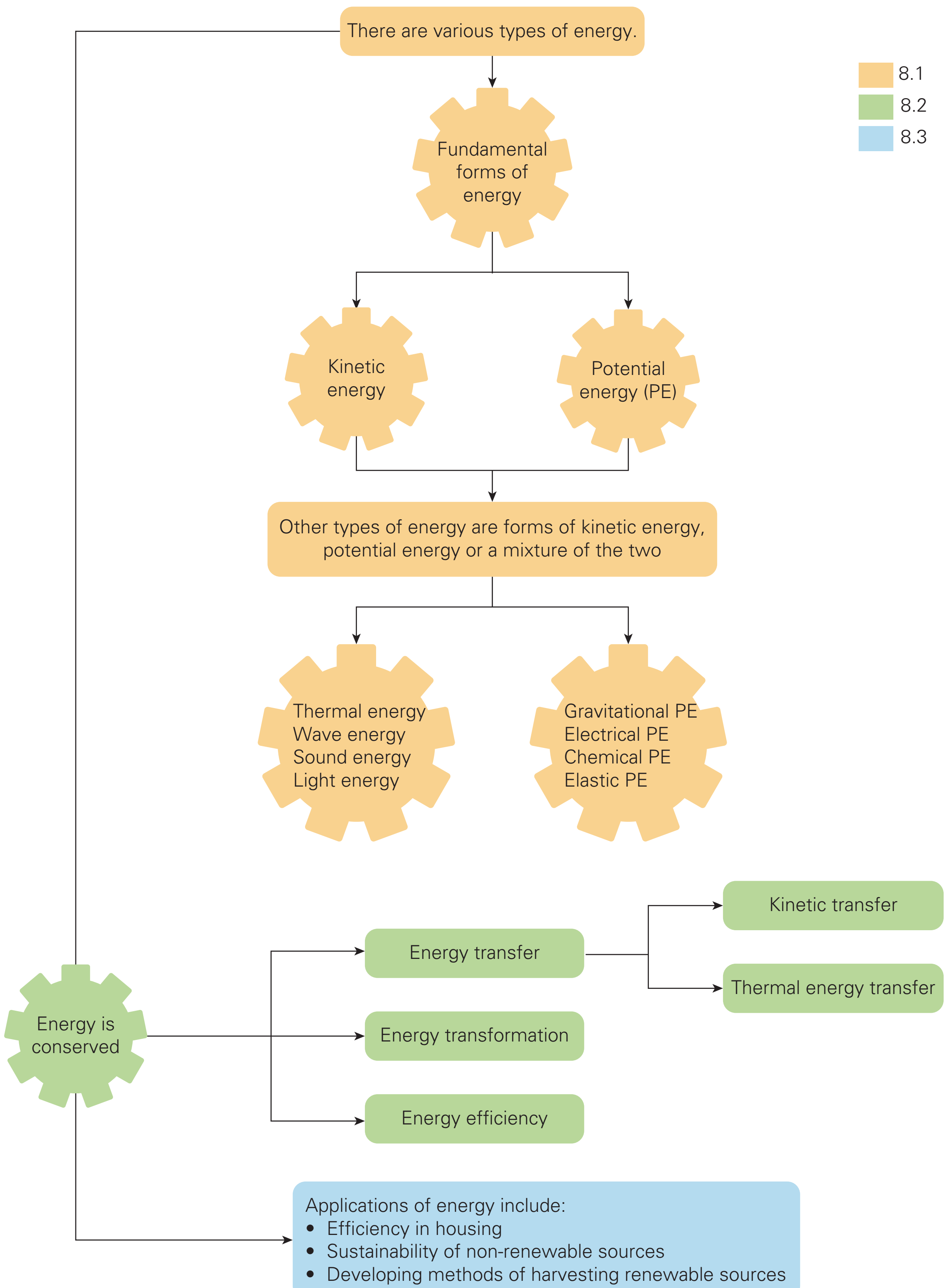
Glossary terms

chemical potential energy
conduction
conductor
convection
efficiency
elastic potential energy
electrical energy
electromagnetic spectrum
energy
energy transfer
fossil fuel
generator
geothermal energy
gravitational potential energy
heat
hydroelectric power
input energy
insulator
joule
kinetic energy
law of conservation of energy
light energy
magma
non-renewable
nuclear energy
output energy
potential energy
radiation
radioactive
renewable
rotational kinetic energy
solar energy
sound energy
sustainable
temperature
thermal energy
travelling wave
turbine
useful energy
waste energy
wave energy

ISBN 978-1-108-61069-8

Cambridge University Press

Concept map



ISBN 978-1-108-61069-8

Cambridge University Press

8.1 What is energy?

WORKSHEET

energy
the capacity to do work; the total amount of energy is conserved in any process

Energy is the ability to do work or make things happen. It can't be created or destroyed – that is, the amount of energy in our universe is always the same. However, energy can change form, be transferred from one object to another, or stored for later use. For all the different types of energy, the unit of measurement is **joules** (J).

joule
the unit of energy or work done

Our senses enable us to experience energy in different ways such as heat, light and movement. There are several different ways to classify these different types, but actually there are just two fundamental forms of energy: kinetic energy and potential energy. All the other forms are one or other of these, or a mixture of the two.

Kinetic energy

The energy an object has when it is moving or spinning is called **kinetic energy**. The amount of energy depends on the mass of the object and its speed.

kinetic energy
the energy an object has because it is moving

Figure 8.1 Fast-moving cars have a lot of kinetic energy.

Objects that are spinning also have kinetic energy, but this energy is called **rotational kinetic energy**.

rotational kinetic energy
the energy an object has because it is rotating

Potential energy

Some objects can store energy until it is ready to be used. This stored energy is called **potential energy**, because it has the potential to do work or make things happen. For example, a stretched rubber band has stored elastic potential energy. The energy is not being used at that point, but it has the potential to make something happen. Some forms of stored energy are summarised in Table 8.1.

VIDEO
Types of stored energy

potential energy
the energy stored in something because of its height above the ground, or because it is stretched or compressed, or in chemical form

Form of potential energy	Description
Gravitational potential energy (GPE)	Energy stored when an object is lifted off the ground; energy released when the object falls
Electrical energy	Energy stored in electrostatic situations (eg thunderclouds, capacitors); energy released when current flows (includes sparks like lightning)
Chemical potential energy	Energy stored in chemicals such as fuel and in batteries (when connected to an electric circuit, the chemical energy is converted to electrical energy); energy released in a chemical reaction
Elastic potential energy	Energy stored when an object is stretched or compressed; energy released when object returns to original size and shape
Nuclear energy	Energy stored in unstable (radioactive) atoms; energy released when atoms decay or undergo fission or fusion in unstable (radioactive) atoms

Table 8.1 Forms of energy that can be stored

ISBN 978-1-108-61069-8 Cambridge University Press

Forms of energy we can detect with our senses

We can detect kinetic energy with our senses, and there are other types listed in Table 8.2. Although these are forms of kinetic or potential energy or a mixture of the two, it is still useful to treat them as different forms of energy for practical purposes.

Form of energy	Description
Thermal energy	The energy in an object due to the random motion of its particles
Wave energy	The energy carried by a wave
Sound energy	The energy carried by a sound wave
Light energy	The energy carried by light (electromagnetic energy)

Table 8.2 Types of energy, other than kinetic energy, that we can sense

Thermal energy

In Year 7 you learned in particle theory that **heat** is related to the vibration and movement of the particles of matter. So heat is related to the kinetic energy of particles of matter. Now that you are in Year 8, you can use the more technical term for 'heat' and that is **thermal energy**. To change an object's **temperature** thermal energy needs to be either added (to raise it, i.e. heating) or subtract it (to lower it, i.e. cooling). The amount of thermal energy in an object depends on three things:

- temperature – hotter objects have more thermal energy than identical cold objects
- mass – heavier objects have more thermal energy than lighter ones of the same material and temperature
- material – some materials are better at storing thermal energy than others.

heat
thermal energy that is in transit due to differences in temperature

thermal energy
the kinetic energy of particles of matter

temperature
a measure of the average kinetic energy of the particles making up the material

The total thermal energy depends on all three factors. For example, a warm bath contains a lot more thermal energy than a burning match. This is because, even though the match has a higher temperature, the hot bath is much bigger, and water is very good at storing thermal energy.

Increasing the temperature of water is one of the most expensive energy costs in the home, because hot water requires a lot of heating and therefore thermal energy.

Figure 8.2 A warm bath contains more thermal energy than a burning match.

ISBN 978-1-108-61069-8

Cambridge University Press

Practical 8.1

Investigating thermal energy

Aim

To investigate the heating of different volumes of water when provided with the same amount of energy

Materials

- microwave oven
- glass beaker
- thermometer

> **Be careful**
> Ensure safety equipment is worn at all times. Do not stand over beaker once it has come out of the microwave oven.

Method

1. Put 200 mL of water in a beaker and measure the temperature. Record this in your results table.
2. Remove the thermometer and place the beaker in the microwave for 30 seconds.
3. Stir the water and measure the final temperature after it has been heated. Record in your results table.
4. Repeat steps **1–3** using 300 mL, 400 mL and 500 mL of water. Make sure the glass beaker is cooled between experiments, so that the initial temperature is the same. It might save time to start with four identical beakers with water at room temperature.

Results

Complete the following table with your results.

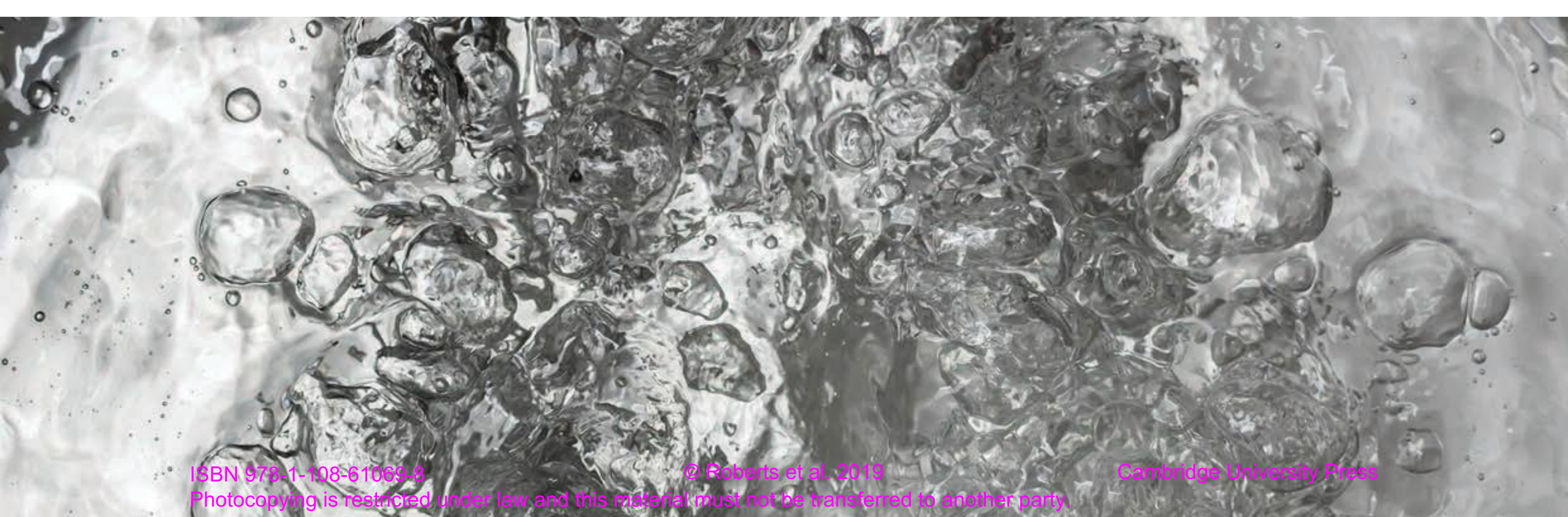
Volume (mL)	Initial temperature (°C)	Final temperature (°C)	Change in temperature (°C)	Volume × change in temperature
200				
300				
400				
500				

Evaluation

1. How did the change in temperature differ between volumes of water? Discuss your results.
2. What do you think would happen if a different liquid was used? Explain the reasoning behind your prediction.

Conclusion

1. Make a claim regarding temperature change and volume, from this experiment. Start your sentence with: 'This experiment suggests that the temperature increased … '.
2. Support your claim by using the data you gathered and include potential faults with the experiment. Start your sentence with: 'It was observed that … '.
3. Explain how the data supports your claim. Start your sentence with: 'This means that … '.



Quick check 8.1

1 Recall the unit for energy.
2 Look at Figure 8.3 and identify some of the different forms of energy you can see.

Figure 8.3 Birthday parties always involve energy!

3 Define the term 'thermal energy' of an object.
4 List the three factors that the total thermal energy of any object depends on.
5 Explain why a warm bath contains more thermal energy than a burning match.

Wave energy

Water waves carry **wave energy** as the waves move on the surface of the water. The waves can vary in size from small ripples formed when a stone is thrown into water, all the way up to ocean swell, long waves that travel along the surface of the ocean. Because waves in water are generally able to move from place to place, they are called **travelling waves**.

wave energy
the energy carried by a travelling wave (e.g. an ocean swell) or trapped in a standing wave (e.g. a guitar string)

travelling wave
a wave that can carry energy from one place to another

Figure 8.4 Water waves can have a lot of energy.

Water waves are not the only type of waves that can carry energy. Waves can travel through the Earth after an earthquake. These are also an example of a travelling wave. They occur when the ground suddenly moves, and can transmit a huge amount of energy.

Figure 8.5 An earthquake-damaged road in New Zealand

Sound energy

Sound energy is a form of wave energy; it consists of vibrations in the air. You will learn more about sound in the next chapter.

sound energy
a form of travelling wave; sound consists of vibrations in the air

ISBN 978-1-108-61069-8 Cambridge University Press

Science as a human endeavour 8.1

Printing using sound

Researchers at Harvard University have developed a method of printing using sound waves. The researchers used sound to control the size of the droplet being ejected from the printer nozzle, regardless of the viscosity (thickness) of the liquid. A higher amplitude of sound wave makes a smaller droplet. A wide range of liquids can be used, which means this technology has applications in many different industries, from pharmaceuticals to food.

Figure 8.6 Using sound waves in printing

Light energy

light energy
a form of energy that we can see with our eyes; part of the electromagnetic spectrum

electromagnetic spectrum
a way of organising electromagnetic waves according to their frequency

Light energy is a special kind of wave that is part of the **electromagnetic spectrum**. Light can travel through air or through a vacuum (such as space). You will learn more about light in the next chapter.

Did you know? 8.1

Light waves

A light wave is made up of energy in the form of magnetic and electric fields. These fields vibrate at right angles to the wave's direction of movement and at right angles to each other.

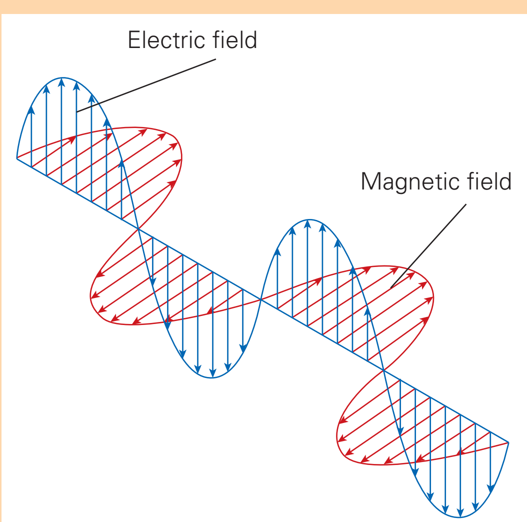


Figure 8.7 A light wave has an electric field and a magnetic field.

Quick check 8.2

1. Provide five examples of objects that could have kinetic energy.
2. Give two types of wave energy.

Gravitational potential energy

gravitational potential energy
a type of mechanical energy; the energy an object has because of its height; GPE = *mgh*

When an object is lifted, it gains **gravitational potential energy**. 'Gravitational' means related to the pull of the Earth, and 'potential' means the energy is stored for later. Gravitational potential energy (GPE) depends on three things: the strength of gravity, the mass of the object, and the height the object is lifted.

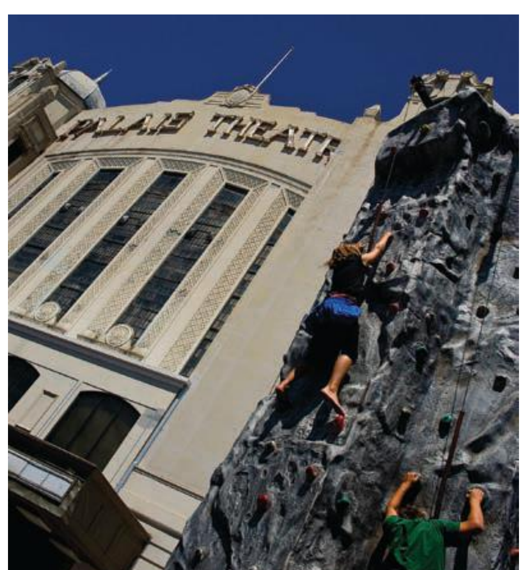


Figure 8.8 Rock climbers gain gravitational potential energy as they climb.

ISBN 978-1-108-61069-8 Cambridge University Press

Try this 8.1

Investigating energy with a bouncy ball

Take a bouncy ball and hold it higher than your head. Allow the ball to fall onto the floor and continue bouncing until it comes to rest.

Describe the transformations involved as GPE changes to KE until the ball stops. Explain where elastic potential energy fits in.

Electrical energy

electrical energy energy carried by electricity moving in a wire; voltage is used to measure how much energy is carried by each unit of eletricity

Electrical energy is carried by tiny, negatively charged particles, called *electrons*, that can move from one atom in a wire to the next, carrying energy as they do. Voltage (V) is related to the amount of electrical energy each electron carries. For example: AAA batteries supply 1.5 joules of electrical energy per unit of charge, so they have a voltage of 1.5 volts; cell phones operate at 5 volts; car batteries are 12 volts; in Australia, electricity in the home is 230 volts.

Did you know? 8.2

Tiny charges

An electron is so small that the unit we use for charge contains 6.24 million million million electrons.

Did you know? 8.3

Lightning strikes

Electrical energy can be very dangerous when it causes a large electric current to flow through the body. The highest voltages on Earth are in lightning strikes, which can be hundreds of millions of volts. Think about lightning strikes: what other forms of energy are released when lightning strikes?

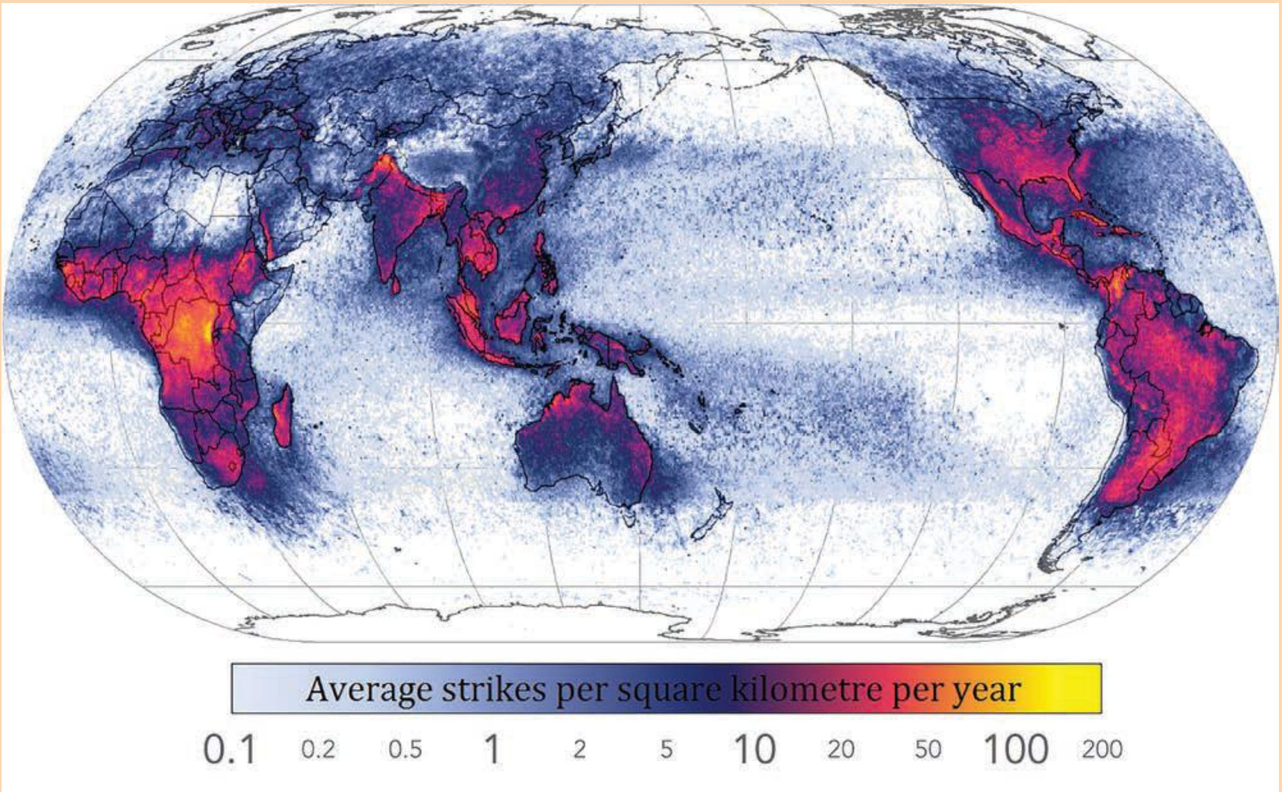


Figure 8.9 This map of the world shows where lightning strikes occur most often.

ISBN 978-1-108-61069-8

Cambridge University Press

Quick check 8.3

1 List some types of energy that can be stored.
2 Look at the following image of a playground. Explain where you would stand, to have the greatest gravitational potential energy.

Figure 8.10 Where is GPE greatest?

3 Figure 8.11 shows a roller coaster. Roller coasters are a great example of GPE. Answer the following questions, remembering that as an object loses GPE, it gains KE (kinetic energy).

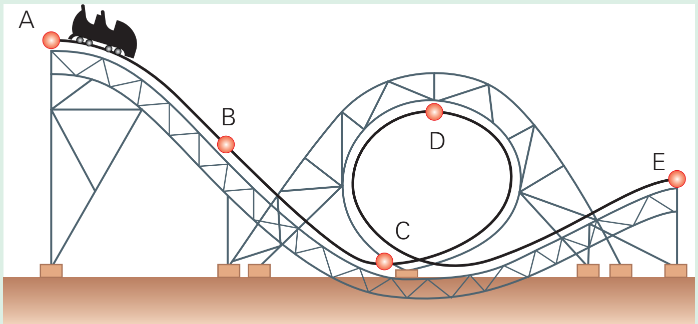


Figure 8.11 Roller coaster

a Identify the step (A, B, C, D or E) where the cart would have the greatest GPE.
b Identify the step where the cart would have the greatest KE.

Chemical potential energy (chemical energy)

Many substances contain stored **chemical potential energy**, which can be released in a chemical reaction. For example:

chemical potential energy
the energy stored in the molecules of a chemical

- When fireworks are lit, chemical potential energy is released as heat, sound and light.
- Trees store chemical potential energy in their wood, and it is released when the wood is burned.
- The food we eat contains chemical potential energy, which is released slowly in our bodies, giving us the energy we need to keep warm and move around.
- Cars that use petrol as fuel have engines that convert the chemical energy in petrol to kinetic energy, heat and sound.

ISBN 978-1-108-61069-8

Figure 8.12 Fireworks over Melbourne. Fireworks contain chemical potential energy, which is released when the fireworks are lit.

Elastic potential energy

Elastic potential energy is energy that is stored whenever an elastic material is either stretched or compressed by a force. For example, energy is stored in a rubber band when it is stretched, and in a rubber ball when it is compressed. Trampolines, bungee cords and metal springs are all examples of objects that can store elastic energy. Another name for elastic potential energy is 'spring energy'.

elastic potential energy the energy stored when an elastic material is compressed or stretched

Figure 8.13 A giant rubber band stores energy when it is stretched.

Figure 8.14 A bungee cord stores elastic potential energy when it is stretched.

ISBN 978-1-108-61069-8

Try this 8.2

Exploring elastic potential energy

Take a rubber band and stretch it as tightly as possible. Explain how the stretched rubber band is an example of potential energy. Point the rubber band at the wall and let it go. Explain how the potential energy stored in the band was converted to a different form of energy.

Nuclear energy

The *nucleus* (plural *nuclei*) of an atom contains **nuclear energy**, a form of potential energy. Most atoms are stable and don't release the energy but the **radioactive** atoms of some elements break down, emitting electromagnetic wave energy and/or particles with kinetic energy. The energy released shows up as heat when absorbed by the surrounding material. One kind of radioactivity is called fission ('splitting'). Nuclear power stations use *fission* reactions in radioactive material such as uranium to produce thermal energy which in turn is used to generate electricity.

nuclear energy
a non-renewable source of energy that uses the energy released by the nucleus of radioactive atoms

radioactive
having or producing the energy that comes from the breaking up of atoms

Unfortunately, such radiation can be hazardous to health. Great care has to be taken to prevent people being exposed to it in nuclear power stations.

Did you know? 8.4

Nuclear energy and the Sun

Energy can also be released when two smaller atoms join to make a bigger atom, in a process called *fusion*. The Sun generates all its energy from this process. In fact, it is not just the Sun – the whole universe is full of stars that are fusing hydrogen into helium, releasing light and heat as they do so. Two atoms of hydrogen are fused to make one atom of helium, and a small amount of mass is turned into a large amount of heat.

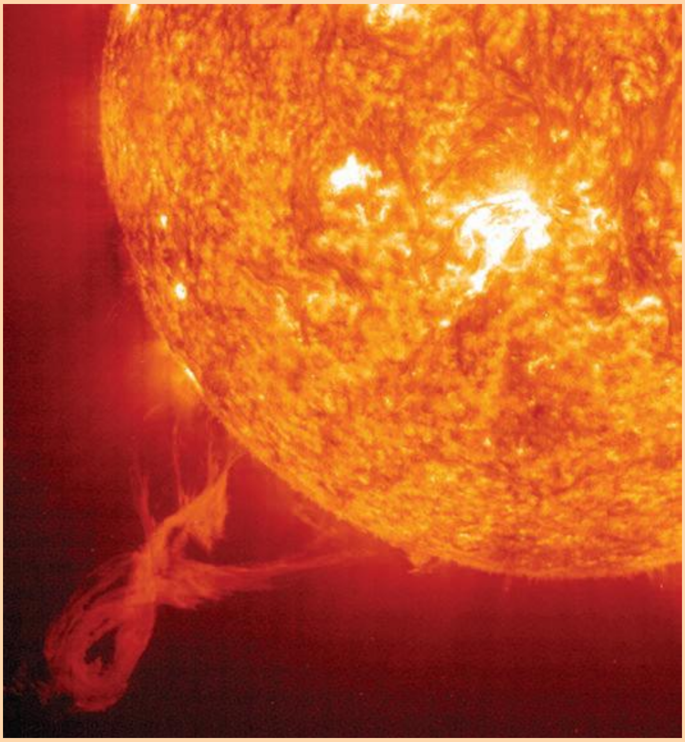


Figure 8.15 Nuclear energy has allowed the Sun to keep shining for at least 4 billion years.

Quick check 8.4

1 State three examples of chemical potential energy.
2 Explain when elastic potential energy is stored.
3 State the name of the process in which energy is released from the nucleus when it breaks apart or releases a particle.

Try this 8.3

A world without energy

Think about a world in which there is no electrical energy. Suppose there was no light or sound energy either. Could life exist in such a world? Write down a few sentences to say if you think it could, and what it would be like. Now imagine that there is no potential or kinetic energy of any type. What would that world be like? Discuss and collate your ideas as a class and see if you agree.

ISBN 978-1-108-61069-8 Cambridge University Press

QUIZ

Section 8.1 questions

Remembering

1 Copy and complete the table below.

Form of energy	Definition	Is this an example of potential energy?
Kinetic energy		
	Energy an object possesses when it is lifted	
Chemical energy		Yes

2 Describe a situation that involves elasic potential energy.

3 Describe how sound energy travels.

4 Recall the three factors that determine how much thermal energy is present in an object.

5 State the form of energy contained in a piece of wood.

6 State the form of energy a piece of wood gives out when it burns (Figure 8.16).

Figure 8.16

Understanding

7 Explain what is meant by the term 'potential energy'.

8 Explain why it is harder to stop a bicycle when it is going downhill than when it is going uphill.

9 Identify the form of energy other than heat gained when a person climbs stairs (Figure 8.17).

10 Identify the forms of energy emitted by lightning (Figure 8.18).

11 Identify a form of energy that is *not* a form of wave energy.

Figure 8.17

12 Identify the forms of energy possessed by a hot air balloon when it is aloft (Figure 8.19).

13 Identify the main form of energy that peanuts contain.

Figure 8.18

Figure 8.19

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Applying

14 Look at the diagram in Figure 8.20 and use it to answer the following questions.

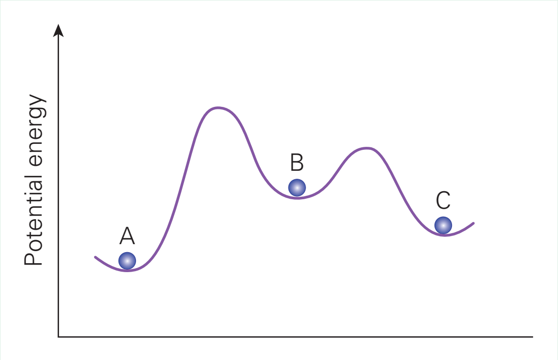


Figure 8.20

- **a** Which letter represents the position where the ball has the most GPE?
- **b** If the ball moved from C to A, would there be an overall gain or loss of GPE?

15 Explain which balloon in Figure 8.21 has the most elastic potential energy.

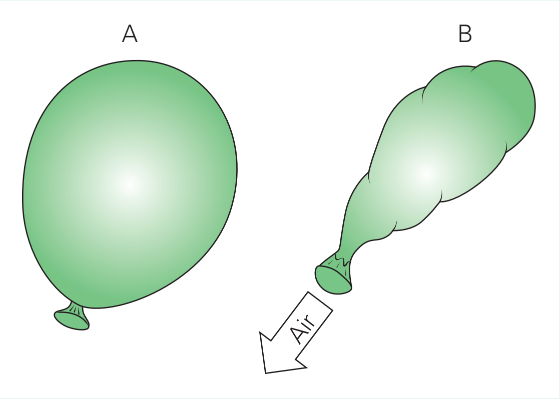


Figure 8.21

Analysing

16 Analyse the following list of energy sources, and rank them from most used to least used in your household.

Electrical energy
Chemical energy
Sound energy
Light energy
Thermal energy

17 List all the different forms of energy that you can see evidence of in Figure 8.22.

Figure 8.22

Evaluating

18 List the devices in your home that use energy. Include at least two that don't use electricity, and at least one of these should be a manual (unpowered) device. For each device in the list, state the form of energy used as the input (that operates them) and the forms of energy that they output (include the 'useful' output as well as the outputs that represent wasted energy).

ISBN 978-1-108-61069-8 Cambridge University Press

8.2 Energy is conserved

WORKSHEET

Objects possess energy, and energy can be changed from one form to another. When energy changes from one form to another, it obeys the **law of conservation of energy**, which states that 'Energy can neither be created nor destroyed'. In any process, the amount of energy present at the beginning must equal the amount of energy present at the end, taking into account all the energy gained or lost. In everyday life this law always holds. However, early in the last century, Einstein found an exception. He discovered that mass and energy are equivalent and can be converted into one another!

law of conservation of energy
the law that states that energy cannot be created or destroyed

Figure 8.23 Street lights in Melbourne. The law of conservation of energy means the amount of electrical energy used by each light is exactly the same as the amount of heat and light energy given out.

Did you know? 8.5

Where does the Sun get its energy from?

Einstein stunned the world when he proposed that mass can be converted into energy (and vice versa), according to a simple and famous formula:

$$E = mc^2$$

In this formula, E = energy, m = mass and c = the speed of light (3×10^8 m/s). Basically, the formula means that a small amount of mass can be converted into a lot of energy, or the reverse.

This explains where the Sun has been getting its energy from, to shine so bright for so long. Deep inside the Sun, nuclear reactions are converting 4300 million kilograms of matter into energy every second. This energy is emitted at the Sun's surface as heat and light.

Will the Sun ever run out of fuel? Luckily for us, the answer is: not for a very long time. The Sun is so big that, even at its current rate, much less than 1% of its mass has been radiated away since it was formed. Current estimates indicate that it will be at least 1.75 billion years before the Earth becomes uninhabitable.

Figure 8.24 The Sun will not run out of fuel any time soon – *phew*!

ISBN 978-1-108-61069-8

Quick check 8.5

1 State the law of conservation of energy.
2 Explain the meaning of the law of conservation of energy.

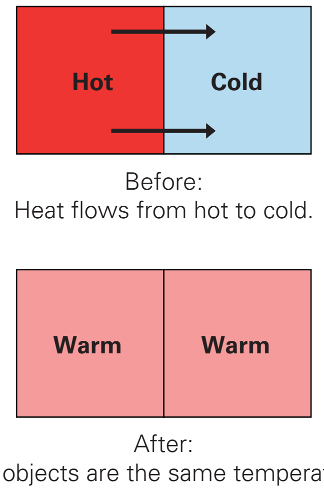


Figure 8.26 Heat (thermal energy in transit) flows from hot to cold, until the objects are at the same temperature.

Energy transfer

Kinetic transfer

Energy is the ability of an object to do work, and this energy can be transferred from one object to another. This is known as an **energy transfer**. For example, a golf club has kinetic energy when it swings through the air. When the club hits a golf ball, this kinetic energy is transferred to the ball, making it move.

energy transfer the movement of energy from one place or object to another

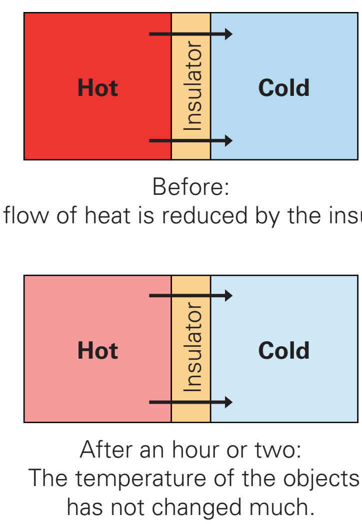


Figure 8.27 If an insulator, such as plastic or foam, is placed between the hot and cold objects, the heat flow between them is reduced.

Figure 8.25 A golfer preparing to transfer kinetic energy from the golf club to the ball

Heat transfer

Thermal energy is another type of energy that can be transferred. If a hot object is placed next to a cold object, thermal energy will flow from the hot object to the cold object. The thermal energy will continue to flow until the objects are the same temperature. Thermal energy always flows naturally from hot to cold, never the other way around.

There are three different ways in which thermal energy can be transferred from a hot object to a cold object:

- **conduction**
- **convection**
- **radiation**.

conduction the process by which thermal energy travels through a material or between materials from hot regions to cooler regions by the collisions of molecules

convection the flow of thermal energy though a fluid material by the movement of the material itself, often caused by temperature differences.

radiation one of the three ways that thermal energy can travel, and the only way that heat can travel through a vacuum

ISBN 978-1-108-61069-8 Cambridge University Press

Conduction

When heat is transferred between particles of matter (molecules), it is referred to as conduction. A hotter particle, object or region naturally transfers thermal energy to a colder particle, object or region. When substances are heated, their particles start to vibrate faster. If a hot faster-vibrating particle bumps into a cooler slower-vibrating one, it transfers some energy to it. This causes the cooler slower-vibrating particle to vibrate faster, making it hotter.

Note that conduction does not happen only in the solid state. A hot solid surface transfers heat to cooler gas or liquid particles in contact with it by conduction.

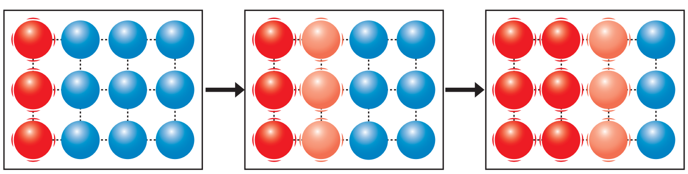


Figure 8.28 A time sequence showing heat flowing through the particles of a solid by conduction. The heat source (not shown) is on the left of the particles. At first only the particles next to the heat become hot and vibrate. They bump into the particles next to them, which warm up, and so on.

Conduction occurs when you warm up your hands when holding a hot drink. Your hands warm up because thermal energy is being transferred from the mug to your hand.

Figure 8.29 Warming up your hands with a hot drink on a cold day is an example of conduction.

How would holding the hot drink feel different if it was a polystyrene cup? Or a metal cup? Some substances, such as metals, are good **conductors** of heat. Other materials, such as polystyrene, do not conduct heat well and so we call them **insulators**.

conductor
a substance or material that allows heat to pass through it easily

insulator
a substance or material that does not allow heat to pass through it easily

Try this 8.4

Heat-sensitive slime

You will need:

- $\frac{1}{4}$ cup PVA glue
- 1 tablespoon of water
- food colouring
- 3 teaspoons of thermochromatic pigment
- $\frac{1}{4}$ cup liquid starch.

Mix together the glue, water and food colouring. Then mix in the thermochromatic pigment. Add half of the liquid starch and mix until combined. Your slime should be thick and slimy.

Mix in the rest of the starch, bit by bit, until well combined. Your slime will no longer be sticky.

Observe what happens as the slime cools. When it is hot, it will be the colour of the food colouring. When it is cold, it will be the colour of the thermochromatic pigment.

Convection

Convection is the flow of thermal energy through a liquid or a gas caused by movement of the liquid or gas itself. Heating water in a pot and warming up a room with an oil heater are both examples of heating via convection.

Have you ever heard the saying, 'Hot air rises'? That's because it does. When a liquid or a gas is heated, the particles vibrate faster and the liquid or gas expand. This means that the hot regions are less dense than the cooler regions, and so the hotter regions rise. Figure 8.30 on the following page shows water in a pot being heated from the bottom, causing the hot water to rise. The cold water sinks and takes its place at the bottom, and is heated. This cycle is called a 'convection current'.

ISBN 978-1-108-61069-8 Cambridge University Press

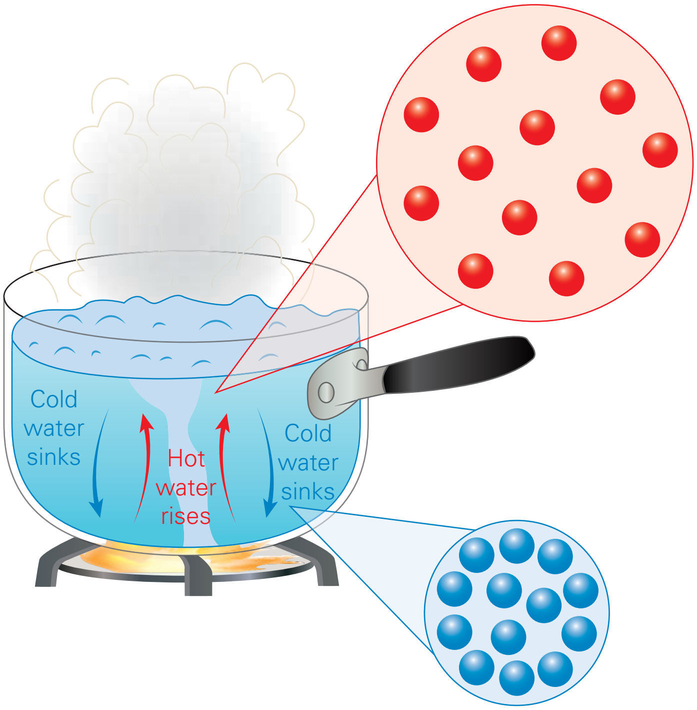


Figure 8.30 When water is heated, the hotter less dense water at the bottom rises and the colder more dense water sinks to take its place.

Convection is a major factor driving weather patterns. The Sun heats the Earth's surface, warming the air, which then rises, creating an upward current in the atmosphere. That current can result in wind, clouds or other weather. Within the Earth, convection currents move layers of **magma**. In the oceans, convection creates currents.

magma
molten rock under the Earth's surface

Convection spiral

Try this 8.5

Take a piece of paper and cut out a spiral that is 6 cm in diameter. Attach a piece of string to the centre of the spiral. Turn on a desk lamp and shine it towards the ceiling. Hold the spiral by the string, suspended 10 cm over the top of the lamp. Observe what happens, and explain why.

Radiation

Any hot object radiates heat. You do not need to be in contact with the object to feel the radiant heat. This is why you can feel the warmth of a radiant heater when you stand in front of it, or feel the Sun's warmth when you are outside. Radiant heat travels in waves because it is a form of electromagnetic radiation (infrared radiation). It does not rely on particle movement. Your toaster also works via radiant heat. The bread does not touch the source of heat but gets toasted because of the transfer of thermal energy through space by radiation.

Figure 8.31 Bread being toasted via radiant heat transfer

How do animals stay warm?

Explore! 8.1

Conduction, convection and radiation all play an essential role in nature. All warm-blooded animals can generate their own body heat, and radiate thermal energy. Cold-blooded animals need to lie in the sun to get warm.

Research how animals living in cold environments prevent heat loss via conduction, convection and radiation.

Quick check 8.6

1 Define the term 'energy transfer'.
2 Provide three examples of energy transfer.
3 Explain how thermal energy travels around a liquid or a gas.

ISBN 978-1-108-61069-8 Cambridge University Press

Practical 8.2: Self-design

Self-design: Modelling heat transfer

Aim

To design your own experiment that models the three types of heat transfer

Materials

- metal, wooden and plastic spoons
- water
- Bunsen burner
- tea bags and tea leaves
- ice blocks
- radiant heater

Method

Design an experiment that demonstrates the three types of heat transfer. In a group, discuss ways in which you could do this. Choose the best method and write a step-by-step method for how you will carry out the experiment.

Results

Record your observations for each of the experiments in an appropriate manner.

Evaluation

1. Explain how your self-designed experiments demonstrated how thermal energy is transferred through conduction, convection and radiation.
2. Propose some ways in which your experiments could have been improved.

Conclusion

1. Make a claim regarding how thermal energy can be transferred. Start your sentence with: 'This experiment suggests that thermal energy … '.
2. Support your claim by using the data you gathered, and include potential sources of error in any measurements you make. Start your sentence with: 'It was observed that … '.
3. Explain how the data supports your claim. Start your sentence with: 'This means that … '.

Science as a human endeavour 8.2

Powered by the Sun

Researchers have discovered a new material that could provide solar thermal power cheaper, and of course solar power has zero greenhouse gas emissions. By combining ceramic zirconium carbide and the metal tungsten, scientists at Purdue University have created a composite material that can withstand high heat and pressure. This technology will allow heat exchangers at solar thermal power plants to run at extremely high temperatures, generating electricity more efficiently. It is also more efficient to store energy as heat rather than in batteries. This may make solar thermal power stations an attractive alternative to solar power stations that use photovoltaic panels which convert sunlight directly into electricity..

Figure 8.32 A solar furnace like this turns the Sun's radiation into heat, reaching above 3500°C. Such a furnace could be used to generate electricity, though this one in France is used for research into materials at high temperatures.

ISBN 978-1-108-61069-8

Energy transformations

There are many ways in which energy can be converted from one form to another. Combustion involves burning, and converts chemical energy into heat and light.

generator
a device that converts rotational kinetic energy into electrical energy, the opposite of a motor

turbine
a device that converts the kinetic energy of a fluid into rotational motion, for example a windmill

Machines use fuel or electrical energy and convert it into kinetic energy. **Generators**, powered by steam **turbines**, can convert kinetic energy into electrical energy.

In leaves, the biological processes in photosynthesis convert light energy from the Sun into chemical energy in the form of carbohydrates, such as sugars.

Energy transformations can be represented in a flow diagram (see Figure 8.33). On the left-hand side of the flow diagram are the energy inputs. On the right-hand side are the energy outputs. Waste energy may be included as an energy output, but is sometimes omitted. A brief description of how the machine works may be placed between them, and arrows can be added to show the flow of energy.

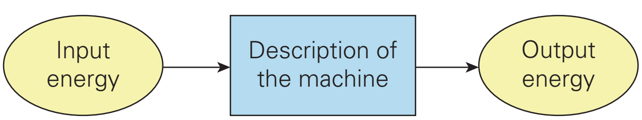


Figure 8.33 A simple energy flow diagram

For example, Figure 8.34 shows the energy flow diagram for a candle that has been lit.

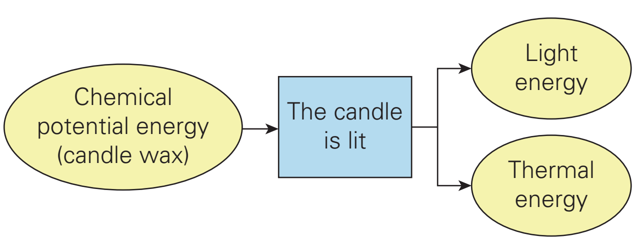


Figure 8.34 Energy flow diagram for a candle burning

Some energy flow diagrams may have intermediate steps involving another form of energy. For example, a battery-powered torch has a more complex energy flow diagram (see Figure 8.36).

Investigating an electric kettle

An electric kettle uses electrical energy to boil water. It contains a heating element that gets hot when electricity passes through it. The heating element then heats up the water in the kettle to 100°C, at which point the water boils.

Figure 8.36 An electric kettle converts electrical energy into thermal energy.

Figure 8.37 shows a flow diagram representing the changes in energy in the example of the kettle.

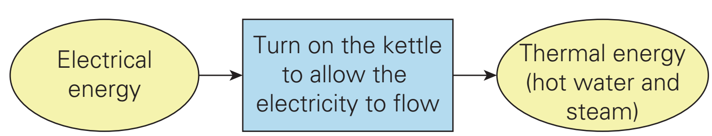


Figure 8.37 Energy flow diagram for an electric kettle

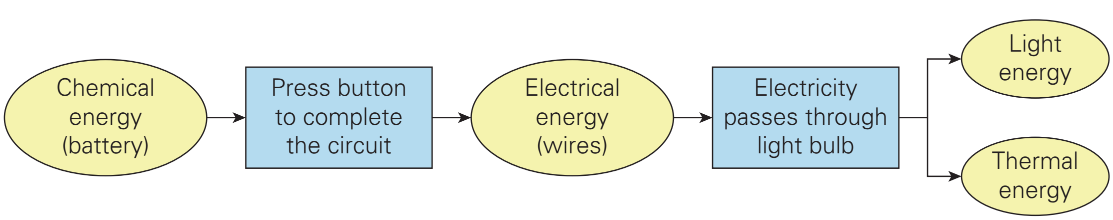


Figure 8.35 Energy flow diagram for a battery-powered torch

Quick check 8.7

1 Explain what occurs during an energy transformation.
2 Provide two examples of an appliance that transforms energy.

Investigating a car accelerating from rest

A petrol-powered car accelerating on a flat road uses its engine to convert the chemical potential energy of the fuel into kinetic energy as the car increases its speed.

Figure 8.38 An accelerating car is gaining kinetic energy.

Figure 8.39 shows a flow diagram for a petrol-driven car accelerating from rest.

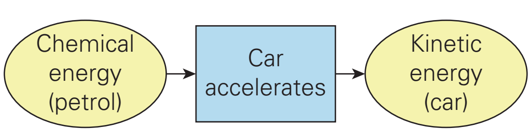


Figure 8.39 Energy flow diagram for a petrol-driven car accelerating from rest

If the car was powered by an electric battery, then the energy flow diagram would be slightly different (Figure 8.40).

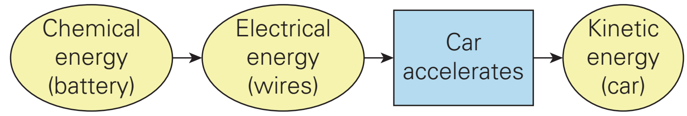


Figure 8.40 Flow diagram for a battery-powered car accelerating from rest

Try this 8.6

Transforming potential energy into kinetic energy

Stand with your legs far apart and your arms above your head, in a star-jump position. Discuss what type of energy you are storing as you hold this position. As you complete a star-jump, think about what type of energy your stored energy is being transformed into. With your classmates, discuss which parts of your star-jump contain stored energy and which parts use kinetic energy.

Investigating a bow and arrow

When a bow is stretched to shoot an arrow, the wood bends with an elastic force, and this stores energy. The further the bow is pulled, the more energy is stored. When the arrow is released, the elastic potential energy is converted to kinetic energy as the arrow increases its speed.

Figure 8.41 A bow converts elastic potential energy to kinetic energy.

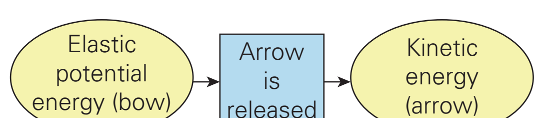


Figure 8.42 Energy flow diagram for an arrow being shot from a bow

ISBN 978-1-108-61069-8 Cambridge University Press

Investigating a hot air balloon

The operation of a hot air balloon involves two energy changes. When the hot air balloon first takes off, chemical potential energy is stored in the form of natural gas (in the gas cylinder in the basket of the balloon). When the gas is burned, it releases thermal energy, which heats up the air in the balloon. The air in the balloon expands as it warms up, and this makes the air inside the balloon lighter than the air around the balloon. The balloon then rises, due to buoyancy forces, gaining kinetic energy and gravitational potential energy as it gains altitude.

Investigating an aircraft taking off

Sometimes a machine can convert a source of energy into two forms at the same time. When an aeroplane takes off, it starts moving slowly from one end of the runway and then accelerates under full power until it leaves the ground at the other end. When it first starts its take-off, the jet has chemical potential energy stored in the form of aviation fuel in its tanks. The fuel is ignited in the jet engines to create a force that accelerates the aircraft along the runway, gaining kinetic energy as it does so. When the

VIDEO
Energy transformations in a hot air balloon

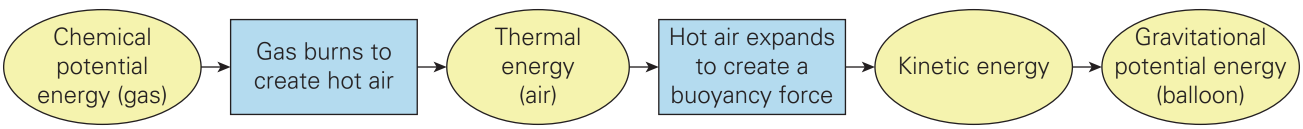


Figure 8.43 Energy flow diagram for a hot air balloon

Figure 8.44 A hot air balloon converts chemical energy to thermal energy, then kinetic energy as it moves, then gravitational potential energy.

ISBN 978-1-108-61069-8

Cambridge University Press

aeroplane reaches sufficient speed, it lifts off and gains gravitational potential energy as it rises into the air.

Look closely at the picture of the aircraft taking off, and you can see that the air behind the aircraft's engines is blurred. This is because it is hot. The thermal energy produced by the aircraft's engines should be added to the energy flow diagram. Aircraft are also very noisy when taking off, so sound energy is also produced. To describe the flow of energy in an aircraft engine, you need to remember to include waste energy, such as heat and sound.

WIDGET
Energy forms and transformations

Figure 8.45 An aircraft converts chemical potential energy to kinetic energy and gravitational potential energy.

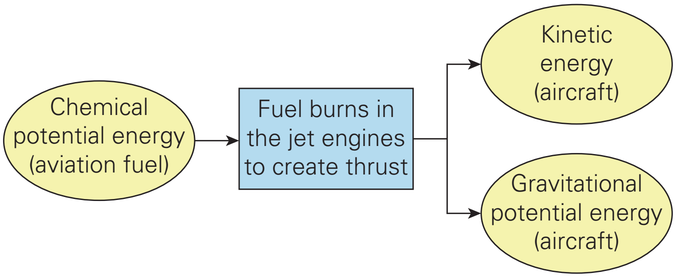


Figure 8.46 Energy flow diagram for a jet aircraft taking off

In Figure 8.47, the two forms of waste energy have been added to the flow diagram for the jet aircraft. The approximate

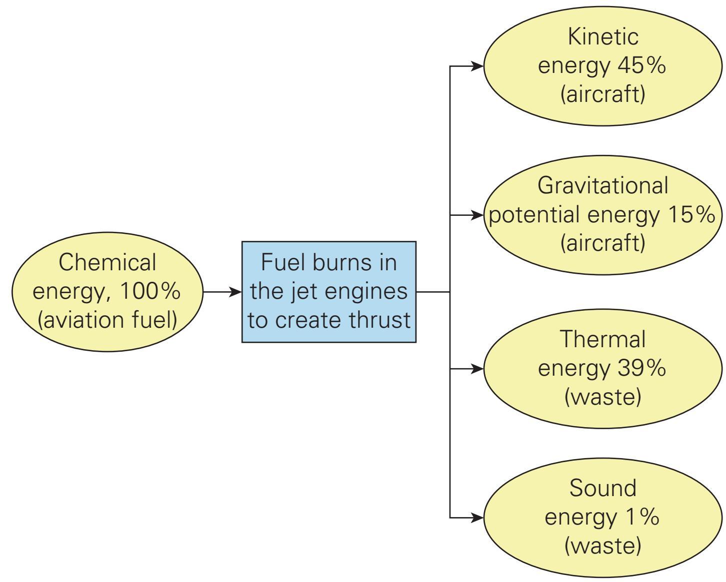


Figure 8.47 Energy flow diagram for a jet aircraft taking off, with waste energy added

percentages of each type of energy have also been added. These can be included if they are known. Remember, the total amount of **input energy** must exactly equal the total **output energy** when waste energy is included.

input energy
the energy that a machine or device uses as its source of energy

output energy
the energy that a machine or device provides or wastes

In this example, the useful energy is kinetic energy (45%) and gravitational potential energy (15%), which adds up to 60%. This means that 60% of the energy input is converted to useful energy and the efficiency rating of the aircraft's engines is 60%. The other 40% is wasted through heat and sound energy.

Quick check 8.8

1 Draw flow diagrams for the following energy transformations.
  a A television converting electrical energy to sound and light
  b A light bulb converting electrical energy to light and heat
  c A human converting chemical potential energy from food into kinetic energy when moving

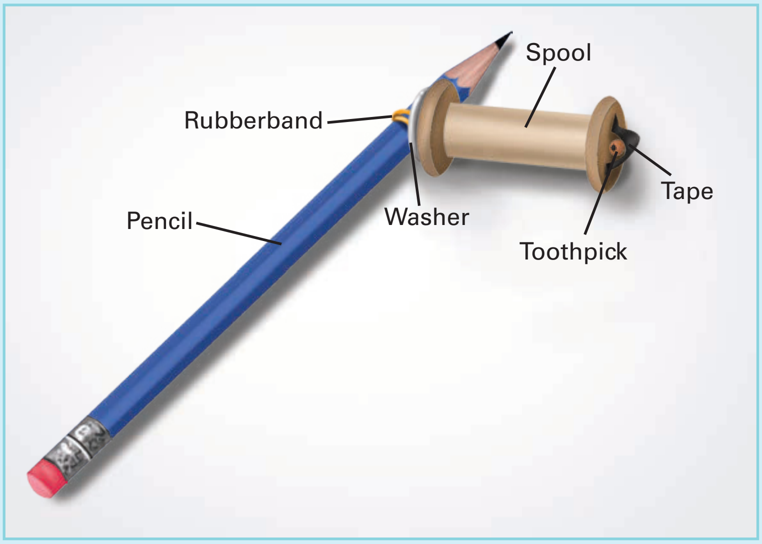
ISBN 978-1-108-61069-8 Cambridge University Press

Practical 8.3

Spool racer

Aim
To demonstrate how a rubber band can store and transform energy

Materials
- wooden spool (from spools of thread)
- rubber band
- washer
- toothpick
- tape
- pencil



Method
1 Insert the rubber band through the hole of the spool so some of it is sticking out at each end.
2 Insert a toothpick into the rubber band loop that sticks out of the spool hole, and tape the toothpick and rubber band loop to the spool. Break off any length of the toothpick that is wider than the spool diameter.
3 On the other side of the spool, insert the other end of the rubber band through a washer.
4 Insert a pencil through the rubber band loop that sticks out from the washer.
5 Give the pencil two twists, so it winds up the rubber band inside the spool.
6 Set the spool and pencil down on a counter or floor and let go.
7 Record your results as per the results table.
8 Increase the number of twists for subsequent trials and repeat steps **6–7**.

Results

Trial	Number of turns of rubber band	Observations
1	2	
2		
3		

Evaluation
1 Describe what happens as the spool racer is released.
2 Explain where the energy used to drive the racer comes from.
3 Describe what happened as the number of turns of the rubber band increased.

Conclusion
1 Make a claim regarding energy storage and transformation in rubber bands. Start your sentence with: ‘This experiment suggests that rubber bands … ’.
2 Support your claim by using the data you gathered. Start your sentence with: ‘It was observed that … ’ .
3 Explain how the data supports your claim. Start your sentence with: ‘This means that … ’.

ISBN 978-1-108-61069-8 Cambridge University Press

Energy efficiency

efficiency
the percentage of input energy that is converted to useful energy by a machine

useful energy
the output energy that a machine is designed to produce; an efficient machine will maximise the useful energy it creates

The **efficiency** of a machine is a measure of how good the machine is at converting the input energy to **useful energy**. The percentage of input energy that is converted to useful energy is used to give the machine an efficiency rating.

The formula used to calculate the efficiency rating of a machine is:

$$\text{Efficiency (\%)} = \frac{\text{useful output energy}}{\text{input energy}} \times 100$$

Figure 8.48 Running upstairs converts chemical energy into GPE.

Examples of efficiency calculations

Example 1

A kettle uses 261 500 J of electrical energy to heat 500 mL of water. If the thermal energy of the water is 209 200 J, calculate the efficiency of the kettle.

$$\begin{aligned}\text{Efficiency (\%)} &= \frac{\text{useful output energy}}{\text{input energy}} \times 100 \\ &= \frac{209\,200}{261\,500} \times 100 \\ &= 80\%\end{aligned}$$

Example 2

A girl runs upstairs and uses up 4000 J of energy from food she has eaten. If she gains 1000 J of gravitational potential energy, calculate the efficiency of her muscles.

$$\begin{aligned}\text{Efficiency (\%)} &= \frac{\text{useful output energy}}{\text{input energy}} \times 100 \\ &= \frac{1000}{4000} \times 100 \\ &= 25.0\%\end{aligned}$$

The other 75% would be waste energy, lost mainly as heat as she climbs.

Try this 8.7

Calculating energy efficiency

Calculate the energy efficiency of each of the globes shown below. State which globe is no longer recommended for household use, and justify your choice.

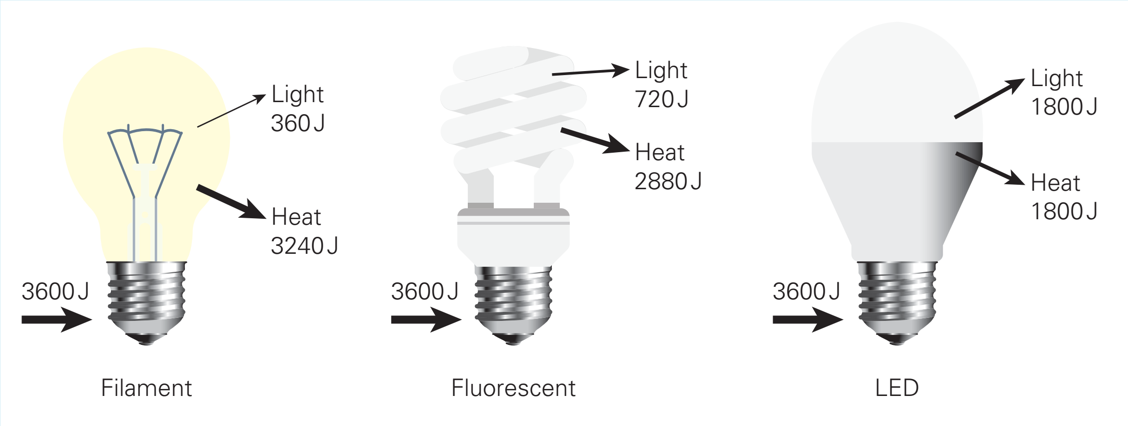


Figure 8.49 How efficient is each type of globe?

ISBN 978-1-108-61069-8 Cambridge University Press

Waste energy

An electric light uses electrical energy to create light as useful energy; any heat produced is **waste energy**. A petrol-driven lawnmower converts chemical energy in the petrol into kinetic energy and rotational kinetic energy, with heat and sound as waste forms of energy.

waste energy
the output energy that a machine creates that is not useful; waste energy is often in the form of thermal energy and sound

Figure 8.50 A petrol-powered lawnmower

When a candle burns, chemical potential energy is converted by combustion into light, with heat released as waste energy. A television converts electrical energy to light and sound, which are useful, and thermal energy, which is waste.

A two-step example is a battery-powered torch. The input energy source is chemical potential energy in the battery. This is converted first to electrical energy and then to light energy in the bulb, with some waste heat also. In the same way, a battery-powered radio converts chemical energy (in the batteries) to electrical energy, then to sound.

Useful energy is the output energy the process is designed to produce. Waste energy is any other form of energy, usually heat or sound, that is not wanted.

Figure 8.51 A battery radio converts chemical energy in the batteries into sound energy.

Did you know? 8.6

Efficient light globes

Old-fashioned incandescent light bulbs work by passing electricity through a thin metal filament, which glows white hot. However, about 90% of that electrical energy is transformed into thermal energy. These days, compact fluorescent lights (CFLs) and light-emitting diodes (LEDs) are more efficient. About 50% of the electrical energy is wasted as heat.

Quick check 8.9

1 Define 'energy efficiency'.
2 Give an example of the useful and waste energy produced by each of the following devices.

Device	Useful energy output	Waste energy output
Light bulb		
Car		
Lawnmower		

3 A light bulb uses 3000 J of electrical energy. Of this, 600 J is transformed into light energy and 2400 J is transformed into thermal energy. Calculate the energy efficiency of this globe.

ISBN 978-1-108-61069-8 Cambridge University Press

Practical 8.4: Self-design

Energy efficiency of bouncy balls

Aim
To investigate which type of bouncy ball is most energy efficient

Materials
- a range of bouncy balls
- meter rulers

Method
Design an experiment that will test the rebound height of a range of bouncy balls. In a group, discuss how you will carry out this experiment, and write out a step-by-step method.

Results
Record your results in a results table.

Evaluation
1. By using the energy efficiency equation, calculate the efficiency of each type of ball. Use the drop height and the rebound height in your calculations.
2. Identify sources of uncertainty in your experiment.
3. Suggest how your experiment may be improved.

Conclusion
1. Make a claim regarding bouncy balls and energy efficiency from this experiment. Start your sentence with: 'This experiment suggests that the bouncy balls … '.
2. Support your claim by using the data you gathered and include potential sources of error in any measurements you made. Start your sentence with: 'It was observed that … '.
3. Explain how the data supports your claim. Start your sentence with: 'This means that … '.

QUIZ

Section 8.2 questions

Remembering
1. Describe the difference between an energy transfer and an energy transformation.
2. Recall the three ways in which heat can be transferred.
3. Complete the following sentences.
   Heat naturally moves from a __________ object to a __________ object. A liquid or gas is generally heated through the process of __________. Heat moves through __________ in a process called conduction.

Understanding
4. Using the law of conservation of energy, explain why a light bulb gives off thermal energy.
5. Explain how the Sun's thermal energy reaches Earth, if space is a vacuum.
6. Explain why the process of convection is important in nature.
7. Describe the energy transformation that occurs in the Sun.
8. Describe four situations that involve potential energy.

continued…

ISBN 978-1-108-61069-8 © Roberts et al. 2019 Cambridge University Press

...continued

Applying

9 Draw an energy flow diagram for each of the following situations.

- **a** A stone is dropped from the top of a building.
- **b** A car is slowing down as it moves up a hill.
- **c** A charcoal fire is burning in a barbeque.
- **d** A bungee jumper jumps from the top of the jump to the bottom.
- **e** An electric tram starts from rest and builds up to full speed.
- **f** A person rides on an escalator from the bottom to the top.
- **g** A sheepdog runs up a hill.

Figure 8.52

Figure 8.53

Figure 8.54

Figure 8.55

Analysing

10 Think about all the different types of energy we encounter every day – driving a car is one example. Pick another example and suggest how you can make the process more energy efficient.

11 Look closely at Figure 8.56.

- **a** Identify the components of the playground that involve gravitational potential energy.
- **b** Suggest ways in which elastic potential energy could be incorporated into this playground setting.

Figure 8.56

Evaluating

12 Cars are energy inefficient. State the input form of energy and the useful and wasted forms of energy. Propose some other forms of transport that are more energy efficient.

ISBN 978-1-108-61069-8 Cambridge University Press

8.3 Applications of energy

Energy in housing

WORKSHEET

In our homes, there are machines or appliances that we use in our daily lives. Some appliances use little energy, others use a lot, some are very efficient and some are inefficient. The energy source for most appliances in the typical home is mainly electricity, although gas and **solar energy** are also widely used. Items that use little energy, such as radios and torches, can use batteries as the source of energy.

solar energy
a renewable source of energy that converts sunlight directly into electrical energy or thermal energy

One of the big expenses in maintaining a home is the cost of energy. Electricity and gas are both expensive; however, solar energy is free (once you have paid for the solar panels and their installation). Electricity can be generated on the roofs of houses, using solar panels. Thermal energy from the Sun can also be used to heat water directly, using solar water heaters.

Figure 8.57 This house has solar panels on the roof to generate electricity. It also has two panels (at the top right-hand side of the picture) for generating hot water.

Energy ratings

Most appliances have an energy rating label. This is to help people make an informed decision about an appliance they are thinking of buying, by giving them information about its energy efficiency.

The star rating of an appliance allows you to compare the energy efficiency of similar models. The more stars an appliance has, the more energy efficient it is. The label also informs you of the energy consumption of the appliance. The lower this number, the less it will cost to run the machine.

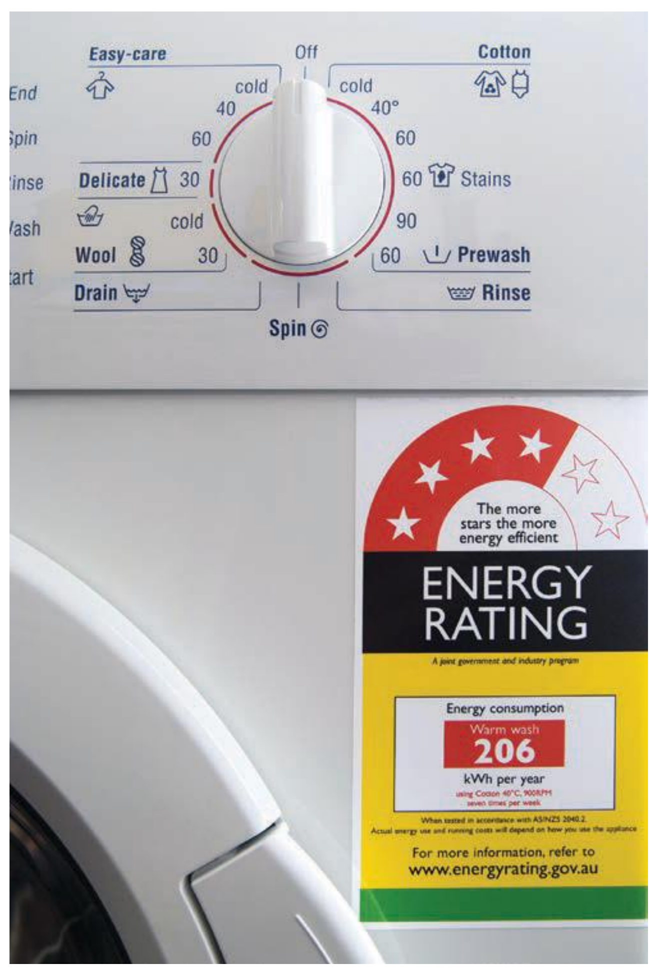


Figure 8.58 Energy rating label on a washing machine

ISBN 978-1-108-61069-8

Home electricity audit

Try this 8.8

Use the Australian Government's 'Energy rating calculator' website to audit the energy efficiency of appliances around your house. You may choose to investigate your TV, washing machine, dishwasher or fridge. Compare how much it costs to run each appliance for a year.

Which appliance costs the most to use? Choose one appliance and compare its yearly running costs with a classmate. Who has the more cost-saving model?

Homes of the future

Explore! 8.2

Imagine it is the year 2100. The way homes are designed and constructed has changed, as we have been tackling energy efficiency problems. Passive housing has become commonplace. Passive housing means designing houses so they are as efficient as they can be without having to rely on technology such as heaters and air conditioners. Go online to research the following questions.

1 What is passive housing?
2 What are the benefits of passive housing?
3 Which parts of a house lose and gain the most thermal energy?
4 Explain the five design principles of passive housing.

Net zero home

Science as a human endeavour 8.3

Leading climate scientist Mark Z. Jacobson is helping the world transition to renewable energy sources. To show us how it can be done, he has built a 'net zero' home, which uses only renewable energy sources.

The house features a thermal shell, which acts as an insulating layer and reduces heating requirements, and is equipped with solar panels. Battery packs store any extra energy generated by the solar panels. This alone is enough to not only meet the energy needs of the home, but to put power back into the grid.

Figure 8.59 An illustration of a net zero house

Figure 8.60 The house has battery packs to store solar energy.

ISBN 978-1-108-61069-8 Cambridge University Press

Practical 8.5

Insulation

Aim

To test different materials for their insulating properties

Materials

- 6 empty soft drink cans
- 6 thermometers
- a range of materials to test insulation
- hot water
- sticky tape
- measuring cylinder
- funnel

Method

1 Cover each can in a different material, leaving one can with no covering.
2 Fill each can with 100 mL of hot water using a funnel. Ensure the water is as close to 80°C as possible when you start measuring.
3 Measure the temperature in each can every 5 minutes, for 20 minutes.
4 Record your results in the results table.

Results

Copy and complete the following table.

Can covering	Temperature (°C)				
	0 min	5 min	10 min	15 min	20 min
None					
…					

Evaluation

1 Which material was the best insulator? How did you know this?
2 Which of the three methods of heat transfer is responsible for the most heat loss from the can?
3 How can the results from this experiment be used in the construction industry when considering energy efficient/passive housing?
4 Are you confident that you would get the same result if you repeat the experiment? Were there any sources of error and, if so, how could you reduce or minimise these?

Conclusion

1 Make a claim regarding materials and insulation properties. Start your sentence with: 'This experiment suggests that various materials … '.
2 Support your claim by using the data you gathered and include potential sources of error. Start your sentence with: 'It was observed that … '.
3 Explain how the data supports your claim. Start your sentence with: 'This means that … '.

Quick check 8.10

1 Name one type of renewable energy that can be easily used in households.
2 Explain how you can easily compare the energy efficiency of two models of a washing machine.
3 Explain why it is beneficial to buy energy-efficient appliances, even though they can be more expensive than other models.

ISBN 978-1-108-61069-8 Cambridge University Press

Energy problems

You may remember from Year 7 that some energy sources, such as wind and solar, will never run out. Methods of energy production that do not use up natural resources are called **renewable**. Other energy sources, such as coal, oil and gas, are not renewable. Once these sources run out, they are gone forever.

renewable
can be produced as quickly as it is used

Another major consideration in choosing an energy source is the effect it has on the environment. Some methods of energy production, such as burning coal, create pollution that damages the environment. In addition, when wood, oil, gas or coal is burnt, greenhouse gases, which have the potential to cause climate change, are created. Methods of energy production that are non-polluting or have a small effect on the environment are called **sustainable**.

sustainable
causing little or no damage to the environment and therefore able to continue for a long time

Figure 8.61 The production of greenhouse gas from burning fossil fuels is leading to habitat loss for many animals, including polar bears in the Arctic.

The demand for energy has increased steadily since the Industrial Revolution 300 years ago, and it is still increasing today as more countries become industrialised. Scientists are constantly looking for ways to make the production of energy more efficient and to reduce the effect of energy production on the environment. Some of the main ways of generating energy are summarised below.

Figure 8.62 A wind-energy turbine with a coal-fired power station in the background

Non-renewable sources of energy

Coal

Fossil fuels are a **non-renewable** source of energy. Most deposits of coal formed 300 million years ago during the Carboniferous Period. This was 100 million years before the dinosaurs, when the Earth was warm, wet and covered with giant forests.

fossil fuel
a non-renewable source of energy obtained from oil, coal or gas

non-renewable
existing in limited quantities that cannot be replaced after they have all been used

Figure 8.63 An open-cut coal mine in Australia, showing how coal is formed in layers

ISBN 978-1-108-61069-8 Cambridge University Press

Figure 8.64 The Loy Yang power station converts the chemical potential energy in coal into electrical energy.

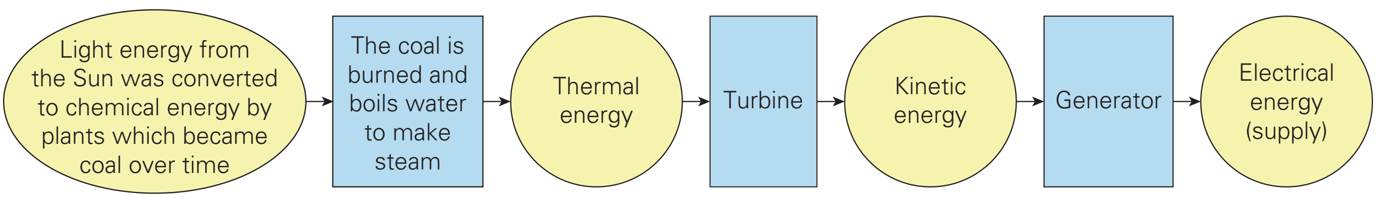


Figure 8.65 Energy flow diagram for a coal-fired power station

Eventually the forests died and layers of sand, which later turned into rock, covered the dead trees. Deep underground and under high temperature and pressure, the remains of the forest trees changed into coal.

Coal is mined and then transported to a power station to be used to generate electricity. When all the coal has been used up, there will be no more left. That is why coal is considered non-renewable.

The energy flow diagram for a coal-fired power station is shown in Figure 8.65.

Nuclear energy

Nuclear energy is an option for countries that have the technology to build nuclear power stations. Unlike all other forms of energy production, nuclear energy does not rely ultimately on the Sun. Instead, the fuel comes from radioactive materials, mainly uranium, found within the Earth's crust. These materials were inside the Earth when it formed, around 4.5 billion years ago. The mass of fuel required is a tiny fraction of the fuel required to run a coal-burning power station. Although the materials used in nuclear power generation are not renewable,

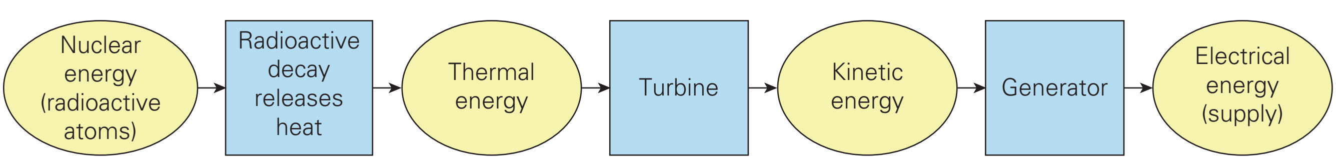


Figure 8.66 Energy flow diagram for a nuclear power station

ISBN 978-1-108-61069-8

Cambridge University Press

it is unlikely that the world will ever run out of nuclear fuel. Nuclear power stations do not release greenhouse gases and though potentially reliable and inexpensive, may not be so in practice.

Although nuclear energy has the potential to supply the world's energy needs when fossil fuels start to run out, there are some problems with nuclear energy that need to be taken into account. Can you remember the problems associated with nuclear energy from your investigations in Year 7?

Did you know? 8.7

Australia is the world's third-largest uranium producer, after Kazakhstan and Canada. All the uranium mined in Australia is exported, because there is no nuclear power plant here to use it. However there is a nuclear reactor at Lucas Heights on the outskirts of Sydney operated by the Australian Nuclear Science and Technology Organisation. It is used for research and nuclear medicine purposes. It generates 20 MW.

Quick check 8.11

1. Define the term 'non-renewable'.
2. Recall the types of non-renewable energy sources used in Australia.
3. State where non-renewable energy sources in Australia can be found.
4. State how and why the demand for energy has changed over the years.

Renewable energy sources

Most people recognise that our current use of fossil fuels cannot be sustained indefinitely, because eventually these fuels will run out. This has led to a great deal of research into finding and implementing renewable energy sources.

Wind energy

Wind energy is a renewable energy source in which electrical energy is generated using large wind turbines, usually built in groups, called wind farms. The advantage of wind energy is that, once the wind turbine has been built, wind energy is free, non-polluting and available at night. The main disadvantage is that it depends on the availability of the wind. For this reason, the energy that wind turbines produce is intermittent and must be combined with a storage capability, such as a battery, to provide a continuous energy supply.

Figure 8.67 Wind turbines are a striking sight in the countryside.

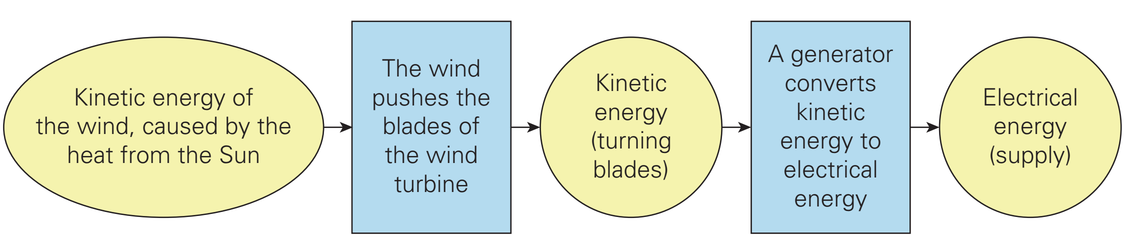


Figure 8.68 Energy flow diagram for a wind turbine

ISBN 978-1-108-61069-8 Cambridge University Press

Figure 8.69 Solar panels at Royalla in New South Wales

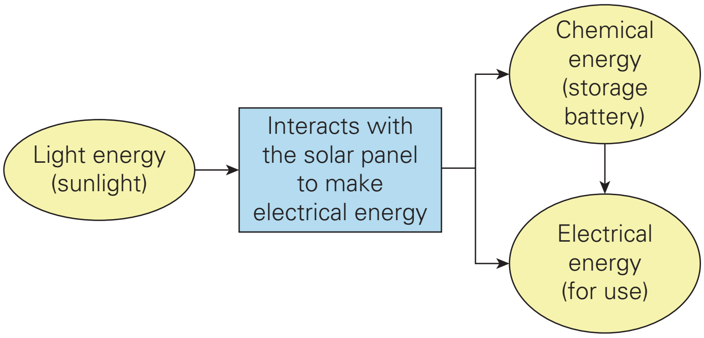


Figure 8.70 Energy flow diagram for a photovoltaic solar panel with a storage battery

Figure 8.71 In this hydroelectric power station in the Snowy Mountains, water is carried by gravity through the pipes shown from a dam located near the top of the mountain down to turbines and generators in the power station, converting gravitational potential energy into electrical energy.

Solar energy

Solar energy is a renewable energy source. Solar panels are used to convert the energy in sunlight directly into electrical energy and can also supply energy to provide hot water. The advantages of solar panels are that the energy they produce is free once the initial cost is met, and they are non-polluting to use. When solar panels are combined with storage batteries, they can provide a constant supply of energy, as the batteries store energy during the day and release it at night.

Hydroelectric power

hydroelectric power
a renewable source of energy harnessing the gravitational potential energy of water to generate electrical energy

Hydroelectric power is generated by using the gravitational potential energy of water held in dams to drive turbines that generate electricity. You may recall from Year 7 that dams are designed so that the water surface is as high above the turbines and generators as possible. The water's gravitational potential energy is then converted to kinetic energy by turbines at the base of the dam or as far below it as possible. These turbines turn generators that convert this kinetic energy into electrical energy.

Some countries are mountainous and are well suited to hydroelectric energy generation. Norway, for example, generates around 95% of its energy in this way. In Australia, hydroelectric energy accounts for around 6% of total energy production. The biggest single producer of hydroelectric power in Australia is the Snowy Mountains Scheme.

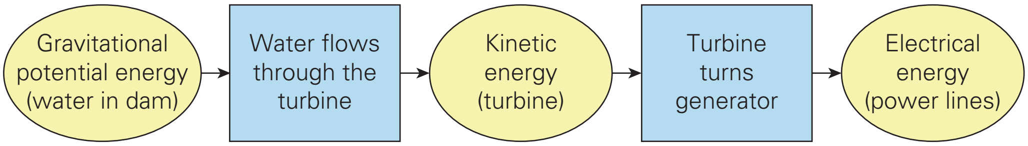


Figure 8.72 Energy flow diagram for hydroelectricity generation

ISBN 978-1-108-61069-8

Geothermal energy

geothermal energy thermal energy that originates from inside the Earth

Geothermal energy is, in practical terms, both sustainable and renewable. Recall Table 7.2 in the previous chapter: its source is thermal energy left over from the Earth's formation, plus thermal energy produced by radioactive decay, as with nuclear energy. Recall also that the Earth's crust may be fractured or thin, and at these locations, it is possible to drill down to find rocks hot enough to boil water. Cold water is pumped down to this hot rock. The water boils, producing steam, which is brought to the surface and used to generate electrical energy.

Figure 8.73 The Wairakei Power Station in New Zealand uses geothermal energy to produce electricity.

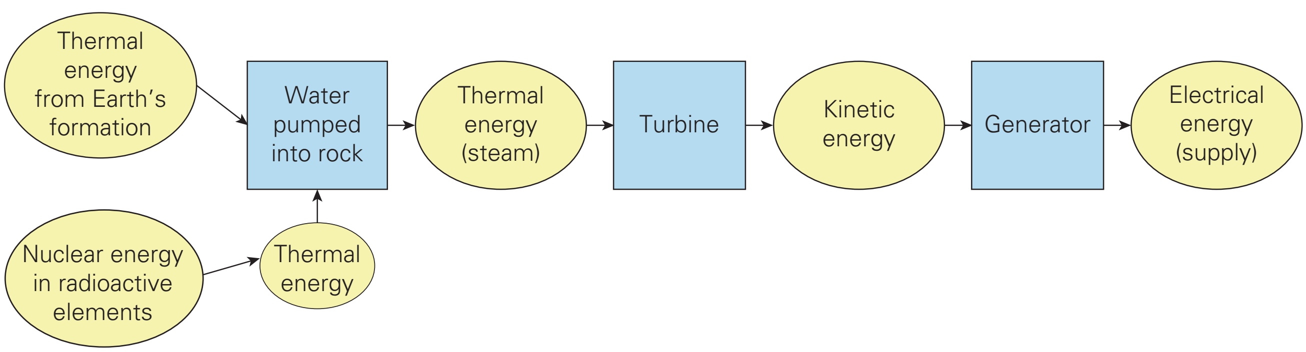


Figure 8.74 Energy flow diagram for geothermal energy

Quick check 8.12

1 Define the term 'renewable energy source'.
2 Recall some different types of renewable energy.
3 Draw a flow diagram to show the energy transformations that occur while producing electricity from wind turbines.

Explore! 8.3

Turning waste into energy

A lot of energy in modern life goes unused in the form of food scraps and animal wastes.

A UK-based company is trying to change that, and harness the power of detritus (waste material). Use the website of SEaB Energy (a UK company that converts organic waste into energy) to answer the following questions.

1 Why is food and animal waste such an issue for the world and the environment?
2 Explain how SEaB Energy's two main products, the Muckbuster® and the Flexibuster®, work.
3 Draw a flow diagram showing the energy transformations that would occur in harnessing energy from food and animal waste.

ISBN 978-1-108-61069-8 Cambridge University Press

QUIZ

Section 8.3 questions

Remembering

1 List the fossil fuels used to provide energy in Australia.
2 Recall approximately how many years ago coal deposits were formed.
3 State some sources of energy that harness water.
4 Describe the main reason behind switching to renewable energy sources.

Understanding

5 Explain how energy is produced using thermal energy from the Earth.
6 Draw an energy flow diagram for a hydroelectric power station.
7 Explain the difference between the terms 'renewable' and 'sustainable'.
8 Explain why nuclear energy is not considered renewable.
9 Explain how non-renewable energy sources are causing global warming.
10 Explain why each of the renewable sources of energy is considered 'renewable'.

Applying

11 Draw an energy flow diagram for a petrol engine car travelling at a constant speed on a flat road.
12 Make a list of ways in which you can make your house more energy efficient. For each suggestion, explain how it works.
13 A cyclist used 1000 kJ of energy riding to work. Of this, 250 kJ was transformed into kinetic energy to move his muscles. The other 750 kJ was transformed into heat. Calculate the energy efficiency of the cyclist.

Analysing

14 The following information applies to two different models of fridge. Note that the cost of electricity in Victoria is about $0.1/kWh.

	Model 1	Model 2
Energy star rating	4	3
Energy consumption per year (kWh)	195	234
Price ($)	600	499

State which fridge you would buy. Justify your choice.

15 Take a look at Figure 8.75. Explain what is happening in the picture and why.

Figure 8.75

continued...

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Evaluating

16 Suggest one drawback of using solar energy as an energy source.

17 Suggest two reasons why coal may not be suitable as a long-term energy source.

18 Suggest why inner city trains and trams are powered by electrical energy.

Review questions

SCORCHER

Remembering

1 Recall the name of the energy associated with moving.

2 What kind of energy do you increase if you climb a mountain?

3 Recall the term for energy that is stored when a spring is compressed.

4 Rewrite the following words with their correct descriptions.

Word	Description
Sound energy	Moving objects have this sort of energy
Kinetic energy	A form of wave energy that can travel through space
Wave energy	A form of wave energy consisting of vibrations in the air
Thermal energy	Energy carried by a wave travelling on or through a substance
Light energy	Hot objects contain this sort of energy

5 Recall what is meant by the term 'energy efficiency'.

Understanding

6 State the energy transformations that occur when someone climbs a set of stairs.

7 State whether each of the following sentences is true or false.

- **a** When bouncing a ball, elastic potential energy is involved.
- **b** An object can have energy even when it is stationary.
- **c** An object must be moving to transform energy from one form to another.
- **d** When driving a car, chemical potential, gravitational potential and kinetic energy are involved.

8 Explain why a light globe with an input energy of 1200 J cannot produce 1500 J of light energy.

9 Explain the difference between an energy-efficient light globe and a less efficient light globe.

10 Name an object that transforms:

- **a** electrical energy into thermal energy
- **b** elastic energy into kinetic energy
- **c** chemical potential energy into kinetic energy
- **d** chemical potential energy into thermal energy.

Applying

11 List as many sources of light energy as you can think of.

12 Look around your environment and list as many examples of energy as you can see.

13 As you go about your day, make a list of all the different types of energy transformations that occur.

14 Draw a flow diagram showing the energy transformation that occurs in a gas stove.

ISBN 978-1-108-61069-8 Cambridge University Press

Analysing

15 Use the diagram of a waterwheel in Figure 8.76 to draw an energy flow diagram for this process.

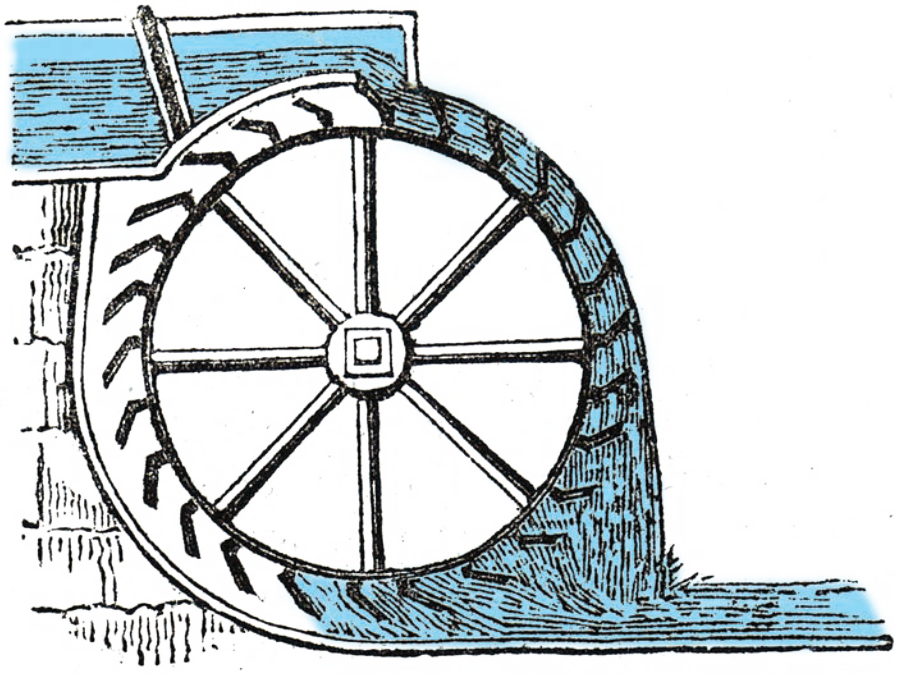


Figure 8.76 An overshot waterwheel

16 Some people use wood-burning stoves to heat their homes. Conclude whether or not this source of energy is renewable and/or sustainable. Explain your answer.

Figure 8.77 A wood-burning stove

17 Consider the Sun's role in life on Earth. Explain why there would be no life on Earth without the Sun.

ISBN 978-1-108-61069-8

Cambridge University Press

Evaluating

18 Heavy items of freight are often sent by cargo ships. These boats are powered by diesel, which has replaced coal during the past 100 years.
Evaluate the alternative modern sources of energy and determine whether you think diesel is likely to be replaced soon. Possible alternatives to consider are: wind turbines, solar panels, nuclear power.

Figure 8.78 A modern container ship

19 List the pros and cons of using nuclear energy.

Figure 8.79 An operator in a nuclear power station

ISBN 978-1-108-61069-8 Cambridge University Press

STEM activity: Wind power

Background information

VCSSU104 VCMMG258 VCSIS110 VCSIS111 VCSIS112

Nepal is a small country located in Asia between India and China, and it is home to Mount Everest (Nepali name: Sagamartha), the tallest mountain in the world. On the morning of 25 April 2015, a powerful earthquake (magnitude 7.8) struck the capital, Kathmandu, causing mass destruction and killing 9000 people. Unfortunately, most of these people died beneath the rubble. This is because, in Nepal, most people can only afford to build with the cheapest materials available.

Unfortunately, the rebuilding effort in Nepal has been extremely slow for a number of reasons, including lack of funding for individual families, the remoteness of the country areas, absence of good roads to transport materials and, sadly, the fact that most people in small isolated villages died. Many non-government agencies (NGOs) advocated for the use of renewable energy to assist the local population during the recovery process.

Figure 8.80 Different types of wind turbines

ISBN 978-1-108-61069-8

Cambridge University Press

Design brief: Design a wind turbine capable of lifting an object.

Activity instructions

In this task, you will work in a group (three students maximum) to design a simple wind turbine capable of lifting weight from the floor up to bench height. The aim of this activity is to simulate how energy from the wind could be used to lift objects, livestock or even people from a dangerous location within a natural disaster zone.

Suggested materials

- a medium-sized fan (to simulate a constant flow of wind)
- cardboard (different thicknesses if possible)
- masking tape (optional)
- string
- pencils
- scissors
- paper or plastic cup for carrying the load
- weights (you can use Lego® characters as well)
- electronic scale (optional)

Evaluate and modify

1. Propose a measure of design efficiency. Think about how you can quantitatively measure how effective one design/prototype is compared with another. This may include measures for sturdiness, speed of lift, and maximum capacity.
2. Discuss with your colleagues the relationship between blade shape and blade spin for your designed wind turbine. In other words, describe what factors (such as material, shape, thickness of cardboard) make the turbine's blades spin faster or slower.
3. How can you improve your design? Incorporate these modifications into your design and test it again. How does it compare to the first prototype?
4. Imagine that the attachment used to allow the shaft to spin is not sturdy enough, which would make it less reliable during a rescue operation. Discuss and suggest three possible solutions to the problems you encounter, and decide on the best course of action to modify your design.
5. Predict what would happen to the cup (there might be people inside!) if you turn the fan (wind) off when the cup is halfway between the floor and the tabletop. Now test this scenario and write down your observations. Does it match your prediction?

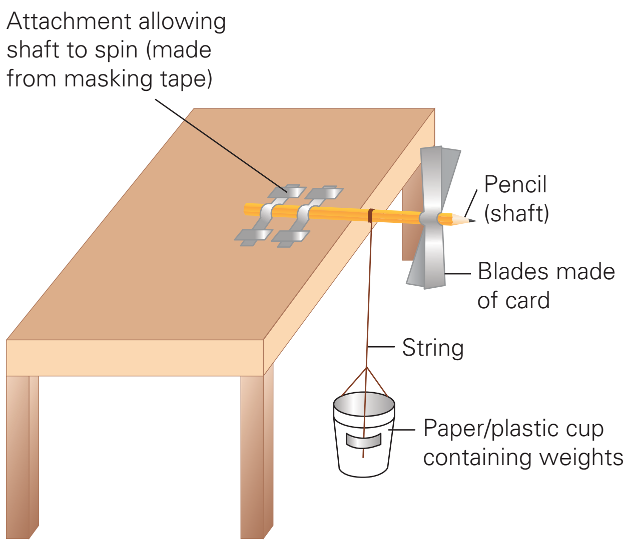


Figure 8.81 You can build ideas around this basic design.

ISBN 978-1-108-61069-8

Chapter 9 Light and sound

Chapter introduction

In this chapter, you will explore two types of wave energy: light and sound. You will learn how light interacts with objects and why you can see your reflection in some objects and not others. You will also take a look at the human eye, and learn how light interacts with the structures in the eye to form an image for our brain to interpret. This chapter also explores sound – how fast sound travels, and how sound is produced by musical instruments. You will also see how the wave model can be used to describe the properties of both light and sound.

ISBN 978-1-108-61069-8 © Roberts et al. 2019 Cambridge University Press

Curriculum

Light can form images using the reflective feature of curved mirrors and the refractive feature of lenses, and can disperse to produce a spectrum which is part of a larger spectrum of radiation (VCSSU105)	
• exploring how images can change when the arrangement of the mirror or lens system is altered	9.2
• exploring the mechanism of the human eye and corrective technologies	9.4
• observing the spread and order of colours in the visible spectrum	9.1
• describing the different types of radiation in the larger spectrum of radiation	9.1
The properties of sound can be explained by a wave model (VCSSU106)	
• describing how sounds are produced by different musical instruments	9.3
• measuring the speed of sound	9.3
• using a wave model to describe the measured properties of sound, wavelength and frequency	9.3

Victorian Curriculum F–10 © VCAA (2016)

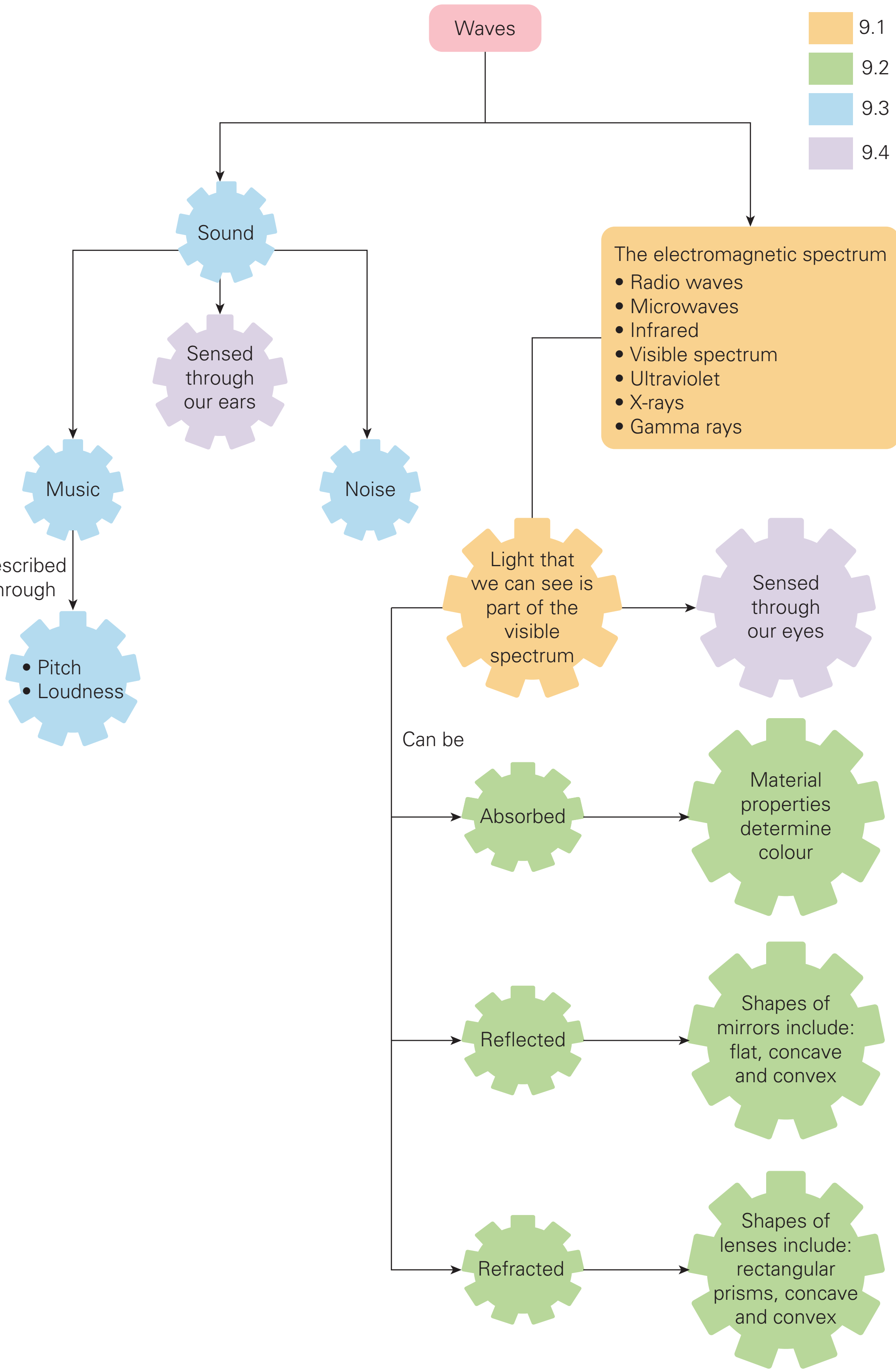
Glossary terms

absorb
accommodation
amplitude
angle of incidence
angle of reflection
cochlea
compression
concave
convex
cornea
diffraction
ear canal
eardrum
electromagnetic spectrum
electromagnetic wave
frequency
fluorescent
gamma rays
Global Positioning System (GPS)
hertz
incident ray
infrared
iris
lens
lens (eye)
longitudinal wave
long-sighted
medium
microwaves
normal
opaque
percussion instrument
pitch
plane mirror
prism
pupil
radar
radio waves
rarefaction
reflect
reflected ray
refraction
refractive index
retina
short-sighted
standing wave
subtractive colour mixing
translucent
transparent
transverse wave
ultraviolet
vibration
visible light
visible spectrum
wavelength
wind instrument
X-rays

ISBN 978-1-108-61069-8

Cambridge University Press

Concept map



ISBN 978-1-108-61069-8 Cambridge University Press

9.1 Light

Light is an electromagnetic wave

WORKSHEET

In 1865, James Clerk Maxwell proposed the theory that light is an **electromagnetic wave**. This means it has both electrical and magnetic components, travelling at right angles to each other.

> **electromagnetic wave** a wave that has both electrical and magnetic components; one of the ways energy travels

All electromagnetic waves, including light, ultraviolet, infrared, radio waves and X-rays, travel at the same speed: 299 792 458 m/s in a vacuum.

Properties of waves

Mechanical waves, such as vibrations, sound and water waves, transfer energy without transferring matter. When sound travels through air it transmits energy but the air molecules only move backwards and forwards, they return to their original position after the sound has passed. Light is even more impressive; it can carry energy through space where there is no matter at all. **Transverse waves** are a type of wave in which the particles move at right angles to the direction of motion of the wave. Light is an example of a transverse wave. The number of waves produced every second is called the **frequency**, and is measured in **hertz** (Hz). The distance between two consecutive waves is called the **wavelength**. As you will see in the next section, wavelengths can range from kilometres to nanometres. The **amplitude** of a wave is how far the wave extends from its middle position.

> **transverse wave** a wave moving through a substance in which the particles are vibrating at right angles to the direction of motion of the wave

> **frequency** the number of vibrations of a wave per second
>
> **hertz** a unit for measuring the number of cycles that happen every second (frequency); abbreviation is Hz
>
> **wavelength** the distance from one wave crest to the next
>
> **amplitude** the distance of a wave crest from the middle position

Try this 9.1

Looking at wavelength and amplitude

In the diagram below, label the wavelength and amplitude of the transverse waves. Use a ruler to measure these properties.

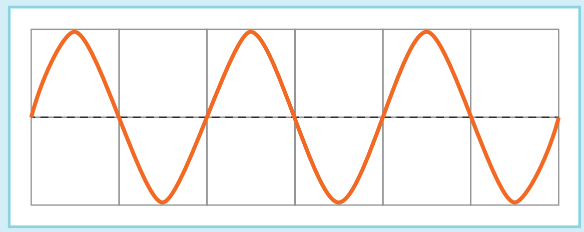


Figure 9.1 A wave

Quick check 9.1

1 Explain what the word 'transverse' means in relation to waves.
2 Recall the three properties of waves discussed in this section.

The electromagnetic spectrum

James Clerk Maxwell also proposed that visible light is just a small part of a much bigger spectrum, called the **electromagnetic spectrum**. Figure 9.2 shows an illustration of the full electromagnetic spectrum. Notice that we use a wave image to demonstrate the differences between different parts of the spectrum. For example, radio waves have lower frequency and a longer wavelength than the rest of the electromagnetic spectrum. There is a long distance between the start of one wave and the start of the next wave. Gamma rays, on the other hand, have the shortest wavelength of all the waves in the electromagnetic spectrum, and this means they have the highest frequency.

> **electromagnetic spectrum** a way of organising electromagnetic waves according to their frequency

ISBN 978-1-108-61069-8 Cambridge University Press

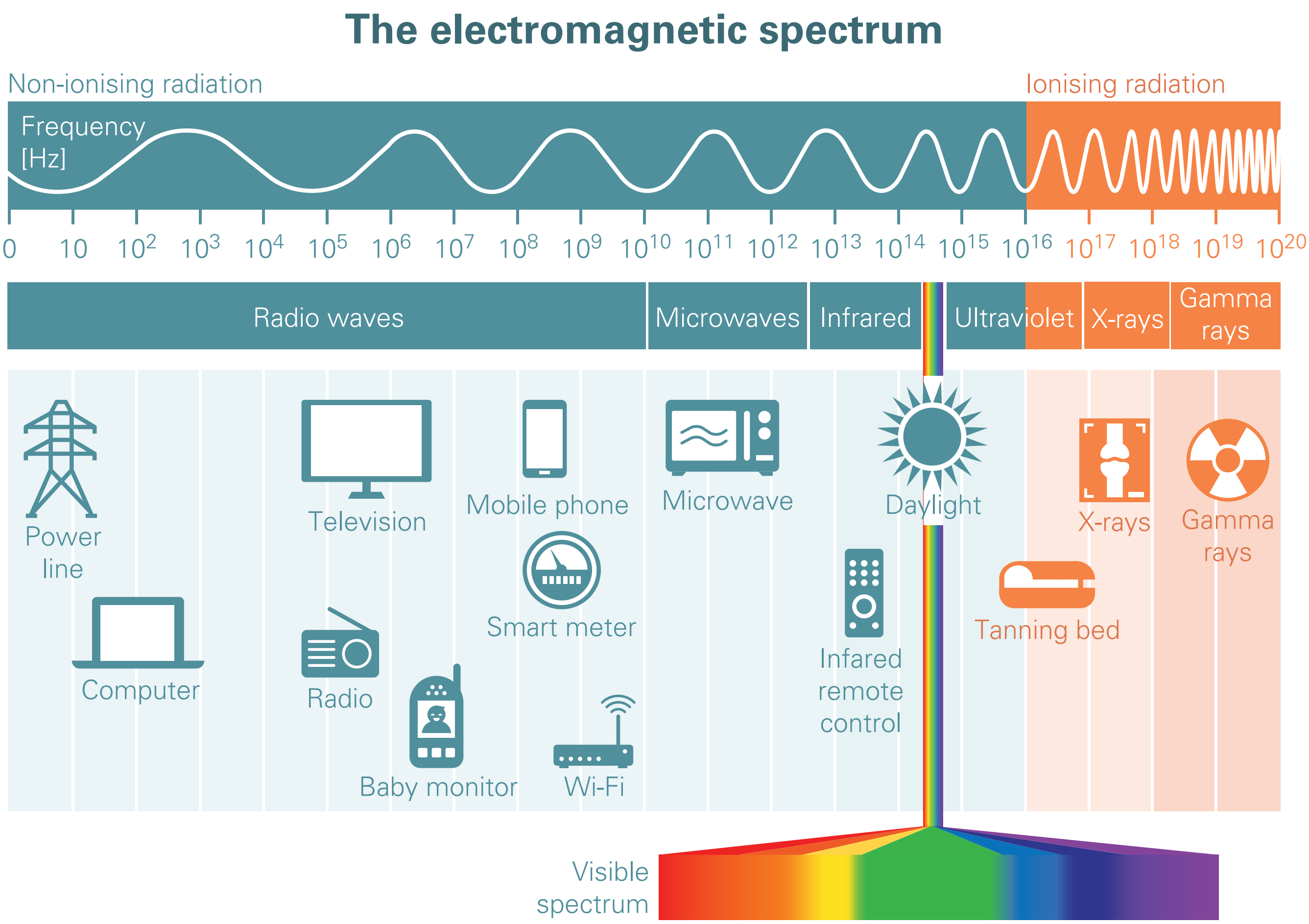


Figure 9.2 The electromagnetic spectrum extends beyond the visible spectrum.

The frequency of a wave determines its position on the electromagnetic spectrum and can be used to determine the wavelength of a wave.

The different types of electromagnetic waves and their uses are listed below.

- **Radio waves** are useful for communications and signals over long distances. Radio waves were originally used for television and radio station broadcasts, and are now also used to send communications around the world via satellites.
- **Microwaves** are used for cooking, Wi-Fi communications and mobile phone technology.
- **Infrared** radiation is the radiation you feel when you stand near a fire or when you feel the heat of the Sun. It is also used in home remote controls.
- **Visible light** is light that you can see with your eyes.
- **Ultraviolet** is invisible radiation that can cause sunburn and skin cancer. Not all ultraviolet is bad. Skin cells use low-frequency ultraviolet to make vitamin D.
- **X-rays** are high-energy electromagnetic waves that are used to create images of bones.
- **Gamma rays** are high-energy rays that are released when atomic nuclei decay.

radio waves
electromagnetic radiation that has the longest wavelength

microwaves
electromagnetic radiation used for cooking, communications and Wi-Fi; lies between radio waves and infrared radiation

infrared
a form of electromagnetic radiation that lies between microwaves and visible light; also known as heat radiation

visible light
the part of the electromagnetic spectrum that we can see

ultraviolet
radiation that lies between visible light and X-rays; is needed by our bodies to make vitamin D; short wavelength UV can cause sunburn and cancer

X-rays
short wavelength electromagnetic radiation that can pass through flesh to give images of bones; hazardous and can cause cancer

gamma rays
high-energy rays produced when radioactive atoms decay; they have a very short wavelength and can cause cancer

ISBN 978-1-108-61069-8 Cambridge University Press

Did you know? 9.1

Super fast!

The speed of light in a vacuum is 299 792 458 metres per second. This is one of the most accurately known values in science. Light, radio waves, microwaves, infrared radiation X-rays and gamma rays all travel at the speed of light. The electrical signals in wires that carry information from computer to computer on the internet, and carry the signal of your voice in a telephone wire, also travel at close to the speed of light.

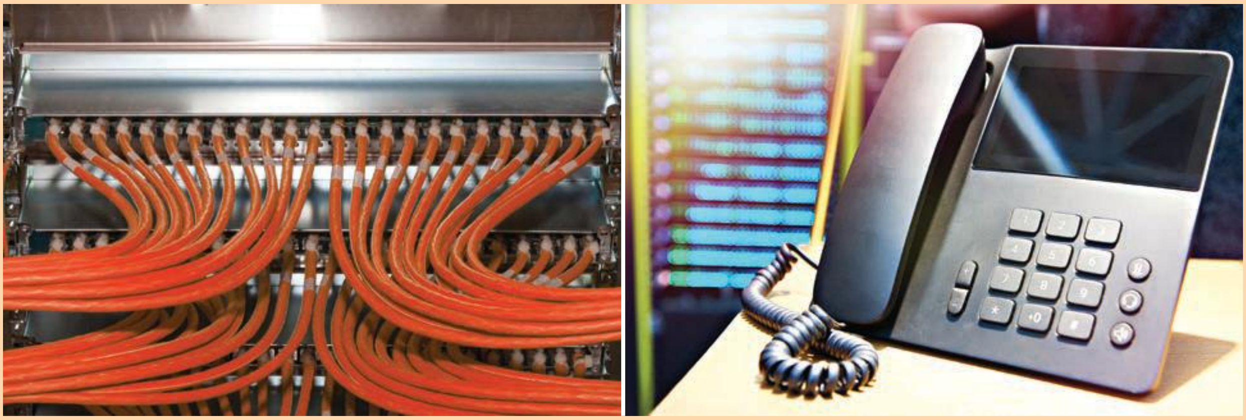


Figure 9.3 The electrical signals that carry information through telephone wires are extremely fast.

The visible spectrum

The colours of the **visible spectrum** are the colours of the rainbow: red, orange, yellow, green, blue, indigo and violet. White light can be split up into these individual colours. These colours can also be recombined to form white light.

visible spectrum the part of the electromagnetic spectrum that we can see; includes all the colours of visible light

Figure 9.4 The visible spectrum

Try this 9.2

Making a rainbow

Put a mirror inside a glass, and fill the glass with water. Then position the mirror so sunlight or light from a torch falls directly onto it. Adjust the angle of the mirror until a rainbow appears on the wall.

Radio waves

Radio waves can have a wavelength anywhere from a metre to a 100 kilometres. They are produced using radio masts or towers, which are often placed on the top of high ground and are used to broadcast radio signals for TV and radio stations. Because they have a long wavelength, radio waves can bend around the edges of mountains and other obstacles, in a process called **diffraction**. Radio waves travel easily through the atmosphere and can be received hundreds of kilometres from where they were transmitted. **Radar** location is a method of finding

diffraction the bending of waves with long wavelengths around a barrier

radar a system that uses radio waves to show the position of objects that cannot be seen

Figure 9.5 Radar is used in air traffic control.

ISBN 978-1-108-61069-8

objects by sending out a pulse of radio waves and collecting an echo. The locations of aircraft are tracked using radar, and radar is also used in fishing, to locate shoals of fish and to show the sea bed.

Did you know? 9.2

Observing the universe

Radio astronomy is an important tool for exploring the universe. Objects called pulsars were first discovered in the 1960s and were initially thought to be radio signals from aliens! It turned out that they were small dense stars made of neutrons, which were emitting radio waves and spinning very quickly. Most galaxies have a giant black hole at their centre – we know this because of the radio waves they emit. Astronomers can also use radio waves to search for quasars, which are strange objects that typically produce thousands of times more light and energy than a whole galaxy.

Figure 9.6 Radio telescopes collect radio waves from distant galaxies.

Microwaves

Microwaves have a wavelength from around one millimetre to one metre. You have probably heard of microwaves in the context of cooking food. The microwaves used in microwave ovens are at exactly the right wavelength to heat up water molecules. This explains why a mince pie cooked in a microwave can be dangerous. The pastry contains little water and is largely unaffected, but the mince, which is moist, is heated strongly. So if you eat a pie that has been in a microwave too long, the inside will be at a much higher temperature than the outside. This is why it is a good idea to allow pies to stand for a few minutes before eating them!

Microwaves are not just used for cooking. Here are some other uses:

- Speed cameras use microwaves to measure the speed of cars, and even measure the speed of a tennis ball during the Australian Open.
- Wi-Fi uses microwaves to allow computers and mobile devices to communicate wirelessly with the internet.
- Mobile phones use microwaves to send signals to and from mobile phone towers.
- **Global Positioning System (GPS)** devices continuously receive microwave signals from human-built satellites orbiting the Earth. Unlike mobile phones, GPS devices do not transmit microwaves.

Global Positioning System (GPS)
a system of satellites that transmit microwaves and are used to find the precise location of objects on the Earth

Figure 9.7 This AFL player is having a GPS device attached to his shirt during a training session, to track his movements.

ISBN 978-1-108-61069-8 Cambridge University Press

A GPS device needs to receive a signal from at least four satellites in order to determine position and time. GPS navigation is used by motorists, and in aircraft and shipping. In sport, GPS devices are used to monitor a player's movements during a game. If a player is being monitored, the device is visible at the back of their shirt, just below the collar.

Explore! 9.1

Wi-Fi

Did you know that an Australian invented Wi-Fi? This physicist and engineer was actually studying radio waves being emitted from black holes, and built a machine to detect these weak signals. He used his machine to allow computers to communicate wirelessly.

1 Who is credited with inventing Wi-Fi?
2 When was Wi-Fi patented?
3 How does Wi-Fi work?

Science as a human endeavour 9.1

New uses for Wi-Fi

Wi-Fi can be used not only to connect computers wirelessly, but also to detect dangerous objects. Wi-Fi signals are able to penetrate bags, so they can be used to identify objects such as weapons or bombs, being carried around public places.

Researchers have also created 3D printed objects, known as 'smart objects', that can connect to other Wi-Fi devices without other electronics. The technology within each object allows it to sense certain aspects of its environment and send this information to your smart phone. So a smart object might, for instance, let you know when you are running low on detergent.

Figure 9.8 This attachment senses how much laundry liquid is being used and can automatically order more when it is running low.

Quick check 9.2

1 Recall the colours of the visible spectrum.
2 State two uses of radio waves.
3 Recall the wavelength range of microwaves.
4 State one similarity and one difference between radio waves and microwaves.

Did you know? 9.3

Very small waves

Some wavelengths in the electromagnetic spectrum are so small that they are measured in special units.

A micrometre (μm) is 1/1000th of a millimetre (or one millionth of a metre).

A nanometre (nm) is 1/1000th of a micrometre (or one billionth of a metre).

A picometre (pm) is 1/1000th of a nanometre (or one trillionth of a metre).

These units are tiny: an atom is about 100 pm across!

ISBN 978-1-108-61069-8

Infrared radiation

You may recall from Chapter 8 that when a metal bar is heated, it starts to glow. In addition to emitting visible energy, it also emits a lot of infrared radiation energy. This is radiation being given out by the surface of the metal bar. Infrared waves have a wavelength between those of microwaves and red light – that is, from one millimetre (1 mm) to just under one-thousandth of a millimetre (0.7 μm). During the heating process, the metal takes on the colours of light in the order of the spectrum: red first, then yellow, then white. Very hot steel is white, because it is emitting all the colours of the spectrum, as well as infrared radiation.

Infrared cameras produce images of heat radiation, called thermal images. These images can be used to investigate the effectiveness of thermal insulation in houses. Thermal images of people can be used to detect whether a person has a high temperature and might be ill, or to find a person in a search and rescue operation, especially at night.

Figure 9.10 A thermal image of people arriving at a hospital can quickly detect anyone who has a high temperature. You may have seen this same technology being used in airports.

Figure 9.9 As hot steel glows, it gives out light. It also produces a lot of infrared radiation.

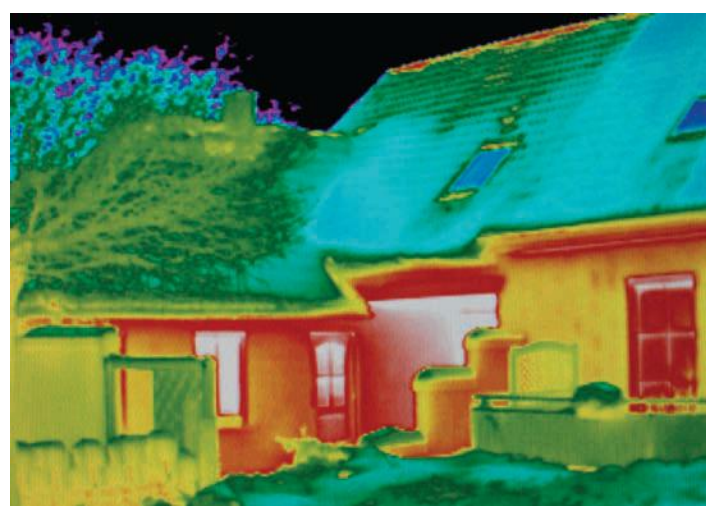


Figure 9.11 This infrared photograph of a house has had false colour added. Hot areas are white or red, while cooler areas are green or blue. It indicates that although this house has very good roof insulation, heat is being lost through the windows and walls.

ISBN 978-1-108-61069-8 Cambridge University Press

Ultraviolet radiation

Ultraviolet (UV) radiation has wavelengths between 400 nm and 10 nm. It starts where the violet end of the visible spectrum ends, and ends where X-rays start. You will already be familiar with UV rays, because in Australia we have a lot of them! Exposure of our skin to some longer-wavelength ultraviolet light (UVB) is necessary for the production of vitamin D. However, too much exposure to these rays is dangerous, because it can cause skin cancer. Of the Sun's total output, 10% is ultraviolet. The Earth's atmosphere, especially the ozone layer, absorbs 75% of these potentially harmful rays, including nearly all the very dangerous wavelengths.

The energy contained in ultraviolet light can cause some chemicals and minerals to glow or fluoresce. **Fluorescent** chemicals are added to washing powder to make white clothes appear even whiter, and fluorescent patterns are added to passports and banknotes to help prevent people copying them.

fluorescent
describes a substance that emits light under an ultraviolet light source

Ultraviolet radiation can be used to identify minerals that are known to fluoresce.

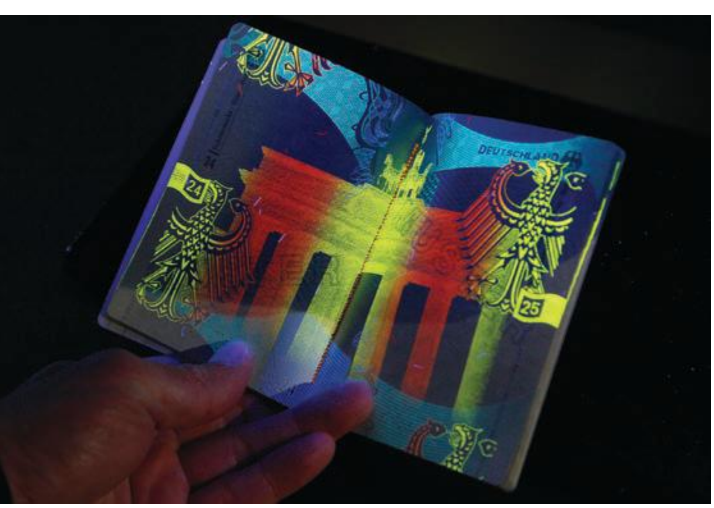


Figure 9.12 A passport viewed under ultraviolet light

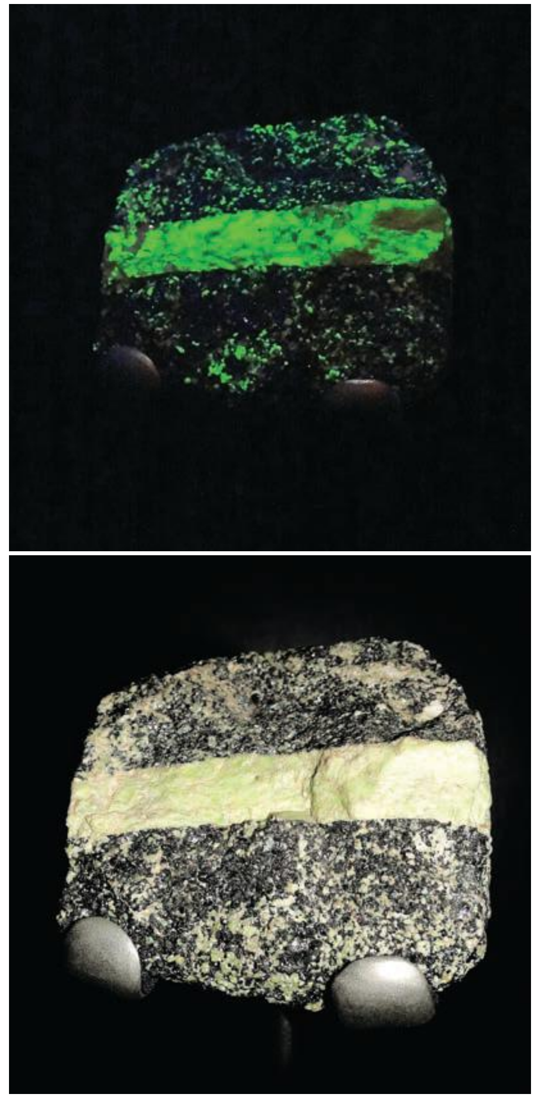


Figure 9.13 Fluorescent minerals emit visible light when they are exposed to ultraviolet light.

X-rays

X-rays have wavelengths shorter than 10 nm (10 nm = one millionth of a centimetre). They were first discovered by Wilhelm Röntgen late in the nineteenth century. At first, people considered X-rays a novelty and had images of their bones made for entertainment. Soon after, doctors began to use X-rays for medical purposes. X-rays are able to pass through flesh easily, but they are blocked by bones, teeth and metal, and so an X-ray image can be used to look at bones or teeth inside the body. If doctors want more detail, they can ask for

ISBN 978-1-108-61069-8

a three-dimensional X-ray image, called a CT scan. X-rays are dangerous, however, and so exposure to them is limited and must be authorised by a doctor or a dentist. Low-energy X-rays are also used in airports for screening luggage, and sometimes for screening passengers, to detect metal.

Figure 9.14 One of the first X-ray photographs. This was taken in 1896 by Wilhelm Röntgen.

Figure 9.15 A radiologist inspects an X-ray of a head and neck.

CT scans **Explore! 9.2**

A computed tomography scan (CT scan) uses X-rays to generate cross-sectional pictures of the human body.

1 How does a CT scan work?
2 When would someone get a CT scan?
3 Are there any risks involved in getting a CT scan?

Figure 9.16 A person undergoing a CT scan

Gamma rays

Gamma rays generally have an even shorter wavelength than X-rays (less than 10 picometres), but the main difference between these two types of rays is the way they are made. Most X-rays are made by firing high-energy electrons into a piece of metal. Gamma rays are emitted by radioactive substances when the nucleus of an atom decays and releases energy. Because of their very short wavelength, gamma rays are more dangerous than X-rays, and they are used mainly in cancer treatment. Gamma rays are so penetrating that they can only be blocked by several centimetres of lead. The Earth's atmosphere protects us from gamma rays and other high-energy rays originating from outer space. These rays, called *cosmic rays*, are the most energetic and have the shortest wavelength of any electromagnetic radiation that we know of.

ISBN 978-1-108-61069-8 Cambridge University Press

Quick check 9.3

1 State which forms of radiation can be harmful to humans.
2 State what kinds of objects emit infrared radiation.
3 Explain the role of Earth's atmosphere in protecting us from harmful radiation.

Section 9.1 questions

QUIZ

Remembering

1 State the name of the person who proposed that light was an electromagnetic wave electromagnetic radiation.
2 State the types of electromagnetic radiation that are outside the visible spectrum.
3 List the colours of the visible spectrum.
4 Recall the wavelength range of radio waves.
5 What other things can microwave radiation be used for, aside from heating food?
6 List some types of electromagnetic radiation that would be in your environment at this moment.

Understanding

7 List all the types of electromagnetic radiation, in order of decreasing energy or increasing wavelength.
8 Explain what occurs when white light is broken up.
9 Explain how microwaves heat up food.
10 Explain why it can be dangerous to heat items of food that have moist and dry components.
11 Explain how X-rays can be used to produce an image of bones.
12 Using your knowledge of infrared radiation, explain how night vision goggles work.

Applying

13 The speed of light in air is 299 704 645 m/s. Calculate how long it would take for light to reach the following destinations from Melbourne. *Hints*: Convert the distances to metres. Divide each distance by the speed of light.
   a Adelaide (726 km)
   b Brisbane (1781 km)
   c Canberra (662 km)
   d Perth (3406 km)
14 Explain why you may need a Wi-Fi booster if you live in a large house.
15 Provide examples of objects that are similar in size to the wavelengths of the following types of radiation. One has been completed for you.

Type of radiation	Wavelength	Object
Radio waves	1 metre to a few kilometres	Buildings
Microwaves	1 mm to 1 m	
Infrared	1 mm to 0.7 μm	
Visible light	700 nm to 400 nm	
Ultraviolet	400 nm to 10 nm	
X-rays	shorter than 10 nm	
Gamma rays	10 pm (picometres)	

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Analysing

16 Propose one conclusion that can be made from the table of data below.

Material	Speed of light (m/s)
Vacuum	299 792 458
Air	299 704 645
Water	224 900 569
Glass	197 231 880
Diamond	123 881 181

17 Figure 9.17 shows an infrared picture of a house. Suggest what the different colours mean.

18 Compare and contrast microwaves with gamma rays.

Evaluating

19 Describe why it is important to find a balance between getting too much or too little UV radiation exposure.

20 Discuss the medical benefits versus risks associated with X-ray machines.

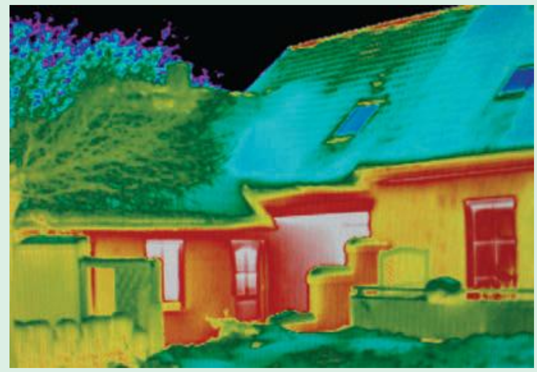


Figure 9.17

9.2 Absorption, reflection and refraction

Absorption

WORKSHEET

Surfaces are able to **reflect** or **absorb** light. Reflected colours are those we can see or detect with our eyes. For example, white objects reflect all the colours in the visible spectrum and absorb none. Black objects absorb all the colours and reflect none. A red car has a pigment in its surface that reflects the red wavelengths in the visible spectrum and absorbs all the other colours, and so we see it as a red car.

reflect
to throw back the energy of a wave (e.g. heat, light, sound) without absorbing it

absorb
to take up the energy of a wave (e.g. absorb light)

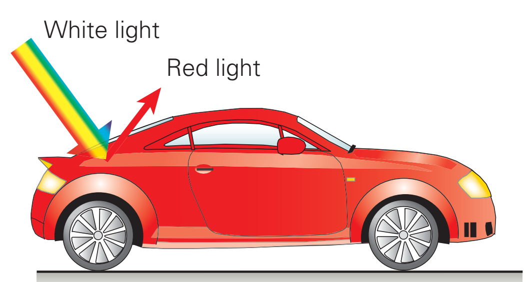


Figure 9.18 A red car reflects all red wavelengths of light and absorbs all the other colours of the visible spectrum.

ISBN 978-1-108-61069-8 Cambridge University Press

The pigments in the surface of a blue car reflect blue wavelengths of visible light and absorb the other colours, so we see the car as blue.

As you know, white light is made up of all the colours. However, white light can also be created by overlapping the three primary colours (red, green and blue). Overlapping two of the primary colours creates one of the secondary colours (magenta, cyan or yellow).

A colour filter only allows light of a certain wavelength (colour) to be transmitted through it. Cellophane is an example of a filter. Blue cellophane only allows blue light to be transmitted, and absorbs all other colours. In photography, combinations of filters are used to achieve different effects in the final picture.

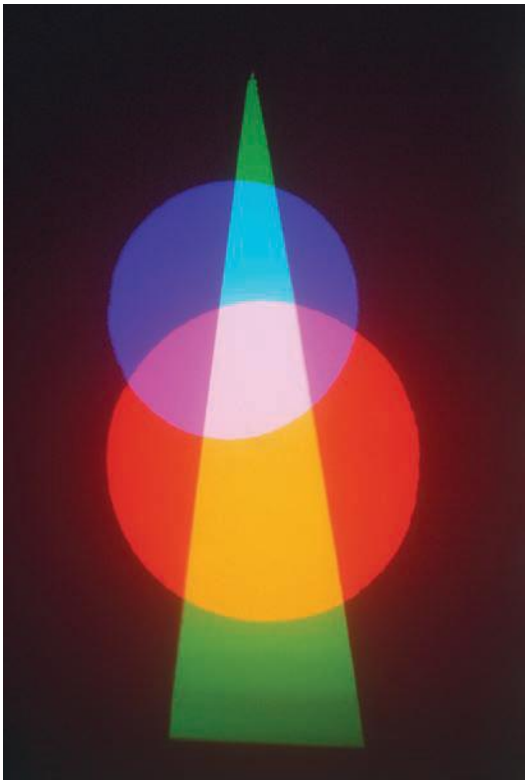


Figure 9.19 Can you identify the different primary and secondary colours? Where is the white light?

Did you know? 9.4

What colour is an apple?

A red apple appears red when looked at in red light. But what if the light is blue?

Because a red apple only reflects red, and does not reflect any blue light, it appears dark when viewed in blue light.

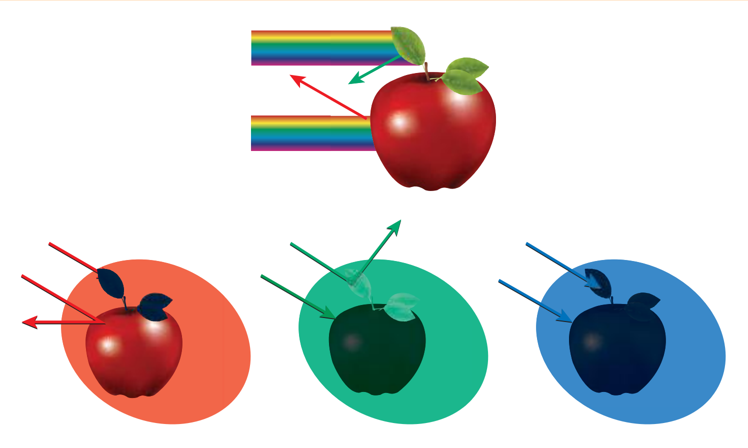


Figure 9.20 A red apple can look different, depending on the colour of light hitting the pigments on its surface.

A yellow shirt reflects both red and green light. So if you look at a yellow shirt in red light, it will appear red. If you look at the same yellow shirt in green light, it will appear green. If you look at the yellow shirt in blue light, it will appear dark, because it does not reflect blue light.

ISBN 978-1-108-61069-8 Cambridge University Press

Practical 9.1

Mixing primary colours

Be careful

Take care when changing the colour filters, as the light box can become hot with prolonged use.

Aim

To investigate the effects of different combinations of colour filters

Materials

- light box
- darkened room
- colour filters: red, green, blue, cyan, magenta, yellow
- coloured cards: white, red, green, blue, cyan, magenta, yellow

Teacher notes

The light box has three windows for light to emerge: the front window allows light to emerge directly and the side windows are fitted with mirrors. Coloured filters can be fitted to each window, and the light can be directed to a screen, where combinations of colours falling on different-coloured cards can be observed.

Method

1. Place the light box in front of a white wall or piece of paper.
2. Darken the room as much as possible.
3. Use the blue, red and green colour filters. Choose two of these colours to insert into the light box and use the mirrors to adjust the direction of light to combine the two colours onto the white paper.
4. Record the colour produced in results Table 1.
5. Repeat steps **3** and **4** until you have tried all colour combinations.
6. Use all three colours to make white.
7. Use the secondary colour filters (cyan, yellow and magenta) and the primary colour cards (red, green and blue) to find out what happens if a secondary colour is shone on a primary colour card. Complete results Table 2 with your observations.

Results

	Red filter	Blue filter	Yellow filter
Red filter			
Blue filter			
Green filter			

Table 1 Colours produced when primary colours are combined

Secondary colour filter	Primary card colour		
	Red	Green	Blue
Cyan	Dark		
Magenta			Blue
Yellow		Green	

Table 2 Colours produced when secondary colours are shone onto primary-coloured cards

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Evaluation

1 State the colours made when each of the primary colours were combined.
2 State the colours made when secondary colours were shone onto red paper.
3 Explain why white is formed when cyan and red are mixed.
4 Suggest how the experiment may be improved.

Conclusion

1 Make a claim regarding light and colours. Start your sentence with: 'This experiment suggests that light ... '.
2 Support your claim by using what you observed when you combined different coloured lights. Start your sentence with: 'It was observed that ... '.
3 Explain how the data supports your claim. Start your sentence with: 'This means that ... '.

Quick check 9.4

1 State what colour an object appears if it:
   a absorbs all colours
   b absorbs no colours
   c absorbs all colours except red.
2 Explain how a colour filter works.
3 Explain why black cars get hotter than white cars on a sunny day.

You already know what you get when you mix all the colours of light: white light! However, as you add different colours of paint to a mixture, it tends to get darker. Paint contains pigments that absorb colours. For example, yellow paint absorbs blue and reflects red and green, and cyan paint absorbs red and reflects blue and green. So when more and more paints are added, more and more colours are absorbed rather than reflected. This process is called **subtractive colour mixing**.

subtractive colour mixing a way of forming new colours by combining different coloured paints or pigments, e.g. mixing red and yellow paint to make orange

Figure 9.21 Cyan (blue) paint mixed with yellow paint makes green paint.

ISBN 978-1-108-61069-8 Cambridge University Press

All materials are either opaque, translucent or transparent to light.

Opaque

A substance that blocks light completely is said to be **opaque**. An example of an opaque material is aluminium foil, which can be used to cover windows to block the light and make a room completely dark, even in the daytime. All metals, not just aluminium, are opaque. So are wood, most plastics and most minerals.

opaque
blocking light completely

Translucent

Some materials are **translucent**. This means they allow light to pass through, but no clear image can be seen through them. Frosted glass, ice made from snow, paper, clouds and milk are examples of translucent materials.

translucent
allowing some light through, but no clear image can be seen through the substance

Transparent

Transparent materials, such as diamond, glass, perspex and water, allow light to pass through them with little or no alteration, allowing clear images to be seen through them.

transparent
allowing light to pass through, and a clear image can be seen through the substance

Figure 9.23 Ice made from snow is translucent.

Figure 9.22 Glass and water are two common examples of transparent materials.

Quick check 9.5

1 Explain the difference between the following terms: opaque, translucent, transparent.
2 Explain what is meant by the term 'subtractive colour mixing'.

Explore! 9.3

Polarising filters

Recall from the start of the chapter that light is an electromagnetic wave. Polarising filters take advantage of this and are used widely in photography, theatre and sunglasses. Conduct some research to answer the following questions.

1 What is polarisation?
2 Explain how polarising filters work.
3 What are some examples of the uses of polarising lenses?

Figure 9.24 A polarising lens from a camera

ISBN 978-1-108-61069-8

Cambridge University Press

Figure 9.25 The light from the mountain and the cloud is reflected by the smooth surface of the lake, giving a very clear image.

Reflection

When light comes into contact with a surface, some or all of it may be reflected. If the surface is rough, the light rays bounce off the surface at different angles. The light is reflected but does not form an image.

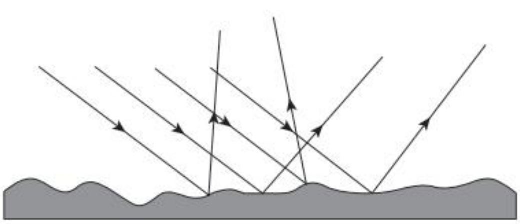


Figure 9.26 Light rays hitting a rough surface are reflected at different angles and scatter the light. No image is formed.

The light rays reflecting from a smooth surface bounce off at the same angle, and an image is seen.

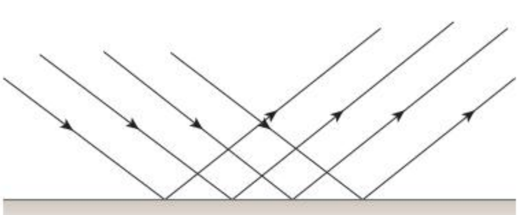


Figure 9.27 Light rays hitting a smooth surface are all reflected at the same angle, and an image can be formed.

Did you know? 9.5

Pepper's Ghost

Pepper's Ghost is an application of light being reflected from a glass surface to make an actor appear as a ghost. It was commonly used in theatres in Victorian times as a special effect. If your school has a dark room, you might like to try and make your own Pepper's Ghost.

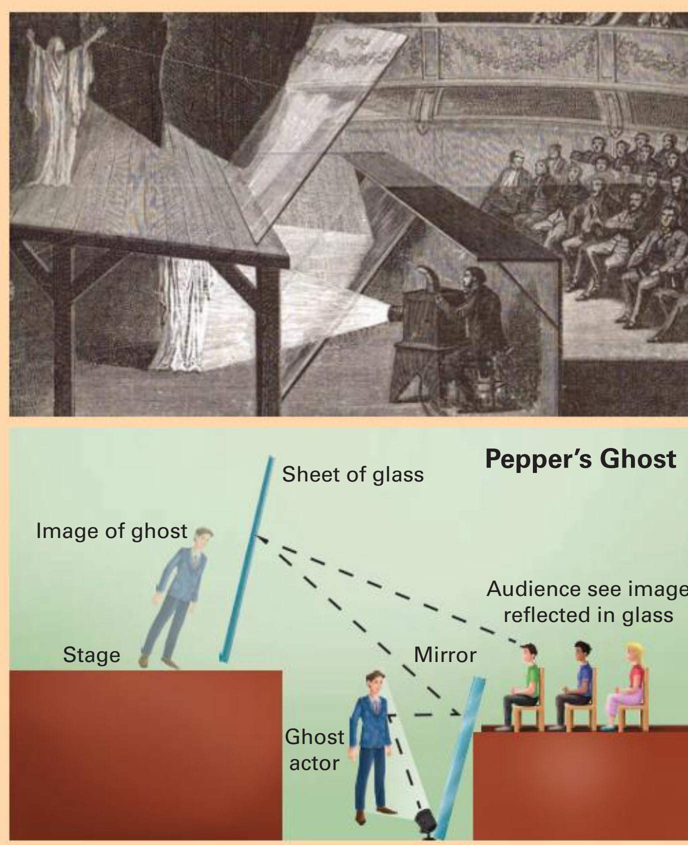


Figure 9.28 Pepper's Ghost apparatus being used in the theatre

ISBN 978-1-108-61069-8 Cambridge University Press

Law of reflection of light

To understand the law of reflection of light, you first need to learn some definitions.

incident ray
a ray of light arriving at a surface

reflected ray
a ray of light that is reflected off a surface

normal
an imaginary line that is at right angles to a surface

angle of incidence
the angle between an incident light ray and the normal when the ray arrives at a surface

angle of reflection
the angle between a reflected light ray and the normal, when the ray leaves a surface

- The incoming ray of light that hits the reflecting surface is called the **incident ray**.
- The outgoing ray of light that is reflected off the surface is called the **reflected ray**.
- The **normal** is an imaginary line that is at right angles to the surface.
- The angle between the incident ray and the normal is the **angle of incidence** (i).
- The angle between the reflected ray and the normal is the **angle of reflection** (r).

The law of reflection of light states that the angle of incidence and the angle of reflection are equal to each other.

angle of incidence (i) = angle of reflection (r)

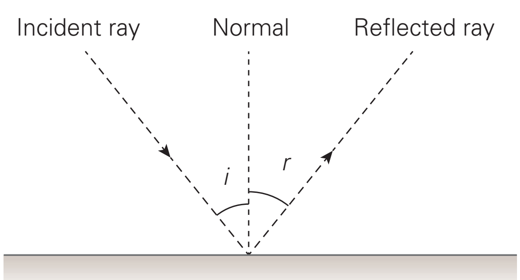


Figure 9.29 The law of reflection of light states that the angle of incidence (i) is always equal to the angle of reflection (r).

Quick check 9.6

1 State the law of reflection.
2 Explain what the law of reflection means.

Flat mirror

plane mirror
a flat reflective surface

The reflection you see in a flat mirror, also known as a **plane mirror,** is called an *image*. The actual thing that is being reflected in the mirror is called the *object*. You will have seen your own reflection

Figure 9.30 Mirrors arranged at an angle to each other can give more than one image.

many times in glass mirrors and windows, polished metal and even the surface of still water. You have probably noticed that the image formed in a mirror is upright but is inverted from left to right (called a lateral inversion), so if you raise your right hand in front of a mirror you will see your image raise its left hand.

When you look at an object in a plane mirror, the image appears to be behind the mirror. This is known as a *virtual image*. The image appears to be the same distance behind the mirror as the object is in front of it. What other characteristics of this virtual image do you notice? Is it the same size as the real object?

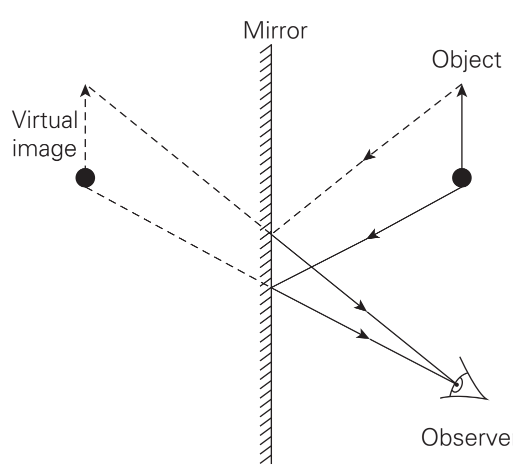


Figure 9.31 A mirror produces a virtual image, which appears to be behind the mirror.

ISBN 978-1-108-61069-8 Cambridge University Press

Did you know? 9.6

Virtual images

A *virtual image* is an image that appears to be in a particular place, but is not really there. An example of a virtual image is your reflection in the bathroom mirror. When you look in the mirror, there appears to be a person and a room on the other side of the mirror. But of course, in reality the only thing behind the mirror is the wall. A virtual image is always upright – your reflection in the bathroom mirror is never upside down. In a ray diagram, the virtual image is located where the light *appears* to be coming from, not where it really is coming from. (*Note:* a ray diagram represents the paths light takes from a certain point of view to a point on the image of an object.)

Practical 9.2

Investigating reflections

Aim
To investigate the difference between images formed from plane mirrors and those formed from curved mirrors.

Materials
- plane mirror
- metal tablespoon (or spherical curved mirrors)

Method
1. Observe your reflection in the back of the metal tablespoon. This is the convex (bulging outwards) side of the spoon. Move the spoon as close as you can to your face and back.
2. Record your observations in the results table.
3. Observe your reflection in the front of the spoon. This is the concave (curving inwards) side of the spoon. Move the spoon as close as you can to your face and back.
4. Record your observations in the results table.
5. Observe your reflection in the plane mirror. Raise your left eyebrow and observe which one of the reflection's eyebrows moves.

Results

Side of spoon	Observation of reflection		
	First observation	Close to your face	Far from your face
Concave side			
Convex side			

Evaluation
1. What happened to your reflection as you moved the spoon towards and away from your face?
2. Which eyebrow appeared to be raised in the reflection?
3. Based on your observations, where might a concave mirror be used? Where might a convex mirror be used?

Conclusion
1. Make a claim regarding plane and curved mirrors. Start your sentence with: 'This experiment suggests that the shape of the mirror … '.
2. Support your claim by using what you observed. Start your sentence with: 'It was observed that … '.
3. Explain how your observations support your claim. Start your sentence with: 'This means that: … '.

ISBN 978-1-108-61069-8 Cambridge University Press

Concave mirror

concave having an outline that is thinner in the middle, or a mirror that is curved inwards, like a cave

A **concave** mirror curves inwards, like a cave. Concave mirrors can be used to magnify images and are commonly used for shaving or applying make-up.

When parallel rays are reflected from a concave mirror, they converge at a *focal point*. The focal point is where an image forms. In Figure 9.33, the image is in front of the mirror, and is known as a *real image*.

Figure 9.32 If you hold a concave mirror close, it will magnify your image (a virtual image), as shown here. But if you moved a long distance away from the mirror, it would turn your image upside down (a real image).

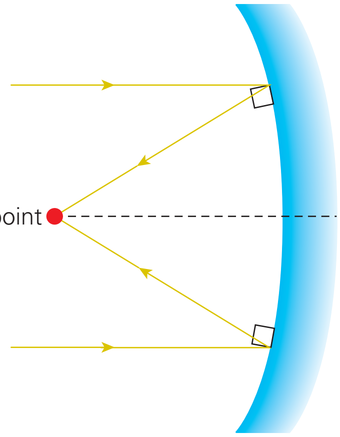


Figure 9.33 When an object is far from a concave mirror, the reflected light rays converge to form a real image. If the object was close to the mirror, it would form a large virtual image, as in the shaving mirror shown in Figure 9.32.

Convex mirror

convex having an outline that is thicker in the middle, or a mirror that bulges outwards

Convex mirrors bulge outwards and give a wider field of view. They are used in car rear view mirrors to allow drivers greater visibility. You may also see large convex mirrors at intersections that have limited visibility, or in the hallways of hospitals to provide a view of what is around the corner.

When light rays are reflected from a convex mirror, the light rays diverge. An image forms behind the mirror – this is a virtual image.

Figure 9.34 A car's side view mirror is often a convex mirror. It gives a wider field of view, but also makes objects appear smaller and closer than they actually are.

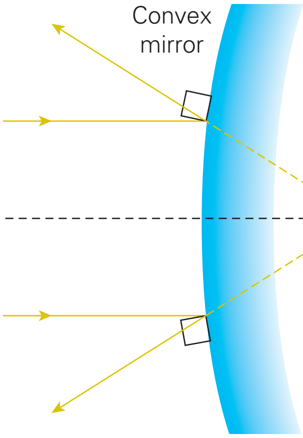


Figure 9.35 Reflected light rays diverge from a convex mirror. The image formed is a virtual image.

ISBN 978-1-108-61069-8 Cambridge University Press

Did you know? 9.7

Real images

A *real image* is an image that can be projected onto a screen, like a film projected onto a cinema screen. In a ray diagram, a real image forms where the light rays actually do converge. A real image is always upside down, like the image that forms on the retina of your eye.

Quick check 9.7

1 Describe the image formed in a plane mirror.
2 Describe three differences between images formed in convex mirrors and those formed in concave mirrors.

Practical 9.3

Investigating ray diagrams with concave and convex mirrors

Aim

To observe and record the way in which light rays are reflected from curved mirrors

Be careful

Take care as the light box can become hot with prolonged use.

Materials

- light box
- clear ruler
- pencil
- concave mirror
- convex mirror
- white A4 paper

Method

1 Plug in the light box and position it at the edge of a piece of A4 white paper.
2 Place the triple ray-forming plate into the slot and turn on the light box. Adjust the position of the bulb until you see three parallel rays of light on the paper.
3 Place the concave mirror about 10 cm in front of the rays, and align it so that the middle ray reflects back on itself.
4 Use a pencil to outline the mirror, and use a clear plastic ruler to trace the incident and reflected rays.
5 Label the point at which they meet the ‘focal point’.
6 Get a new piece of paper and repeat steps **3** and **4** with a convex mirror.
7 Trace the reflected rays back behind the outline of the mirror with dotted lines.
8 Label the point at which the dotted lines meet the ‘virtual focal point’.

Results

On your ray tracing diagrams, measure how far the focal point or virtual focal point is from the mirrors. Include this in your diagrams.

Evaluation

1 Do the focal lengths for the convex and concave mirrors differ?
2 Why does the convex mirror produce a ‘virtual focal point’?

Conclusion

1 Make a claim regarding light rays reflected from curved mirrors. Start your sentence with: ‘This experiment suggests that with curved mirrors … ’.
2 Support your claim by using what you observed when you used convex and concave mirrors. Start your sentence with: ‘It was observed that … ’.
3 Explain how the data supports your claim. Start your sentence with: ‘This means that … ’.

ISBN 978-1-108-61069-8

Refraction

When light travels from one substance into a different substance at an angle, it bends. This bending of light is called **refraction**. Refraction happens because light may slow down or speed up when it enters a different substance. Imagine a line of people running on a hard surface. When one end of the line encounters sand, it has to slow down. The runners in the sand will move slowly, while the rest of the runners continue to run fast. Eventually all the runners will enter the sand, but by now the direction of the runners has changed. The same thing happens when light travels from air into water.

refraction
the bending of light as it passes from one medium to another

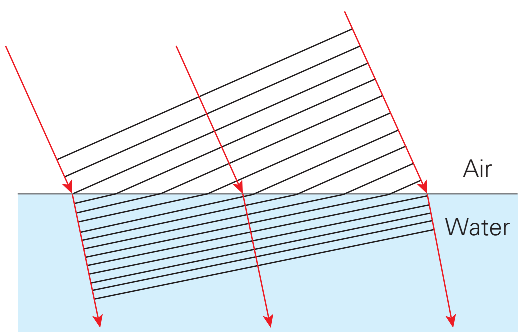


Figure 9.36 The direction the light is travelling in (shown by red arrows) changes when it moves from air (fast) into water (slow).

refractive index
a measure of how much the speed of light changes as it passes from a vacuum into a particular substance

Each material has a **refractive index**, which is a measure of the change in the speed of light as it moves from a vacuum into that material (see Table 9.1). Light travels fastest in a vacuum, and it slows down if it enters other materials such as air, glass or water. It only slows down a little bit in air. In water, the speed decreases by a factor of 1.33, and in glass it decreases by a factor of 1.52.

Light bends in a certain direction as it enters and leaves different materials. When light travels from a material with a lower refractive index into a material with a higher index (for example, from air into water), it slows down and bends *towards* the normal (see Figure 9.38, left).

Material	Speed of light (m/s)	Refractive index
Vacuum	299 792 458	1
Air	299 704 645	1.000 277
Water	224 900 569	1.33
Glass	197 231 880	1.52
Diamond	123 881 181	2.42

Table 9.1 The speed of light in different materials, and their refractive indexes

Figure 9.37 The pencil appears bent due to the refraction of light at the surface of the water.

Try this 9.3

Place a 20 cent coin in the bottom of a cup and move back just until you can't see it. Then add water without moving your head. As you do so, the coin will appear.

Did you know? 9.8

Trick of the light

When travelling through a hot desert, people often think they can see water or trees on the ground ahead of them. In reality, there is nothing there. It is a trick of the light, called a mirage. Light rays coming from distant objects are refracted by cold and warm air. This tricks our eyes into thinking that the light rays are coming from objects on the ground instead of the sky.

Conversely, when light travels from a material with a higher refractive index into a material with a lower refractive index (for example, from water into air), it speeds up and bends *away* from the normal (Figure 9.38, right).

ISBN 978-1-108-61069-8 Cambridge University Press

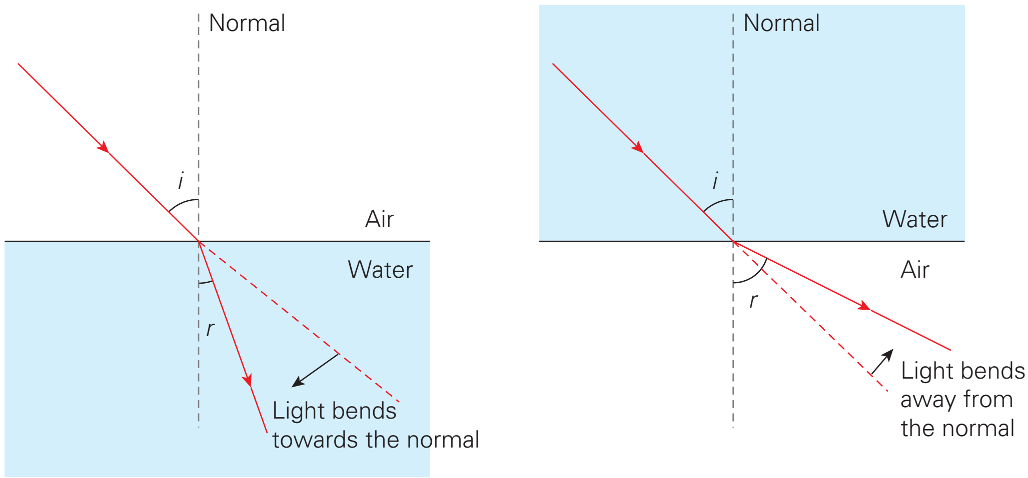


Figure 9.38 The direction light bends is dependent on the refractive index of the materials it enters and leaves from. Water has a higher refractive index than air.

Quick check 9.8

1. Define the term 'refraction'.
2. Explain how refraction differs from reflection.
3. Describe the difference between a material with a refractive index of 1.32 and one with an index of 1.74.
4. State whether light will bend towards or away from the normal when it is travelling from a material with a refractive index of 1.02 into a material with a refractive index of 1.4.

Prisms

Light bends when it enters a rectangular block, and bends back to its original direction when it leaves the block.

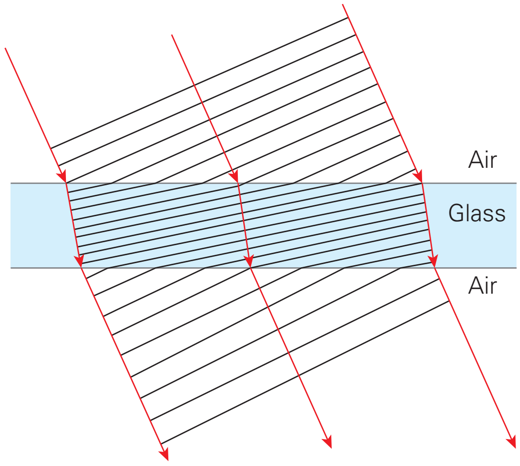


Figure 9.39 Light passing through a sheet of glass or a rectangular block emerges in the same direction as when it entered.

A triangular glass **prism** has a triangular face, usually an equilateral triangle, which is the same throughout its length.

prism
a piece of glass with a triangular cross-section that can be used to separate white light into its colours

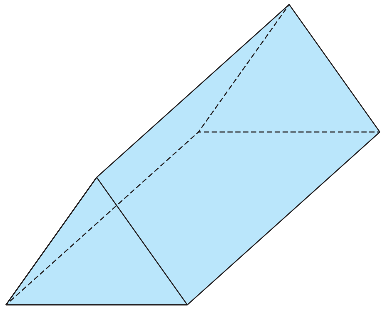


Figure 9.40 A prism

To use a prism, light is shone at an angle through the side of the prism. The light that emerges from the other side has been bent twice – when going into the prism and when coming out.

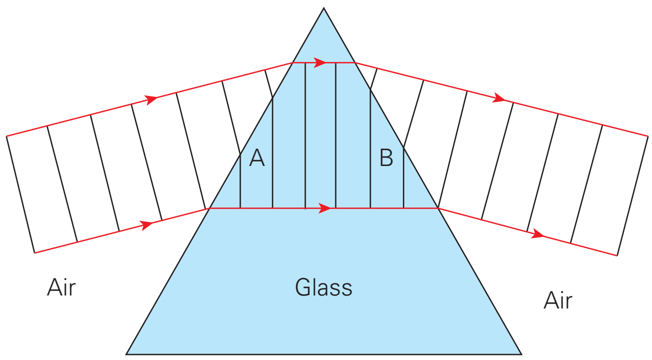


Figure 9.41 As light enters a prism, it slows and bends (A). It travels through the prism and bends a second time when it speeds up as it leaves (B).

ISBN 978-1-108-61069-8 Cambridge University Press

Different colours bend through different angles, and so a prism is able to separate white light into its separate colours. Isaac Newton discovered that white light is a mixture of different colours, which he called the *spectrum*. Newton was the first person to use a prism to separate the colours. He also discovered that once a colour (say, red) is separated, it cannot be separated again. It stays the same in all further experiments. He concluded from this that white light is a mixture of the different colours of the spectrum.

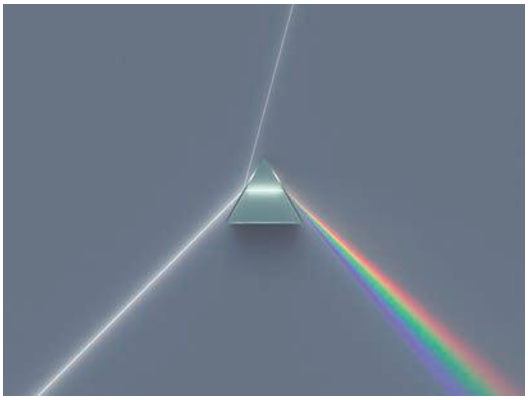


Figure 9.42 A strong beam of white light is refracted by a prism to form a spectrum. There are some reflected rays, and these remain white. Only the refracted rays form a spectrum.

Try this 9.4

Making a rainbow

You will need:

- a light box
- a prism
- a piece of white card.

Set up the light box in a dark room with a single-ray forming plate, so that a thin beam of white light is shining from one end. Place the prism so that the light enters one of the rectangular faces at an angle. Play around with the angle of the beam of light until you get a rainbow.

Quick check 9.9

1 Explain how a prism separates white light into its different colours.
2 Describe how light bends when it enters and leaves a rectangular block.

Practical 9.4

Refracting light

Aim

To investigate refraction of light through a glass block

Materials

- glass rectangular block
- light box
- sheet of A4 white paper
- protractor
- clear plastic ruler
- pencil

Be careful

Take care as the light box can become hot with prolonged use.

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Method

1 Connect the light box to a power source and insert a single-ray forming plate.
2 Place the light box on the piece of white paper and switch it on.
3 Direct the single ray towards the glass block, as shown in in Figure 9.43.

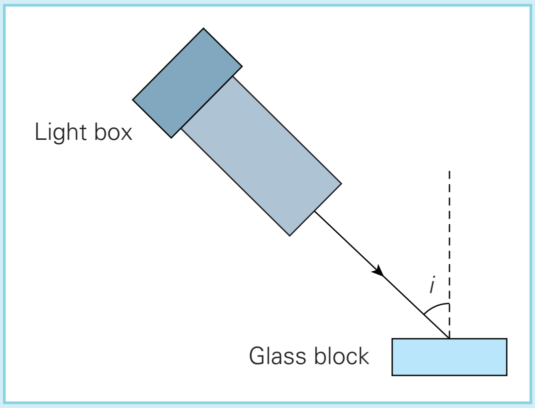


Figure 9.43 Experimental set-up

4 Trace the outline of the glass block onto the white paper. Use the clear ruler to trace the path of the incident ray and the refracted ray.
5 Remove the glass block and connect the two lines to visualise the path of the light through the glass.
6 Use the protractor to make measurements of the angles, and record your results in the results table.

Results

	Angle of incidence	Angle of refraction
Light entering glass		
Light leaving glass		

Evaluation

1 Does light bend towards or away from the normal when:
   a entering glass
   b leaving glass?
2 What do you notice about the beam of light that is entering the glass and the beam of light that is leaving the glass?
3 Does all the light travel through the glass and emerge from the other side?

Conclusion

1 Make a claim regarding light refraction through materials. Start your sentence with: 'This experiment suggests that light … '.
2 Support your claim by using what you observed. Start your sentence with: 'It was observed that … ' and include potential measurement uncertainties and experimental faults.
3 Explain how the data supports your claim. Start your sentence with: 'This means that … '.

ISBN 978-1-108-61069-8 Cambridge University Press

Convex lens

lens
a glass disc used to make images with light; a convex lens makes both enlarged and smaller images image and a concave lens makes a smaller image

There are two types of **lens:** convex and concave.

VIDEO
Lens demonstration

Convex lenses are thick in the middle and thin at the edges. An example of a convex lens that you are probably familiar with is a magnifying glass. If you look carefully at a magnifying glass, you will see that it is fatter in the middle and thinner at the edges. The magnifying glass makes the image appear bigger than the original object. Figure 9.45 shows how this happens.

However, when the distance between the convex lens and the object increases, the image can be upside down and sometimes smaller. This type of image is a real image.

Concave lens

Concave lenses are thin in the middle and thick around the edges. A concave lens has the opposite effect to a magnifying glass – it makes a smaller image. Rays that pass through a concave lens bend in the opposite direction to those passing through a convex lens (see Figure 9.46).

Figure 9.44 A magnifying glass creates an image that is larger than the actual object.

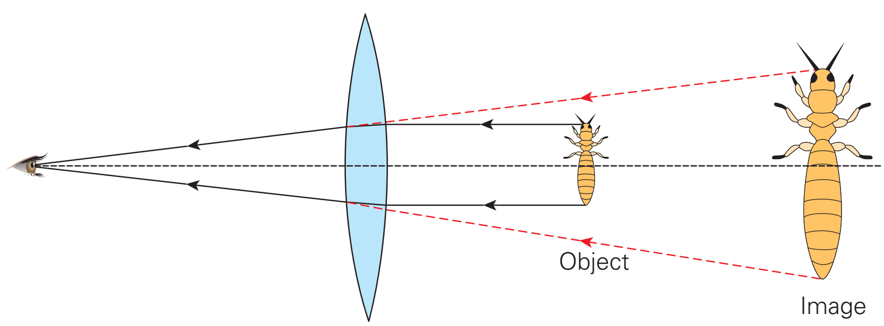


Figure 9.45 How a magnifying glass works. A convex lens makes the light rays converge, or bend inwards from their original path. The black lines represent the actual path of the light, the red dashed lines show where the light appears to come from. The image is upright, virtual and magnified.

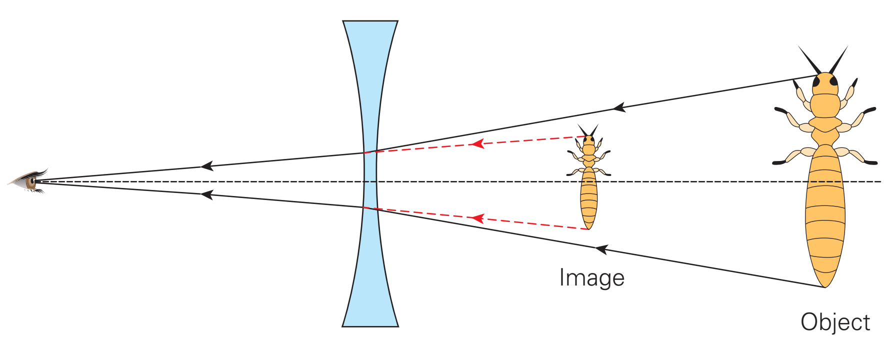


Figure 9.46 A concave lens makes an image that is smaller than the object. A concave lens makes the light rays diverge, or bend outwards from their original path. The black lines represent the actual path of the light, the red dashed lines show where the light appears to come from. The image is upright, virtual and smaller than the real object.

ISBN 978-1-108-61069-8

Practical 9.5

Focusing light

Aim
To investigate the refraction of light through different lenses

Materials
- light box
- A4 white paper
- clear ruler
- pencil
- biconvex lens
- biconcave lens

Be careful
Take care as the light box can become hot with prolonged use.

Method
1. Connect the light box to a power source and place it on the white paper.
2. Insert a triple-ray forming plate into the light box so that three parallel light rays fall onto the paper.

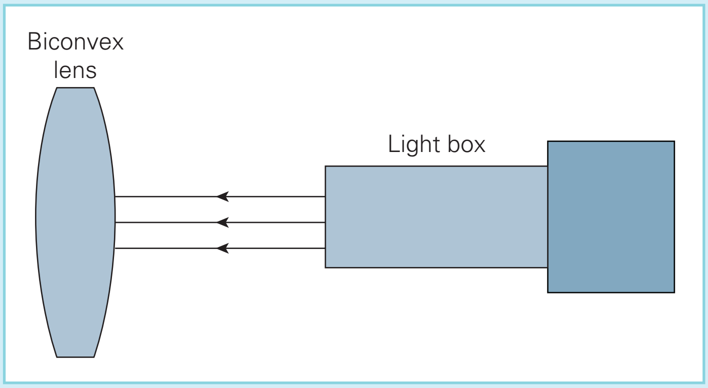


Figure 9.47 Experimental set-up

3. Place the biconvex lens onto the paper and trace its outline. Use the clear ruler to trace the three incident rays and the three refracted rays.
4. Repeat step **3** on a new piece of paper, but replace the biconvex lens with a biconcave lens.

Results
1. Label all your diagrams and give each page a title.
2. Measure and record the distance from the centre of each lens to the focal point.

Evaluation
1. Describe the difference in the refraction of light between biconcave and biconvex lenses.
2. Which lens produces a real focal point and which lens produces a virtual focal point?
3. Do all the incident rays refract? If not, which ones do not?

Conclusion
1. Make a claim regarding refraction through curved lenses. Start your sentence with: 'This experiment suggests that curved lenses … '.
2. Support your claim by using what you observed. Start your sentence with: 'It was observed that … '.
3. Explain how the data supports your claim. Start your sentence with: 'This means that … '.

ISBN 978-1-108-61069-8

Quick check 9.10

1 Describe the difference between a convex lens and a concave lens.
2 Which type of lens is used to magnify images?
3 Which type of lens makes light rays diverge?

Explore! 9.4

Total internal reflection

As you know, when light travels from one medium to another, it is refracted either towards or away from the normal. If the light is bending away from the normal, the angle of refraction could increase to 90°C. Here the angle of incidence is called the 'critical angle'. If the angle of incidence is greater than the critical angle, light cannot escape at the boundary. It is instead reflected back into the first medium. This is known as *total internal reflection*. Fibre optic cables use total internal reflection to confine light to the cable in order to transmit information with minimal signal loss.

Do some research to find answers to the following questions.

1 What does total internal reflection have to do with diamonds?
2 What other examples of total internal reflection can you find?

Figure 9.48 Multi-coloured fibre optic cables

Science as a human endeavour 9.2

Reflecting ants

Researchers have found that the Saharan silver ant uses total internal reflection to survive in extremely hot environments. Silver in colour, these ants have body hairs that totally internally reflect light, allowing them to forage in deserts where the temperature is over 50 degrees Celsius! Each hair has a triangular cross-section, like a long prism, and reflects most of the light (and heat) that hits it. This reflection of light and heat helps keep the ant cool and gives it a silvery sheen.

Figure 9.49 These ants are silver due to total internal reflection of sunlight.

ISBN 978-1-108-61069-8 Cambridge University Press

QUIZ

Section 9.2 questions

Remembering

1 Complete the following sentences.

a White objects ____________ all light, while black objects ____________ all light.

b An object that blocks all light from passing through is described as ____________.

c A transparent object allows ____________ light to pass through, while a translucent object allows ____________ light to pass through.

2 State the law of reflection of light.

3 Define the term 'refraction'.

4 Describe what a concave lens and a convex lens do to an image.

5 Recall the shape of the lens in the human eye.

6 Recall which colour of visible light bends the least.

7 Copy and complete the table below.

	Definition	Example of material
Transparent		Glass
Translucent		
Opaque	Does not let light pass through	

Understanding

8 Explain why some objects are reflective and create an image, and others are not reflective.

9 Copy the diagram below into your book and label it with the following terms:

Incident ray

Reflected ray

Angle of incidence

Angle of reflection

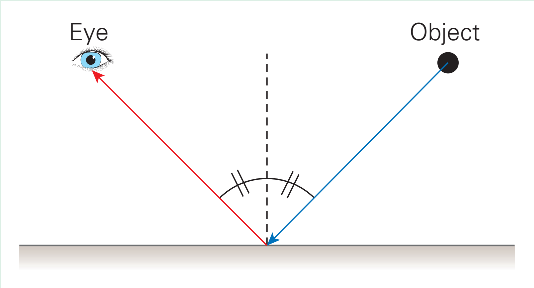


Figure 9.50

10 Explain how the reflection of an object in a mirror differs from the actual object in real life.

11 Explain the difference in uses for concave and convex mirrors.

12 Describe what happens to light rays as they pass through a convex lens versus a concave lens.

13 Describe what type of material (transparent, translucent or opaque) you would normally use in the following situations.

a A car windscreen

b Curtain for a changing room in a clothes store

c Windows in a bathroom

continued...

ISBN 978-1-108-61069-8

Cambridge University Press

...continued

Applying

14 Explain the reason why the woman in the swimming pool in Figure 9.51 looks distorted.

Figure 9.51

15 For each of the following types of electromagnetic radiation, describe an example of how they are used.

- **a** Radio waves
- **b** Microwaves
- **c** Infrared radiation
- **d** Visible light
- **e** Ultraviolet
- **f** X-rays
- **g** Gamma rays

16 Identify whether a convex or concave mirror would be useful in the following situations.

- **a** A security mirror in a hospital
- **b** A mirror at an intersection to allow greater visibility
- **c** A mirror to help a person apply detailed eye makeup

Analysing

17 Suggest what sort of object might be used in a reflecting telescope, as opposed to a refractive telescope. Justify your response.

18 Light is shone through a red colour filter.

- **a** State the colour of the light transmitted through the filter.
- **b** Another filter is then applied in addition to the red filter, this time a green filter. State the colour of light transmitted through this filter.

19 Yellow paint absorbs blue and reflects red and green. Cyan paint absorbs red and reflects blue and green. If these two paints are mixed, state which colour the mixture will reflect. Explain your response.

Evaluating

20 Suggest how the reflections of the people in Figure 9.52 are being distorted.

Figure 9.52

ISBN 978-1-108-61069-8 Cambridge University Press

9.3 Sound

Sound waves

You may recall from Section 9.1 that light travels as a transverse electromagnetic wave. Sound also travels in waves, but these are **longitudinal waves**. This is because in air, sound consists of **vibrations** of air particles, which move quite differently to light. Sound is a longitudinal wave, because the air particles vibrate backwards and forwards in the same direction as the travelling sound. The best way to picture the motion of sound through the air is to move the end of a slinky forwards and backwards quickly to send a series of pulses through the spring. You will see that there are sections where the vibrating parts are close together and have high pressure (called **compressions**) and sections where they are far apart and have low pressure (called **rarefactions**).

longitudinal wave
a wave with vibrations in the direction of travel instead of transversely. Sound waves are examples.

vibration
movement backwards and forwards or side to side in a regular way

WORKSHEET

Sound is a form of wave energy that needs a **medium** to travel through, but the medium does not have to be air. It can be a solid or a liquid. In fact, because sound needs particles to vibrate in order for it to travel, sound travels faster through solids, where the particles are close together. It can't travel at all through a vacuum (where there are no particles).

compression
the part of a sound wave where the air molecules are squashed together

rarefaction
the part of a sound wave where the air molecules are spread apart

medium
substance that allows waves to travel in it

When a sound wave passes through air, the movement of the molecules is in a pattern that consists of regions of high pressure (compression) and regions of low pressure (rarefaction).

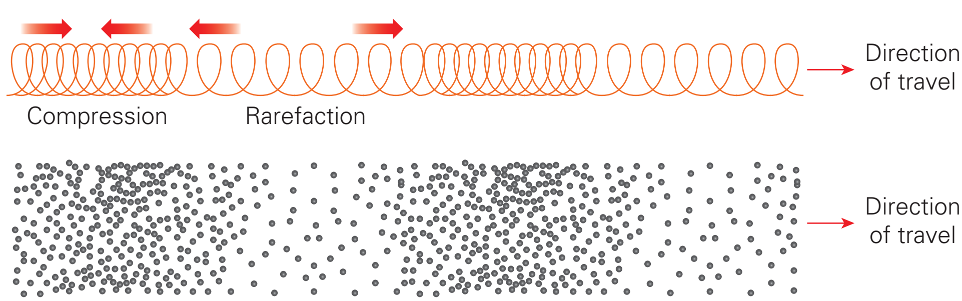


Figure 9.53 Longitudinal waves in a slinky are similar to longitudinal sound waves.

Visualising sound

Try this 9.5

Grab a slinky and stretch it out along the floor until it is a couple of metres in length. Create vibrations in the slinky by moving the coils back and forth. Observe the areas of compression and rarefaction that move back and forth along the length of the slinky.

Quick check 9.11

1 Define the term 'sound'.
2 Define the terms 'compression' and 'rarefaction'.
3 Explain why sound travels faster in solids.
4 Explain how sound is an example of a longitudinal wave.

ISBN 978-1-108-61069-8 © Roberts et al. 2019 Cambridge University Press

Practical 9.6

Making sound

Aim

To hear and observe vibrations in the air

Materials

- water
- tuning forks
- rubber stopper
- 100 mL beaker

Be careful

Avoid bringing the tuning fork near your mouth, as it can cause serious damage to your teeth.

Method

1. Strike the tuning fork on a soft surface, such as the rubber stopper.
2. Bring the tuning fork to your ear and see if you can hear anything. You can use a sounding board to hear the sound clearly.
3. Repeat step **1**, and lightly touch the vibrating ends of the tuning fork to the surface of the water.
4. Observe what happens to the water.

Results

Record your observations in your book.

Evaluation

1. Explain what you heard when you held the tuning fork to your ear. How does this work?
2. What happened when you submerged the ends of the tuning fork in water? Explain why this happened.
3. Could you observe areas of compression and rarefaction in the water?

Conclusion

1. Make a claim regarding sound and vibrations. Start your sentence with: 'This experiment suggests that sound … '.
2. Support your claim by using what you observed when you struck the tuning fork and put it in the water. Start your sentence with: 'It was observed that … '.
3. Explain how the observation supports your claim. Start your sentence with: 'This means that … '.

Properties of sound waves

In the same way that we can describe the properties of the transverse waves of light, we can also describe the properties of the longitudinal waves of sound. First, let's recap the terms 'wavelength', 'frequency' and 'amplitude'.

- *Wavelength* (unit = metre) is the distance between two compressions or rarefactions of a wave. The greater the distance between two crests, the longer the wavelength.
- *Frequency* (unit = hertz) is the number of complete waves or vibrations that pass a point each second. The more wavelengths that pass in a second, the higher the frequency.
- *Amplitude* (unit = metre) is the maximum displacement of air particles from their undisturbed position. This is the displacement amplitude. The pressure amplitude is the difference between the maximum pressure in a compression and atmospheric pressure.

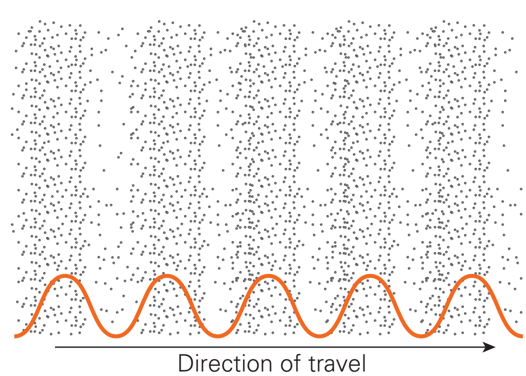


Figure 9.54 The distribution of particles of air as a sound wave moves through, from left to right. The graph at the bottom shows how the air pressure varies between compressions and rarefactions, and shows that sound can be described using the wave model.

ISBN 978-1-108-61069-8

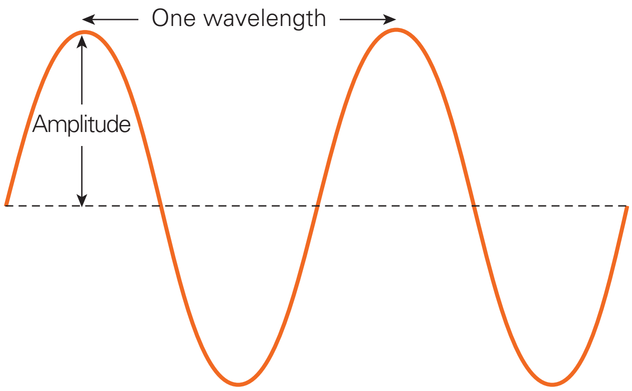


Figure 9.55 The length of a wave, called its wavelength, is the distance between two crests. The amplitude is the distance from the centre line to the top.

Looking at waves — **Try this 9.6**

We can use water waves to model the longitudinal waves that sound exhibits.

Half fill a deep tub with water and place a cork in the water, allowing it to float. Using an eye dropper, release drops of water next to the cork. Observe what happens to the cork as the drops make waves in the water. Now stop releasing the drops of water. What happens to the cork? Has it moved from its original position?

Pitch

pitch
how high or low a sound seems to our ears

The **pitch** of a sound is how high or low it sounds to our ears. The pitch of a sound wave is determined by its wavelength and therefore its frequency. Shortening the wavelength increases how often the wave occurs in each second (frequency), and this increases the pitch of the sound. Low-pitched sounds have a long wavelength, high-pitched sounds have a short wavelength.

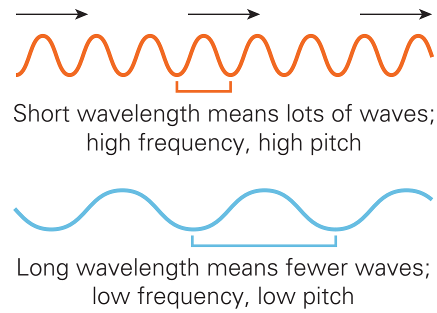


Figure 9.56 Which of the two waves do you think would be a whistle and which would be a bass guitar?

Loudness

The energy of a wave depends on its amplitude. If you look at water waves, you might notice that not all waves look the same: some waves are bigger than others. If you were able to see sound waves, you would notice that loud sounds have a higher amplitude than soft sounds. When a drum is hit harder, with more energy, it sounds louder – the loudness of the sound is a measure of the sound energy.

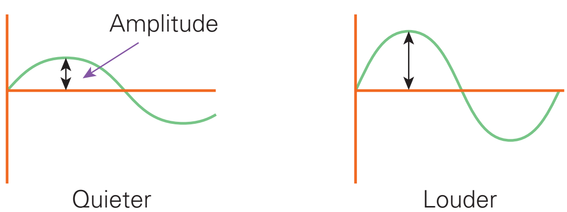


Figure 9.57 The amplitude of a sound wave is an indication of the loudness of the sound.

Quick check 9.12

1 Explain the difference between the terms 'frequency', 'wavelength' and 'amplitude'. Include the units.
2 Look at the waves shown in Figure 9.58, shown as pressure against time, and answer the questions below.
 a Which wave has the highest frequency?
 b Which wave has the longest wavelength?
 c Which wave do you expect to have the highest pitch?
 d Which wave is the loudest?

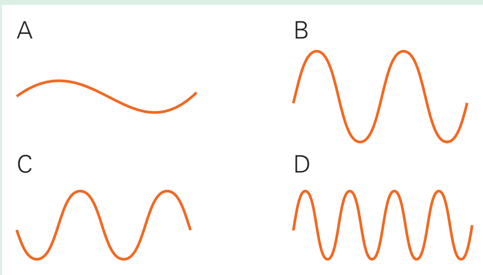


Figure 9.58

ISBN 978-1-108-61069-8

Practical 9.7

Investigating the properties of sound

Aim
To investigate ways of altering pitch and loudness

Materials
- ruler
- scissors
- 2 straws
- spatula
- small beaker
- large beaker

Method
1. Position the ruler so half of it is hanging off the table.
2. Hold your hand firmly over the ruler and use your other hand to flick the edge hanging off the table.
3. Reposition the ruler so more is hanging over the edge, and repeat step **2**.
4. Record your observations in results Table 1.
5. With the scissors cut a straw into two pieces, so that one piece of straw is double the length of the other piece.
6. Blow gently across the opening of the short straw, and then the long straw. Record your observations in results Table 2.
7. Using the spatula, gently tap the side of the small beaker, then the large one. Record your observations in results Table 3.

Results

	Half ruler overhanging table	More than half ruler overhanging table
Observations on sound produced		

Table 1 The difference in sound produced by different lengths of ruler vibrating

	Shorter straw	Longer straw
Observations on sound produced		

Table 2 The difference in sound produced by different lengths of straw

	Smaller beaker	Larger beaker
Observations on sound produced		

Table 3 The difference in sound produced by different-sized beakers

Evaluation
1. Explain how the sound changes when the vibrating part of the ruler is longer.
2. Explain how the sound changes when the straw is longer.
3. Explain how the sound changes when the beaker is bigger.
4. For each of the three parts of the practical, provide an example of an instrument that works by the same principles.

Conclusion
1. Make a claim regarding frequency, loudness and the length of materials used. Start your sentence with: 'This experiment suggests that … '.
2. Support your claim by using what you observed. Start your sentence with: 'It was observed that … '.
3. Explain how the data supports your claim. Start your sentence with: 'This means that … '.

ISBN 978-1-108-61069-8 Cambridge University Press

Speed of sound

Have you ever seen a flash of lightning and sometime later heard thunder? It usually takes a few seconds for the sound to travel from the lightning flash to your ears. This is because light travels about 1 000 000 times faster than sound, which travels at around 340 metres per second.

The graph in Figure 9.59 shows the relationship between the distance to the flash of lightning and the time delay before hearing the sound.

Do you see any pattern in the graph? Look carefully, and you will see that the line of the graph runs close to the points (3, 1000), (6, 2000) and (9, 3000). This gives a simple rule for calculating the distance to a lightning strike: every three seconds is about 1000 metres or 1 kilometre.

WIDGET
Lightning speeds

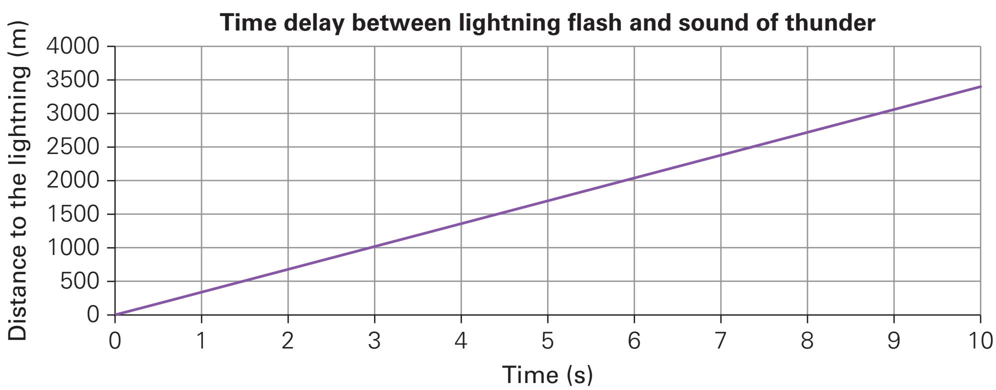


Figure 9.59 Graph of the time between seeing lightning and hearing thunder versus distance to the lightning

Try this 9.7

How far away is the storm?

One way to determine the distance to a lightning strike is to make a movie of the thunderstorm.

Using a mobile device, record a video (from somewhere indoors) during a thunderstorm.

Analyse the video of the storm to accurately determine the time between the flash of lightning and the beginning of the sound of the thunder.

Use the graph in Figure 9.59 to estimate the distance to the lightning.

Stay safe: Record your movie from a place indoors, at a safe distance from a window. This will work well, you will not get wet, and it is not safe to be outside during a thunderstorm in case the lightning hits you.

Figure 9.60 Melbourne during a lightning storm

ISBN 978-1-108-61069-8

Cambridge University Press

Did you know? 9.9

When an object travelling through air breaks the sound barrier (travels faster than the speed of sound), it creates a shock wave, called a sonic boom. A sonic boom releases huge amounts of sound energy, similar to an explosion or thunder. You hear the boom when the shockwave reaches you.

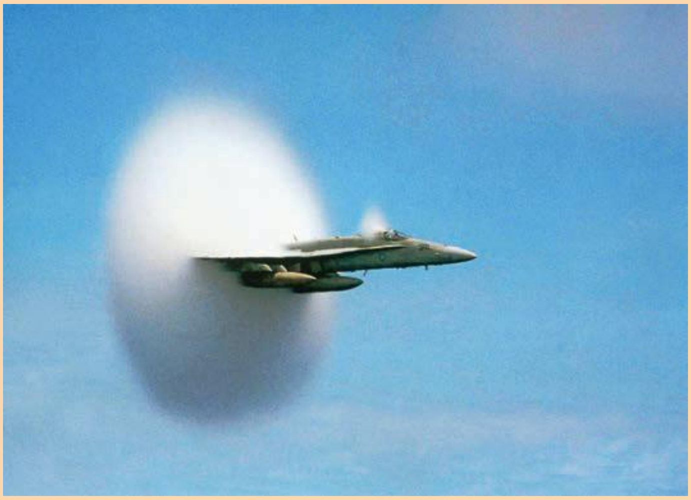


Figure 9.61 Cloud forming behind an aircraft as it breaks the sound barrier

The speed of a sound is not dependent on how loud or quiet the sound is, or whether the pitch is high or low. We normally hear sound travelling through the air, but sound can also travel through other materials, such as liquids and solids, often at much higher speeds (see Table 9.2). For example, sound travels through water four times faster than through air, and it travels through iron 16 times faster than through air. Animals such as whales and dolphins use sound to communicate over long distances under water.

Substance	Speed of sound (m/s)
Carbon dioxide*	260
Air*	330
Hydrogen*	1300
Water	1400
Salt water	1500
Wood	4000–5000
Glass	4500–5500
Steel	5000

*Gases are at 0°C

Table 9.2 Speed of sound in different substances

Figure 9.62 Whales use sound to communicate over long distances

Try this 9.8

Eavesdropping!

Gently place a wide glass with its open end against a wall and put your ear next to the closed end. If there is a noise on the other side of the wall, you should be able to hear it through the glass. This shows that sound can travel through the wall as well as through air.

Quick check 9.13

1. Estimate how long after seeing a flash of lightning it would take to hear the thunder if the lightning strike was 1.5 km away.
2. Estimate how far away the lightning is if you hear thunder 12 seconds after the flash.
3. Explain what 'the speed of sound' is.
4. State whether sound travels fastest through solids, liquids or gases.

ISBN 978-1-108-61069-8 Cambridge University Press

Practical 9.8

Investigating the speed of sound

Aim

To investigate how sound travels more efficiently in solids than in air

Materials

- ticking watch
- wooden rule
- metal ruler
- spatula
- cotton thread

Method

1. Have your lab partner hold the ticking watch close to your ear and slowly move it away until you cannot hear it anymore.
2. Measure the distance between your ear and where your partner is holding the watch. Record this distance in the results table.
3. Repeat steps **1** and **2**, but this time hold the ruler carefully against your ear. Slide the watch down the ruler until you cannot hear it anymore.
4. Cut a length of string approximately 80 cm and tie it to the spatula.
5. Swing the spatula so it hits the side of a lab bench. Listen to the sound it makes.
6. Repeat step **4**, but hold the string against your ear. Listen to the sound it makes. Record your observations in the results table.

Results

	Distance/observations
Watch in air	
Watch on ruler	
Spatula in air	
Spatula on string	

Evaluation

1. Describe the difference in distance between when the watch was heard in air and when it was heard on the ruler.
2. What effect did holding the string next to your ear have on the sound you heard?
3. Does sound travel more efficiently in air or through solids?

Conclusion

1. Make a claim regarding how well sound travels in different media. Start your sentence with: ‘This experiment suggests that sound travels more efficiently … ’.
2. Support your claim by using what you observed. Start your sentence with: ‘It was observed that … ’ and include potential sources of error.
3. Explain how the data supports your claim. Start your sentence with: ‘This means that … ’.

ISBN 978-1-108-61069-8 Cambridge University Press

Explore! 9.5

Echo, echo, echo

An echo is a sound that is repeated due to sound waves being reflected back towards the listener. Sounds bounce off hard surfaces, so in small rooms with hard walls, sounds are echoed more.

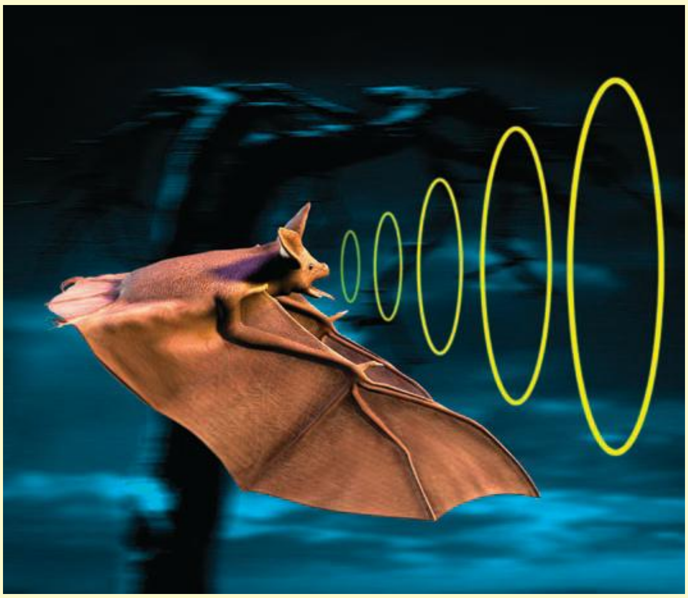


Figure 9.63 Bats use echolocation to navigate.

Find out about echolocation, sonar and ultrasound. Give some examples of how they are used by humans and are found in nature.

Musical instruments

Stringed instruments

Stringed instruments, such as the guitar and the violin, consist of tight strings fitted over a hollow box that amplifies sound – this box is called the body of the instrument.

standing wave
a wave that is trapped between two fixed ends and moves backwards and forwards, reflecting from each end in turn

When the string is plucked, it forms a **standing wave** and vibrates at a fixed frequency. To see how a wave can form a standing wave, use a slinky.

Guitar strings form a wave pattern similar to that of the slinky, as they are fixed at each end and the string moves up and down in the middle. The speed of vibration of

Try this 9.9

Making waves

In pairs, grab a slinky and have each person hold one end, standing about five metres apart. While one student holds their end as still as possible, the other student moves the other end up and down at just the right frequency to make a standing wave shaped like a skipping rope (see Figure 9.64). Once the standing wave is formed, it is easy to maintain but the frequency has to stay the same. Try going a little faster or slower – the standing wave will disappear.

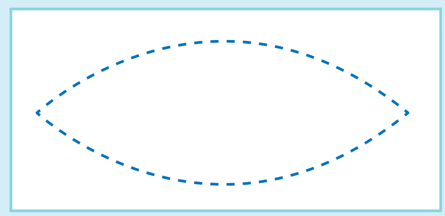


Figure 9.64 The shape of a standing wave

Next, try making the slinky tighter by holding it a little further in, removing some of the coils. Now that the slinky is tighter you should see that it has to be moved faster to get the same pattern as before. The number of times the slinky moves up and down in a second is called its frequency.

Release the coils again and go back to how you started. Now try moving the spring up and down at double the speed (frequency). A new standing wave will form (see Figure 9.65).

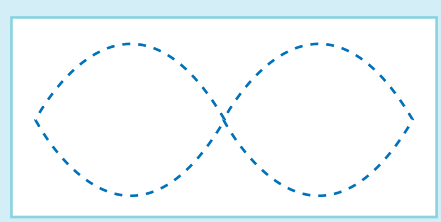


Figure 9.65 A standing wave at a higher frequency

Experiment to see if more patterns can be made if the slinky is moved even faster.

ISBN 978-1-108-61069-8

Figure 9.66 Guitar strings have different length, mass and tension, which all affect the sound produced.

the wave in the guitar string can be altered by changing the tension in the string. You might also notice that some strings have more mass and vibrate more slowly than other, lighter strings. The length of the string is another factor that affects the note heard. Placing fingers on the frets alters the effective length of the string, and this affects the wavelength and frequency of the note. As the string vibrates, it moves backwards and forwards, making sound waves. The sound waves are trapped in the air in the body of the guitar, and are amplified, creating the sound of the guitar.

Wind instruments

Wind instruments rely on the vibrations of air in a tube. To change the note produced, only the length of the tube can be altered, and different mechanisms have been invented to do this. Two categories of wind instruments are brass and woodwind.

wind instrument
a musical instrument that relies on air vibrating inside a tube to make sound; includes brass and woodwind instruments

To make a sound with a brass instrument, the air vibrations are started by vibrating the player's lips inside the mouthpiece.

Figure 9.67 A trumpet (shown at left) is a small brass instrument that makes notes with a high pitch. The length of the tube is altered by opening valves with the three buttons, which allows air to vibrate in different parts of the instrument. A trombone (shown at right) has a sliding tube. The tube is lengthened by moving the end of the tube away from the player.

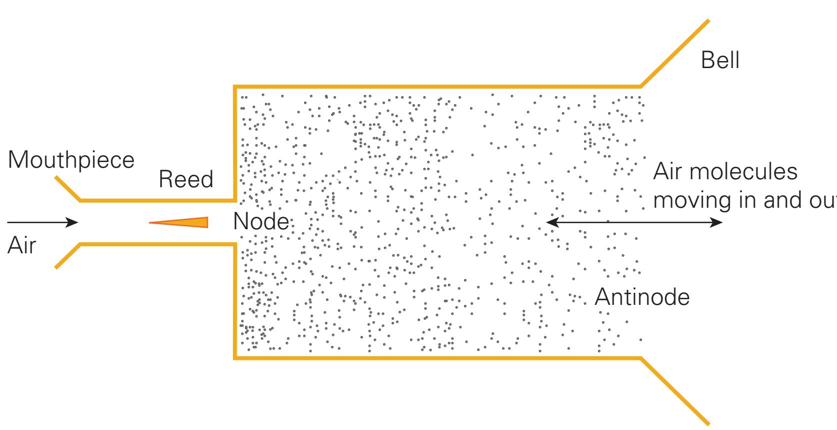


Figure 9.68 Sound is formed as the molecules of air move in and out of the open end of the instrument.

ISBN 978-1-108-61069-8

To make a sound with a woodwind instrument, the air is made to vibrate at the mouthpiece end of the instrument. The is sometimes done with a single reed (clarinets and saxophones), a double reed (oboes and bassoons) or an edge of the mouthpiece (flutes).

Percussion instruments

Drums, cymbals and tambourines are all examples of **percussion instruments**. These are instruments that make sound when their surface vibrates. Because the player operates these instruments with their muscles, a lot of energy can be used to make the sound, and this means percussion instruments can be very loud. The bigger the instrument, the lower the pitch of the sound it makes – big bass drums make the lowest sound of all. Usually a drum has a fitting on the side that allows the surface to be stretched or relaxed; stretching the surface increases the pitch of the note produced by the drum.

percussion instrument a musical instrument that is struck to make a sound; often has a vibrating surface to make the sound (e.g. a drum)

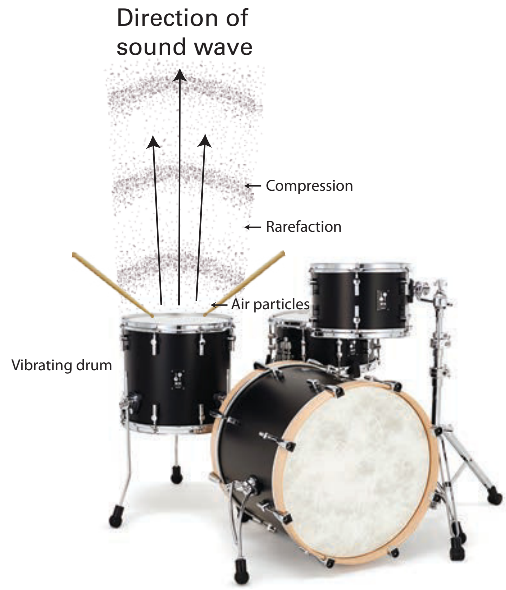


Figure 9.69 A drum kit and a kettle drum after being struck.

Science as a human endeavour 9.3

Instrument or beatboxer?

Beatboxing is a form of music in which performers use their vocal tract to mimic instrumental sounds. Researchers have used real-time MRI to study how beatboxers make percussive sounds. This means the researchers are able to observe the vocal tract of the beatboxer as they make the sounds, to help them differentiate between movements of the vocal tract for speech and movements for making beatboxing sounds. It turns out that beatboxers can create sounds that are not found in any language in the world!

Figure 9.70 Beatboxers can figure out how to make sounds that mimic snare drums.

Try this 9.10

Make your own instrument

It's over to you! You must make your own instrument. It can be wind, stringed or percussion. Musical instruments are easy to make out of scrap materials. Remember to include a sound box like the one on a guitar, to increase the volume. Bottles can make a wind instrument if you blow over the top – adding water to the bottle changes the note. Plastic pipe makes a nice sound if you hit it with a soft shoe. What happens if you cover the end of the pipe – does the note change? Your instrument must be able to play multiple notes, and you need to be able to explain how it works, using scientific terminology.

ISBN 978-1-108-61069-8 Cambridge University Press

Quick check 9.14

1 Provide an example of a stringed instrument.
2 Provide an example of a wind instrument.
3 Explain the difference between a brass instrument and a woodwind instrument.
4 Explain how percussion instruments create sound.

Explore! 9.6

Acoustics

In places where good sound quality is important, such as concert halls, cinemas and recording studios, the rooms are built in a certain way to facilitate this.

1 How does soundproofing work?
2 What types of surfaces absorb sound? What types reflect sound?
3 What kinds of features can be included in a room to improve the acoustics?

Figure 9.71 Soundproofing being used in a recording studio

Science as a human endeavour 9.4

Soundproofed into silence

In order to develop new and improved hearing aids, researchers have built a completely soundproof room. Their goal is to create hearing aids that can filter unwanted background noises. A regular lab is too noisy to test such very sensitive equipment, so they built a specialised one. This new chamber will allow researchers to study where sounds come from and how they travel.

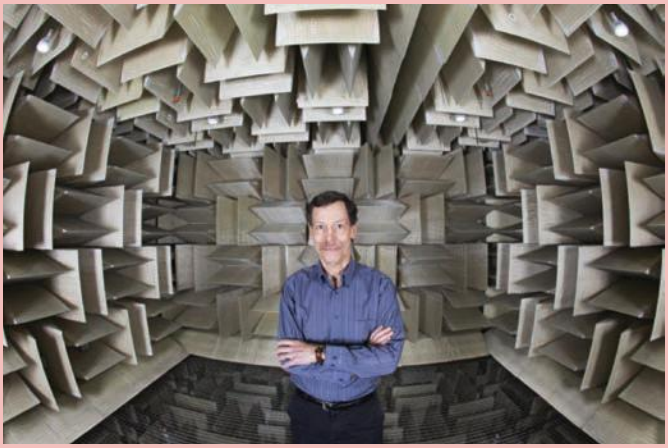


Figure 9.72 Professor Ron Miles inside the completely soundproof chamber

ISBN 978-1-108-61069-8 Cambridge University Press

QUIZ

Section 9.3 questions

Remembering

1 Recall the terms for the high-pressure and low-pressure areas of a sound wave.
2 Recall the speed of sound in air.
3 Copy and complete the table by providing definitions for the following terms.

Word	Definition
Wavelength	
Frequency	
Amplitude	
Pitch	

4 Complete the following sentences.
Pitch is determined by the ____________________ of a wave.
Loudness is determined by the ____________________ of a wave.
5 Sound travels at different speeds in different substances. Arrange the following list of substances in order from fastest to slowest.
Glass
Air
Hydrogen
Water
Steel

Understanding

6 Explain what is meant by the term 'longitudinal wave'.
7 State whether sound would travel faster or slower on a hot day. Justify your response.
8 Explain why sound cannot travel through the vacuum of space.
9 Explain why you see the flash of lightning first before you hear the thunder.
10 Describe what happens to the frequency of a standing wave as the string gets shorter.

Applying

11 If you see a flash of lightning and 20 seconds later hear the thunder, calculate how far away the storm is.
12 A sound wave has a frequency of 5 Hz and a wavelength of 3 m. Interpret what this means.
13 Use Figure 9.73 to explain why sound the loudness of a sound decreases as you move away from the source of the sound.

Figure 9.73

14 Apply your knowledge of kinetic energy to sound. Explain how sound can be an example of kinetic energy.

continued…

ISBN 978-1-108-61069-8

...*continued*

Analysing

15 Distinguish between how different notes are created in a stringed instrument and how they are created in a wind instrument.

16 A cello is bigger than a viola, and a violin is smaller than a viola.

  a Predict which of these three instruments is better for playing a high note.

  b Predict which of the three instruments in part **a** would be better for a low note.

17 A piano is a stringed instrument with a different string for each note. If you were to look inside it, at the strings, infer what you would expect to see for the low-pitched notes.

Evaluating

18 Predict the effect of altering the shape of the body of a guitar.

19 Propose a reason why cinemas have thick, heavy curtains all around the walls and everything is covered in soft material.

Figure 9.74

9.4 Seeing and hearing

WORKSHEET

How the eye works

You already know that eyes are amazing, and ever since you were little you have probably been told to protect your eyes. This is because you only have one set of eyes and they do not grow back if they get damaged.

As you can see in Figure 9.75 on the next page, light enters the human eye through the **cornea** and then through the small hole at the front, called the **pupil**. The size of the pupil is controlled by the **iris** muscles, which form the coloured part of the eye.

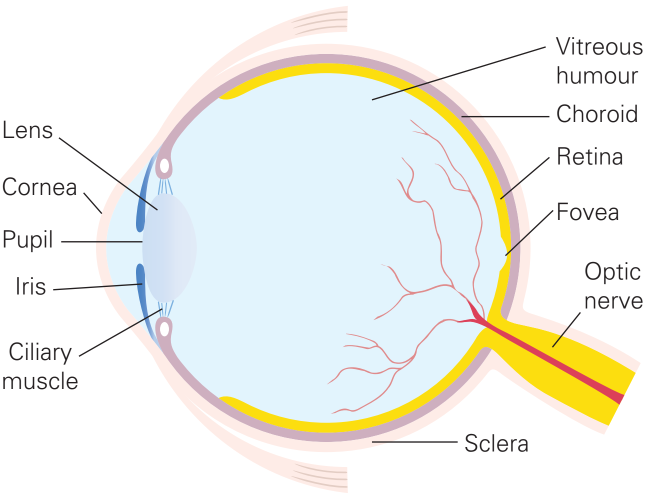
cornea
the transparent outer covering of the eye

pupil
the circular black area in the centre of the eye, through which light enters

iris
the coloured circular part of the eye that surrounds the black pupil

ISBN 978-1-108-61069-8

Cambridge University Press



Cornea: clear protective covering in front of the iris
Pupil: a gap in the front of the eye where light enters
Iris: muscles that change the size of the pupil to control the amount of light entering the eye
Lens: a convex shape that is flexible and helps to focus light on the back of the eye
Ciliary muscles: muscles that control the shape of the lens by changing its shape
Vitreous humour: clear jelly-like substance in the eyeball through which light passes
Choroid: contains the blood vessels that supply the retina
Retina: light-sensitive lining at the back of the eye that converts light into electrical signals
Fovea: the point of best focus, and where the lens aims to direct the light
Optic nerve: carries the information from the retina to the brain
Sclera: the white outer layer of the eyeball of the eye

Figure 9.75 The structure of the human eye, side-on view

If you are somewhere dark, the pupil's size will increase to let in as much light as possible. On a bright sunny day, the pupil's size will reduce, to limit the amount of light that enters the eye. Just behind the iris is the **lens** (just like the convex lenses you saw in Section 9.2), which produces a smaller upside down image on the retina of the image being looked at, and allows the eye to focus on distant and near images. It focuses the light on the fovea, a small area on the **retina**. The light passes through the pupil and the lens, travels to the back of the eye, and forms an upside-down image on the retina. A tiny area of the eye where the optic nerve connects to the retina has no cells that detect light. This area is known as the *blind spot*.

lens (eye)
a small disc of transparent tissue behind the pupil that allows near and far objects to be focused

retina
an area of tissue at the back of the eye that contains cells that can detect light and colour

When you change what you are looking at, the lens automatically adjusts to become more curved for near objects and less curved for distant objects. The ciliary muscles controlling the lens are involuntary, which means you do not have to think about focusing when you lift your eyes from a book to look at a distant tree. This process of adjustment is called **accommodation**.

accommodation
automatic adjustments made by the eye when looking at objects at different distances

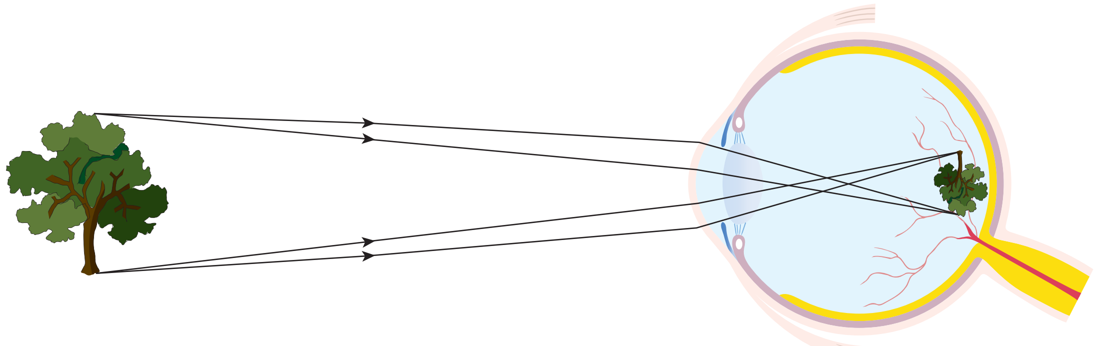


Figure 9.76 The light reflected from the tree passes through the pupil and the lens to form an image on the retina.

ISBN 978-1-108-61069-8 Cambridge University Press

Practical 9.9

Eye dominance vs hand dominance

Most of us have a dominant hand, that is, the hand that we prefer to use for more precise performance. Just like a dominant hand, most of us have a dominant eye. This is the eye that our brain has more of a preference for when processing visual input. Visual information is still seen through both eyes, but more precise visual information comes from the dominant eye. This is the eye that we should use in activities that involve aiming.

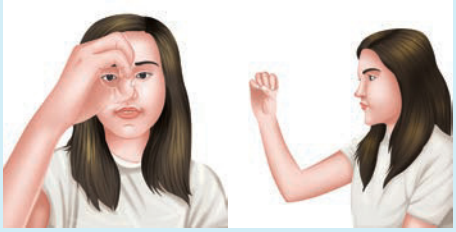
Aim

To determine if eye dominance is related to hand dominance.

Materials

An object on a wall or far away that can be the subject of focus.

Method



1. Will an individual's eye dominance always be the same as their hand dominance? Propose your hypothesis.
2. Use your dominant hand to create a 'binocular' with your fingers as shown.
3. Find an object in the distance, such as a clock. With both eyes open, try to view it through the hole.
4. Once you can clearly view the object through the hole, close your left eye so you are only looking at it with your right eye. If you can see the object, then you are right eye dominant. If you cannot see it, then close your right eye so you are only looking with your left eye. You should now be able to see it and it means you are left eye dominant.
5. Survey your entire class. Out of those who are right eye dominant, how many are right handed? How many are left handed? Out of those who are left eye dominant, how many are left handed? How many are right handed? Fill out the results table.

Results

Copy and complete this table using data from the entire class.

	Right eye dominant	Left eye dominant	Total
Right hand dominant			
Left hand dominant			
Total			

Evaluation

1. Out of the entire class, what percentage are right hand dominant? What percentage are left hand dominant? Is there a preference? (Recall that to calculate the percentage of right hand dominant individuals, use $\frac{\text{total number of right hand dominant individuals}}{\text{total number of students in the class}} \times 100$)
2. Out of the entire class, what percentage are right eye dominant? What percentage are left eye dominant? Is there a preference?
3. Are all right hand dominant individuals right eye dominant as well? What of left eye dominance?
4. Does your data support the hypothesis?

Conclusion

1. Give a statement regarding what claim could be made from this experiment on eye dominance. Start your sentence with: 'This experiment suggests that eye dominance … '.
2. Support the statement by using what you observed. Start your sentence with: 'It was observed that … ' and include potential measurement uncertainties and experimental faults.
3. Explain how the observation supports the statement. Start your sentence with: 'This means that … '.

ISBN 978-1-108-61069-8

Cambridge University Press

Explore! 9.7

Different eyes

Not all eyes are the same.

Some organisms have very different eyes, depending on how they live. In fact, most animals see very differently to one another. The world looks very different to a bee than the way we see it!

1. How does an earthworm see?
2. How are scallop's eyes different to those of almost every other animal on the planet?
3. How does the position of the eyes on the face differ between animals? How does this change their view of the world?

Quick check 9.15

1. Draw a flow chart to summarise the path of light from outside the eye to the retina.
2. Copy and complete the following table.

Part of the eye	Function
Cornea	
	To focus light onto the retina
Retina	
Optic nerve	

Science as a human endeavour 9.5

Figure 9.77 Close-up view of a cat's eye. The pupil is a vertical slit.

Different-shaped windows for seeing

Researchers have found that an animal's ecological niche (the environment in which it lives) determines the shape of its pupil. Remember, the pupil is the hole through which light is let into the eye. In humans, the pupil is round. Some animals, such as cats, have slits for pupils. This is typical of animals that are active in both the daytime and the nighttime. Grazing animals, such as sheep, have horizontally elongated pupils, in order to easily survey the landscape for predators.

Corrective technology

Sometimes the eye needs a bit of help. For example, the lens in a person's eye may be unable to curve sufficiently to enable them to see nearby objects. If this is the case, they can see distant objects clearly but near objects are fuzzy. We call this condition **long-sightedness** and for many people it starts in middle age. Because the activity most associated with close-up vision is reading, the glasses used to treat long-sightedness are often called reading glasses. Reading glasses are essentially a support for the lens, helping by adding a little bit of extra curvature to the lens.

long-sighted able to see distant things clearly, but not things that are close

People who are **short-sighted** can see near objects clearly but distant objects are fuzzy or blurred. The lens in their eye is too curved, or their eyeball is too long. Concave lenses can be used to cancel some of the effect of the curved lens in the eye and can enable the person to see distant objects clearly. Contact lenses act in a similar way and are an alternative to wearing glasses.

short-sighted able to see close things clearly, but not things that are far away

Condition	Cause	Solution
Long-sighted	The lens in the eye is not curved enough	Convex lenses worn as glasses to provide extra curvature
Short-sighted	The lens in the eye is too curved	Concave lenses worn as glasses to cancel some of the curvature

Table 9.3 Causes and solutions for long-sightedness and short-sightedness

Figure 9.78 Reading glasses are designed to help people who are long-sighted.

ISBN 978-1-108-61069-8

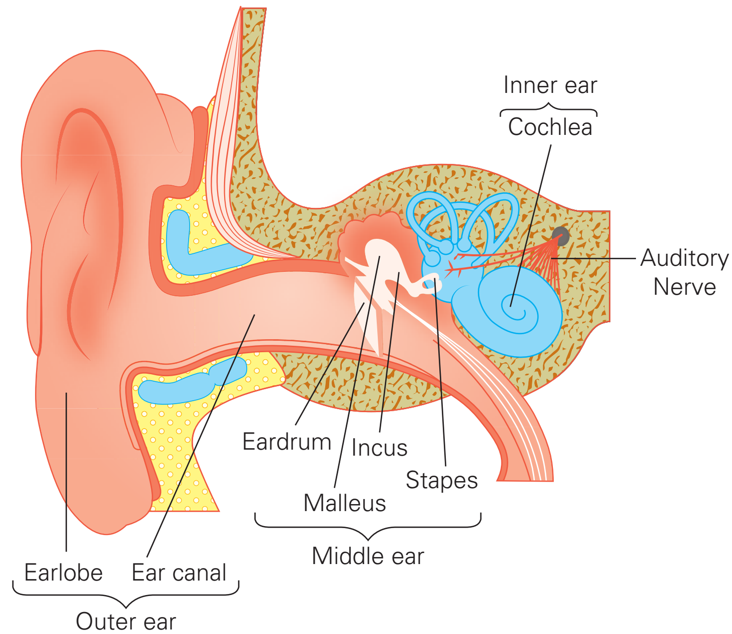
Correcting sight **Explore! 9.8**

There are a number of problems people can have with their sight. Some of them can be corrected using surgery. An ophthalmologist is a doctor who treats people with eye disorders and diseases.

1 List the different types of eye surgery that are available.
2 Pick one type of surgery and explain why someone would need it.
3 What is the process involved in your chosen surgery?
4 What is the outcome for the patient undergoing your chosen surgery?

Quick check 9.16

1 Explain what the terms 'long-sightedness' and 'short-sightedness' mean.
2 Explain how reading glasses help long-sighted people.



Ear canal: funnels sound waves into the middle ear

Eardrum: receives vibrations from the ear canal and passes them on to the malleus, incus and stapes

Cochlea: contains fluid that detects vibrations from the middle ear and converts them to electrical signals

Auditory nerve: collects electrical signals from the cochlea and sends them to the brain for interpretation

Figure 9.79 The structure of the human ear

How the ear works

Like the eye, the ear is amazing! How does it turn vibrating air particles into messages our brain understands as sound? Let's have a look at the structure of the ear.

In order for us to hear a sound, the energy from the sound needs to be transmitted from our outer ear to our inner ear. However, it must pass through a number of structures before it gets there. The part of the ear that you can see has the job of funnelling sound waves from the environment into the ear. The sound waves travel through the **ear canal** and arrive at the **eardrum**. As you know, sound is the vibration of particles – these vibrations cause the eardrum to vibrate. The vibrations are passed on to three tiny bones, called the incus, the malleus and the stapes. These three bones together are part of the middle ear. The eardrum causes these three bones to move, and in turn this causes the vibration of fluids in the **cochlea**. This part of the ear is the inner ear.

ear canal a tube that connects the outer ear and the middle ear

eardrum a thin piece of skin inside the ear that moves backwards and forwards very quickly when sound waves reach it

cochlea a spiral tube inside the inner ear that is the main organ of hearing

Finally, in the cochlea, the vibrations are converted into electrical impulses, which travel along the auditory nerve to the brain, where they are interpreted as sound.

You have already learned that the loudness of a sound depends on the amplitude of the sound wave. The unit of measurement for loudness of sound is the decibel (dB). Carrying on a normal conversation with someone is usually around 60 dB. A rock concert is around 105 dB. Humans can

ISBN 978-1-108-61069-8 Cambridge University Press

hear sounds as low as 0 dB – this limit is called the *threshold of hearing*. Meanwhile, anything at about 90 dB can start to damage your hearing. Sounds louder than 120 dB can quickly cause irreversible damage.

Corrective technology

Some people who experience mild hearing loss wear a *hearing aid*. Hearing aids make sounds louder, so people with hearing loss can participate in everyday life more effectively. However, some people have severely impaired hearing and cannot hear any sounds at all. This kind of impairment can sometimes be solved with a *cochlear implant*.

Unlike a hearing aid, which is worn outside the ear, a cochlear implant is surgically placed inside the ear. It consists of a microphone worn outside the ear to detect sounds, and a processor that can be worn in a pocket that converts the sound into electrical signals. These signals are sent to the implant in the cochlea, which stimulates the auditory nerve.

Quick check 9.17

1 Copy and complete the following table.

Part of the ear	Function
	Contains fluid that detects vibrations from the middle ear and converts this to electrical signals
Eardrum	
Ear canal	
	Collects electrical signals from the cochlea and sends them to the brain for interpretation

2 Recall the threshold of human hearing.

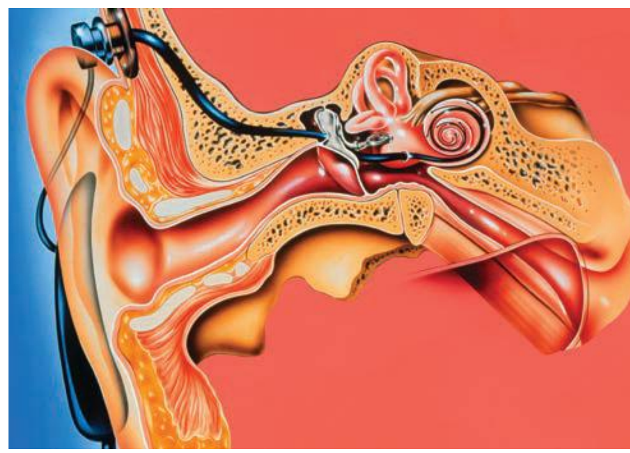


Figure 9.80 A cochlear implant. A microphone outside the ear can be seen. The transmitter behind the ear sends electrical signals through to the implant in the cochlea.

Figure 9.81 Left: A person wearing a hearing aid. Right: A person with a cochlear implant fitted

ISBN 978-1-108-61069-8 Cambridge University Press

Did you know? 9.10

Protecting our hearing

Excessive noise can damage the delicate hearing cells in the inner ear. People who work with noisy machinery can be exposed to sounds above 90 dB, which can damage their hearing over time. If the delicate hair cells that detect sound in the inner ear are damaged, they cannot be replaced. This can cause hearing loss or a disorder called *tinnitus*, where a person permanently hears a ringing noise in their ears. To prevent this from occurring, people who are constantly exposed to loud sounds wear ear muffs to protect their hearing.

Figure 9.82 People who work with aircraft can be exposed to sounds above 140 dB, so they wear ear muffs.

Quick check 9.18

1 Recall one reason why someone can lose their hearing.
2 Explain the difference between a hearing aid and a cochlear implant.

Science as a human endeavour 9.6

Music to my ears

Although cochlear implants enable people to hear sounds when they would not be able to otherwise, the sounds are not as clear as they would be for a person with normal hearing. The implants are designed to process speech, so listening to music is nearly impossible. Researchers are currently trying to develop music that listeners with cochlear implants can enjoy. The researchers are trying to isolate the parts of music that are most enjoyable, such as the vocals, in order to simplify it.

Section 9.4 questions

QUIZ

Remembering

1 State which structures in the eye bends light.
2 Name the type of lens that is in the human eye.
3 Recall the parts of the ear that make up the middle ear.
4 Define the term ‘accommodation’.
5 Recall the purpose of the ear canal.

Understanding

6 Explain how the iris and the pupil work together.
7 Explain which part of the eye deteriorates over time, causing long-sightedness.
8 Draw a diagram showing how light enters the eye and is focused on the retina.
9 Explain how the shape of the lens changes if an object is:
  a up close
  b far away.
10 Explain which part of the eye corresponds to our ‘blind spot’.

continued…

ISBN 978-1-108-61069-8 Cambridge University Press

...continued

Applying

11 Suggest which type of corrective lens a person with long-sightedness should be wearing.

12 State what will happen to your pupil in the following situations:

- **a** standing outside on a sunny day
- **b** walking into a dark room.

13 Describe the shape of the pupil of animals that need to watch the landscape for predators.

14 'Retinal detachment' occurs when the retina becomes separated from the back of the eye. It is a medical emergency. Apply your knowledge of the retina to explain why it is an emergency. Use Figure 9.75 to help you.

Analysing

15 Predict whether light speeds up or slows down as it enters the cornea. Justify your prediction.

16 Compare and contrast the kinds of corrective technology needed for long-sightedness versus short-sightedness. Explain the reasons for the difference.

17 Suggest what may happen to a person's hearing if they had to get their outer ear removed.

Evaluating

18 Suggest why people need to return to the optometrist every year to get their eyes checked.

19 State what may happen to a person's ability to hear if their eardrum has burst. Explain your answer.

Review questions

SCORCHER

Remembering

1 State the unit of frequency of waves, and describe what it measures.

2 Define the threshold of hearing.

3 Complete the following sentence.

Sound waves are ______________ waves, whereas electromagnetic radiation is made up of ______________ waves.

4 State which types of electromagnetic radiation have a higher frequency than visible light.

5 State what occurs when light encounters:

- **a** a transparent surface
- **b** a translucent surface
- **c** an opaque surface.

Understanding

6 Describe the difference between compression and rarefaction.

7 Explain what is necessary for a sound wave to travel from one place to another.

8 Explain why the image formed on our retina is upside down, and suggest why we do not see the world upside down.

9 Explain how wearing glasses can help correct sight problems such as long- and short-sightedness.

10 Explain why a concave lens creates a reduced image, and why this is called a 'virtual' image.

Applying

11 State whether altering the frequency or the amplitude would be required in the following situations.

- **a** singing a higher-pitched note
- **b** going from a high note to a low note on the guitar
- **c** changing from talking to whispering

ISBN 978-1-108-61069-8

Cambridge University Press

12 Two astronauts are completing a space walk outside the International Space Station.

- **a** Explain why radios are necessary for communication between the two astronauts.
- **b** Imagine that the radios were broken. Suggest some other ways the astronauts could communicate.

13 A person standing one kilometre away shoots a gun. You see the flash of light to indicate that the gun has been fired but you do not hear anything immediately.

- **a** Suggest why this is the case.
- **b** If it takes three seconds after you see the gun fire to hear the gunshot, calculate the speed of the sound.
- **c** Discuss how close this value is to the actual speed of sound.
- **d** Suggest some reasons why it may be different.

14 If you wrote the word SCIENCE on a piece of paper and held it up to a plane mirror, draw what the reflection in the mirror would look like.

Figure 9.83

Analysing

15 Figure 9.83 shows a crowd at a sporting event participating in a Mexican wave. State whether a Mexican wave is an example of a transverse wave or a longitudinal wave. Justify your response.

16 Use the data in the table to answer the questions below.

- **a** Suggest one reason why wood and glass are given ranges for the speed of sound.
- **b** Predict whether the speed of sound would be faster or slower through hydrogen at a higher temperature.
- **c** Justify your response to part **b**.

Substance	Speed of sound (m/s)
Carbon dioxide (0°C)	260
Air (0°C)	330
Hydrogen (0°C)	1300
Water	1400
Salt water	1500
Wood	4000–5000
Glass	4500–5500
Steel	5000

17 Suggest some careers where excessive exposure to loud noises occur. Propose some policies that could be put in place to prevent permanent hearing loss.

Evaluating

18 The table shows the average smallest distance at which a person can see a clear image, at different ages. Use the table to answer the questions that follow.

- **a** Suggest why sight gets worse with age.
- **b** Propose whether convex or concave lenses would be the best corrective strategy for an older person. Justify your proposition.
- **c** Find out the closest distance at which an image still appears clear for you. Compare this to the information in the table, stating whether it is accurate.
- **d** If the information did not match up with someone's own experience, suggest why this may be the case.

Age	Smallest distance (mm)
10	7.5
20	9
30	12
40	18
50	40
60	90

ISBN 978-1-108-61069-8 Cambridge University Press

STEM activity: Accessible musical instruments

Background information

VCSSU106 VCDSTC048 VCDSCD049 VCDSCD051 VCSIS113

Music is part of most people's lives. Whether you listen to music, play an instrument or even create your own music, it is something that most people encounter every day. Music can be defined as sounds that are organised in time and can vary in pitch (the frequency of the sound), dynamics (loudness and softness) and timbre (the tone of the sound).

All musical instruments have three main components:

- a primary vibrator that produces the sound (for example, a violin string when you draw a bow across it, or a flute mouthpiece when you blow across it)
- a primary resonator that amplifies the sound (for example, the space inside a violin or a flute)
- an opening for the sound to effuse (flow out) from (for example, the F-holes of a violin or the open end of a flute).

Pitch is varied in different ways, depending on the type of instrument. In a wind instrument, the pitch is varied by changing the length of the tube (usually by opening and closing holes). In a stringed instrument, the pitch can be varied by changing the tension in the string, the length of the string or the mass (thickness) of the string.

Musical instruments have been developed by every human culture in history, a uniquely human trait. Studies have shown that listening to music can reduce anxiety, depression and even pain, and it can improve memory, mood and even sleep. Learning to play an instrument has positive effects on the brain, which translate to other areas of learning. Because music strengthens neural pathways, it can also help to delay ageing of the brain.

Traditionally, people with a disability have been limited in the ways they can engage with music, because of the fine motor skills usually associated with learning to play an instrument. Engineers have been able to modify existing instruments or design new ones so that people with disabilities can engage with music.

Figure 9.84 In musical instruments, vibration produces sound, and this sound is amplified in the body of the instrument.

ISBN 978-1-108-61069-8 Cambridge University Press

Design brief: Design and build an accessible musical instrument from recycled materials.

Activity instructions

In small groups, your task is to design and build a musical instrument that is accessible to people with a disability, or the elderly. The first step will be to decide what type of condition you would like to cater for. You may need to do some research into the condition, to help you understand potential problems that elderly people or people with a disability may encounter in using traditional instruments.

You will then need to decide what type of instrument to build (for example, stringed, wind, percussion) and consider the three components required to produce a musical sound. Your instrument should be built out of everyday materials and should be able to produce a variety of pitches.

Suggested materials

- plastic containers
- elastic bands
- bottles
- icy pole sticks
- scissors
- cardboard

Evaluate and modify

1. Discuss the challenges you came across when designing and building your musical instrument, and list the methods you used to overcome these.
2. Describe the method by which your instrument produces sound and changes pitch.
3. Evaluate how easy or difficult your instrument is to use and/or to learn to use.
4. Suggest some improvements to your instrument that could make it easier to use.

ISBN 978-1-108-61069-8

Cambridge University Press

Glossary

Chapter 1

bar graph a type of graph used to display the frequency of a qualitative variable (category)

bias when a source of information is influenced by personal opinion or judgement

continuous data quantitative (numerical) data points that have a value within a range; this type of data is usually measured

controlled variable a variable in an experiment that must be kept constant, so it does not affect the dependent variable

dependent variable the variable in an experiment that you measure

discrete data quantitative (numerical) data points that have whole numbers; this type of data is usually counted

extrapolation using existing data (such as a line of best fit) outside the original data set to make a prediction

hypothesis a prediction, or educated guess, about the effect that the independent variable will have on the dependent variable; a prediction of the outcome of an experiment

independent variable the variable in an experiment that you manipulate, change or test

interpolation using existing data (such as a line of best fit) within the original data set to make a reliable prediction

line graph a type of graph used to display how a continuous quantitative variable changes over time or in reference to another variable

nominal data qualitative (categorical) data where the categories have no order, e.g. male, female

ordinal data qualitative (categorical) data where the categories have an order, e.g. small, medium, large

outlier an extreme data value that is very different from the other data, and could be the result of faulty procedure

primary source a source of information that comes from your own findings or experiments

qualitative data data values that are worded/descriptive/categorical in nature

quantitative data data values that are numerical in nature

secondary source a source of information that comes from someone else's research or findings

trend a pattern in a graph that shows the general direction/shape of the relationship between the dependent and independent variables

Chapter 2

antibiotic a medicine or chemical that can destroy harmful bacteria in the body or limit their growth

bacteria very small organisms with prokaryote cells that are found everywhere and are the cause of many diseases

binary fission a mode of asexual reproduction by bacteria, where genetic information is copied and the cell splits in half

cell membrane the barrier that separates the inside of the cell from the external environment

cell wall a rigid structure that surrounds each plant cell, shaping and supporting the cell

chloroplast a structure in a plant cell that contains chlorophyll

cytosol the water-based mixture that fills the cell, containing different molecules large and small; many chemical processes that happen within a cell occur in the cytosol

endoplasmic reticulum a network of tubes within a cell that transports substances inside the cell

genetic material the code that allows the cell to produce copies of itself and to regulate the functions within the cell

Golgi body a structure in a cell involved in transport between the inside and outside of the cell

mitochondrion a structure in a cell that converts the energy from food into the form needed by the cell

mitosis the type of cell division in which one cell divides into two cells that are exactly the same

multicellular made of many cells

nucleus part of a cell that contains the genetic material

pluripotent stem cell a cell that is able to develop into many different types of cell

protist a unicellular, eukaryotic organism that is part of the kingdom Protista

ribosome a structure in a cell that produces protein from amino acids

unicellular made of just one cell

vacuole a structure in a plant cell that stores water and nutrients

Chapter 3

alveoli the tiny sacs at the end of bronchioles in the lungs; the site of gas exchange with capillaries

anus the opening at the end of the digestive tract, through which solid waste leaves the body

ISBN 978-1-108-61069-8

Cambridge University Press

aorta the largest vessel leaving the heart, from the left ventricle, carrying oxygenated blood to the body

artery a thick, muscular elastic vessel that carries blood away from the heart

atrium one of the two upper chambers of the heart, the left atrium and right atrium

bile a substance produced in the liver and stored in the gall bladder that helps break down fats

bolus a lump of partially digested food

bronchi the two branches of the airways that split off the trachea, one main left bronchus to the left lung and one main right bronchus to the right lung

bronchioles smaller branching tubes that branch off the two large bronchi and lead to the alveoli

capillaries the smallest blood vessels, one cell thick, and the site of gas exchange with cells

carnivore a consumer (heterotroph) that feeds on animal matter

cellular respiration a process that occurs inside the mitochondria, where oxygen and glucose react to form carbon dioxide and water, producing useable energy

chemical digestion a series of chemical reactions that breaks food into simpler chemical substances that can be used by the body

chyme a partially digested mass of food after it leaves the stomach

diaphragm a dome-shaped muscle that separates the chest and abdominal cavities; it contracts to cause us to inhale

duodenum the first section of the small intestine

enzyme a protein that can help speed up chemical reactions

ethical relating to ethics, the field of considering what is right and wrong

function the job that an object does

gall bladder a small gland near the liver that stores bile, and secretes it into the duodenum

guard cells the cells on either side of a plant stoma that control gas exchange by opening and closing the stoma

haemoglobin the red pigment in blood that binds to oxygen, allowing red blood cells to carry oxygen

herbivore a consumer (heterotroph) that feeds on plant matter

ileum the third section of the small intestine, where further food breakdown and nutrient absorption occur

jejunum the second section of the small intestine, where food breakdown and nutrient absorption occur

lenticels small slits on trunks or branches of trees that allow gas exchange

mechanical digestion a series of mechanical processes that breaks food down, such as chewing with teeth, mixing in the stomach and emulsification with bile

neuron a nerve cell

organ a group of tissues working together to perform a function

organ rejection when an organ transplant recipient's immune system recognises the organ as foreign and attacks it

organ transplantation the process of removing a donor organ and then surgically implanting it into a recipient, to improve their organ function or replace a diseased organ

pancreas an organ that secretes pancreatic juices containing enzymes into the duodenum to assist with the digestion of food

pharynx the throat region where the nasal cavity and oral cavity meet, leading into the trachea

plasma the yellow liquid component that makes up 55% of blood; carries water, dissolved gases and hormones

platelets tiny fragments of cells that assist with blood clotting

rectum the second-last section of the large intestine; stores faeces

saliva liquid secreted by the digestive system to lubricate a bolus of food; also contains enzymes to assist chemical digestion

sinoatrial node a natural pacemaker that controls the heartbeat and is located in the wall of the right atrium

sphincter a muscle that surrounds an opening in the body and can tighten to close it, e.g. at the bottom of the oesophagus, leading into the stomach

stomata tiny pores (holes) in leaves that allow entry/exit of gases such as oxygen and carbon dioxide

structure the shape of an object

tissue a group of cells performing the same function

trachea the tube that carries air down to the lungs; also known as the windpipe

vein a thin-walled vessel with valves that carries blood back to the heart

vena cava the large vessel that returns deoxygenated blood to the heart, emptying into the right atrium

ventricle one of the lower two chambers of the heart, the left and right ventricles

villi finger-like structures in the digestive system that have a high surface area and rich blood supply for absorption of nutrients

xenotransplantation transplanting organs from one species into another

ISBN 978-1-108-61069-8

Chapter 4

asexual reproduction a method of reproduction in which there is one parent organism and all offspring are genetically identical

binary fission a mode of asexual reproduction by bacteria, where genetic information is copied and the cell splits in half

budding a mode of asexual reproduction by organisms such as yeast and hydra, where the daughter organism grows off the side of the parent and drops off

cloaca a hole used for defecating, urinating and giving birth that is present in some amphibians, reptiles, birds, fish and monotremes

embryo a fertilised egg cell that has begun dividing

external fertilisation a mode of fertilisation in which gametes are released into the environment and fertilisation occurs outside the body

fragmentation a mode of asexual reproduction by flatworms, where they can be cut and regrow into two genetically identical organisms

gametes the sex cells (eggs and sperm), each of which contains half the genetic material required to make an organism

gestation the pregnancy period, when the offspring are developing inside the mother

gonads the reproductive organs, where gametes are produced; testes for males and ovaries for females

internal fertilisation a mode of fertilisation in which male gametes are delivered into the female reproductive system and fertilisation takes place inside the female

menstrual cycle a cycle controlled by hormones to prepare the body for fertilisation of an egg; if fertilisation does not occur, menstruation will follow

menstruation the cyclical shedding of the unfertilised egg and the uterine lining; also known as menstrual period

nectar a sweet liquid produced by flowers to attract pollinators

ovulation the release of an ovum (egg) into the Fallopian tube

ovule a structure in a flowering plant where the female gamete is produced and where seeds develop

ovum egg

parthenogenesis a mode of asexual reproduction by some insects and reptiles, where females give birth to unfertilised eggs that hatch to produce offspring that are genetically identical to the mother

pollen the male gamete in flowering plants

pollination the process by which pollen sticks to the female structures of a plant and fertilises the ovule

puberty the time of transition from juvenile form to adult form

scrotum a sac that encloses the testes

sexual reproduction a method of reproduction in which there are two parent organisms and genetic variation in the offspring

spore an asexual reproductive cell produced by organisms such as fungi and ferns

vegetative propagation a form of asexual reproduction where only one plant is involved

zygote a fertilised egg cell

Chapter 5

atom the smallest possible piece of any substance; it makes up all matter

bonds forces of attraction that hold atoms together

chemical formula a symbol for a compound that shows which elements, and how many atoms of each element, are present in one molecule of that compound

chemical properties the behaviour of a substance when it reacts with another substance

compound substance made up of two or more different types of atoms

conductivity the ability of a substance to conduct or carry electricity and heat

crystal lattice a three-dimensional shape that allows metal atoms to pack together very tightly and form bonds that are extremely strong because the atoms bond to each other in all directions

diatomic a molecule consisting of two atoms of the same type

ductility the ability of a substance to be drawn into a wire

element substance made up of only one type of atom or molecule

flammability the ability of a substance to ignite

heterogeneous describes a mixture that can be separated into its parts, and the parts retain their original properties; the mixture is not blended evenly

homogeneous describes a mixture of two or more substances that are evenly distributed and do not separate out

lustre the ability of a substance to become shiny when polished

malleability the ability of a substance to be bent or flattened into a range of shapes

metalloid a substance that has some of the properties of both metals and non-metals

metal a substance that is shiny, can conduct electricity, can be bent, is usually silver/grey and is ductile

ISBN 978-1-108-61069-8

mixture a substance made up of two or more different pure substances (compounds or elements) that are not bonded together

molecule two or more atoms joined together by bonds

monatomic made up of single atoms, all of one type

non-metal a substance that is dull, cannot conduct electricity, is brittle and is not ductile

periodic table a list of all the known elements and their symbols

physical properties the way substances look and act, e.g. colour, melting point, hardness, boiling point and density

polymer a compound made of molecules that are long chains of atoms in a pattern that repeats

pure substance a substance made up of only one type of atom or one type of molecule.

Chapter 6

bioluminescence a chemical reaction that produces light in living things

chemical change when the chemical properties of a substance change and a new substance is formed; irreversible; indicators of chemical change include colour change, change in temperature, gas or precipitate being produced

chemiluminescence a chemical reaction that produces light

combustion a reaction that involves the burning or exploding of a substance, usually in the presence of oxygen

condensation the process in which heat is lost, causing a gas to become a liquid

contraction the process of getting smaller, the atoms in a substance move closer together as they cool

corrosion the gradual and natural process of metals breaking down; an example is rusting

decomposition a reaction in which one substance (reactant) breaks up into smaller ones (products)

diffusion the movement of atoms/molecules until they are evenly spread out; occurs in a liquid or a gas

dissolving the process in which a substance (solute) breaks up into small particles that can no longer be seen in a solution

endothermic describes a chemical reaction in which energy is absorbed from the surroundings

evaporation the process in which heat causes a liquid to become a gas

exothermic describes a chemical reaction in which heat or another form of energy is released

expansion the process of getting larger, the atoms in a substance move further apart as they heat up

freezing the process in which heat is lost, causing a liquid to become a solid

galvanisation the process of coating iron or steel in zinc to prevent corrosion

irreversible incapable of going in the opposite direction

melting the process in which heat causes a solid to become a liquid

physical change when the physical properties of a substance change in some way, but no new substance is formed; it is reversible; examples are a change in shape, expansion and contraction, change in state, mixing and dissolving

precipitate the solid that forms when two clear solutions are mixed together and undergo a chemical change

precipitation a reaction that involves the mixing of two clear solutions to produce a solid called a precipitate

products the substances that are present at the end of a chemical reaction

reactants the substances that are present at the beginning of a chemical reaction

reversible capable of going in the opposite direction

synthesis a reaction in which two (or more) elements or reactants combine to form one new substance or product

thermal decomposition decomposition that occurs when a substance is heated

Chapter 7

biological weathering the disintegration of rocks by living things

breccia sedimentary rock composed of angular broken pieces of rock larger than 2 millimetres

cementation the sticking together of sediment

central core the solid centre of the Earth, probably made of iron

chemical weathering the disintegration of rocks caused by substances dissolving in water

cleavage the tendency of a mineral or rock to break in a particular way because of its structure

compaction the process of parts becoming closely positioned together using very little space

conglomerate sedimentary rock composed of rounded rock fragments larger than 2 millimetres

crust the solid outer layer of the Earth; continental crust is on average 50 km thick and the average thickness of the oceanic crust is 20 km

crystal a mineral in which the atoms are arranged in an ordered way to form a geometric shape

deep time the idea first suggested by James Hutton that the Earth is very old

ISBN 978-1-108-61069-8 Cambridge University Press

deposition process that occurs when eroded particles stop moving and build up to form sedimentary rocks

electrolysis a method of extracting a metal from its ore or purifying it using electricity

erosion the transport of rocks from one place to another as a result of weathering

extrusive describes rocks formed on the Earth's surface, also called volcanic rocks

fossil the shape of a bone, shell, plant or animal that has been preserved in rock for a very long time

geology the study of the rocks that make up the surface of the Earth

igneous describes rocks made from lava on the surface or magma below the surface

intrusive describes igneous rocks formed underground; also called plutonic rocks

karst an area of land formed of rock such as limestone that is worn away by water to make caves and other formations

lava molten rock from inside the Earth (called magma) that has reached the surface

lithospere the solid outer layer of the Earth; includes the crust and uppermost mantle

magma molten rock under the Earth's surface

mantle the layer of solid and semi-molten rock that surrounds the outer core and extends up to the Earth's crust

metamorphic describes rocks that are changed by being exposed to high temperature, pressure or both

meteorite a rock from space (meteor) that has entered the atmosphere as a 'shooting star' and reached the ground

mineral a valuable or useful chemical substance that is formed naturally in the ground

Mohs scale a scale from 1 to 10 that indicates the hardness of a rock

opaque blocking light completely

ore a rock that can be mined and smelted to produce a metal

outer core the liquid layer surrounding the central core, also probably made of iron

physical weathering the breaking down of rocks into smaller particles by contract with other rocks, wind, water or ice

radioactivity energy released from the nucleus of an atom when the atom decays; the age of rocks can be determined by measuring their radioactivity

rock solid material forming the Earth's crust; rocks are formed as part of the rock cycle

rock cycle the constant process of change that rocks go through, between igneous, metamorphic and sedimentary forms

sedimentary describes rocks made from deposited materials that are the products of weathering and erosion

sediments sand, stones, etc. that slowly form a layer of rock

seismology the use of shockwaves to investigate the structure of rocks underground

smelting the process of getting a metal from rock by heating it to a very high temperature

streak test a test used to help identify a mineral by scratching a rock on a hard ceramic tile

surface mining method of mining that extracts a mineral by digging an open pit

translucent allowing some light through, but no clear image can be seen through the substance

transparent allowing light to pass through, and a clear image can be seen through the substance

underground mining traditional method of mining by digging tunnels underground to extract ore

Chapter 8

chemical potential energy the energy stored in the molecules of a chemical

conduction the process by which thermal energy travels through a material or between materials from hot regions to cooler regions by the collisions of molecules

conductor a substance or material that allows heat to pass through it easily

convection the flow of thermal energy though a fluid material by the movement of the material itself, often caused by temperature differences.

efficiency the percentage of input energy that is converted to useful energy by a machine

elastic potential energy the energy stored when an elastic material is compressed or stretched

electrical energy energy carried by electricity moving in a wire; voltage is used to measure how much energy is carried by each unit of electricity

electromagnetic spectrum a way of organising electromagnetic waves according to their frequency

energy the capacity to do work; the total amount of energy is conserved in any process

energy transfer the movement of energy from one place or object to another

fossil fuel a non-renewable source of energy obtained from oil, coal or gas

ISBN 978-1-108-61069-8

Cambridge University Press

generator a device that converts rotational kinetic energy into electrical energy, the opposite of a motor

geothermal energy thermal energy that originates from inside the Earth

gravitational potential energy a type of mechanical energy; the energy an object has because of its height; GPE = mgh

heat thermal energy that is in transit due to differences in temperature

hydroelectric power a renewable source of energy harnessing the gravitational potential energy of water to generate electrical energy

input energy the energy that a machine or device uses as its source of energy

insulator a substance or material that does not allow heat to pass through it easily

joule the unit of energy or work done

kinetic energy the energy an object has because it is moving

law of conservation of energy the law that states that energy cannot be created or destroyed

light energy a form of energy that we can see with our eyes; part of the electromagnetic spectrum

magma molten rock under the Earth's surface

non-renewable existing in limited quantities that cannot be replaced after they have all been used

nuclear energy a non-renewable source of energy that uses the energy released by the nucleus of radioactive atoms

output energy the energy that a machine or device provides or wastes

potential energy the energy stored in something because of its height above the ground, or because it is stretched or compressed, or in chemical form

radiation one of the three ways that thermal energy can travel, and the only way that heat can travel through a vacuum

radioactive having or producing the energy that comes from the breaking up of atoms

renewable can be produced as quickly as it is used

rotational kinetic energy the energy an object has because it is rotating

solar energy a renewable source of energy that converts sunlight directly into electrical energy or thermal energy

sound energy a form of travelling wave; sound consists of vibrations in air

sustainable causing little or no damage to the environment and therefore able to continue for a long time

temperature a measure of the average kinetic energy of the particles making up the material

thermal energy the kinetic energy of particles of matter

travelling wave a wave that can carry energy from one place to another

turbine a device that converts the kinetic energy of a fluid into rotational motion, for example a windmill

useful energy the output energy that a machine is designed to produce; an efficient machine will maximise the useful energy it creates

waste energy the output energy that a machine creates that is not useful; waste energy is often in the form of thermal energy and sound

wave energy the energy carried by a travelling wave (e.g. an ocean swell) or trapped in a standing wave (e.g. a guitar string)

Chapter 9

absorb to take up the energy of a wave, e.g. absorb light

accommodation automatic adjustments made by the eye when looking at objects at different distances

amplitude the distance of a wave crest from the middle position

angle of incidence the angle between an incident light ray and the normal when the ray arrives at a surface

angle of reflection the angle between a reflected light ray and the normal, when the ray leaves a surface

cochlea a spiral tube inside the inner ear that is the main organ of hearing

compression the part of a sound wave where the air molecules are squashed together

concave having an outline that is thinner in the middle, or a mirror that is curved inwards, like a cave

convex having an outline that is thicker in the middle, or a mirror that bulges outwards

cornea the transparent outer covering of the eye

diffraction the bending of waves with long wavelengths around a barrier

ear canal a tube that connects the outer ear and the middle ear

eardrum a thin piece of skin inside the ear that moves backwards and forwards very quickly when sound waves reach it

electromagnetic spectrum a way of organising electromagnetic waves according to their frequency

electromagnetic wave a wave that has both electrical and magnetic components; one of the ways energy travels

frequency the number of vibrations of a wave per second

fluorescent describes a substance that emits light under an ultraviolet light source

ISBN 978-1-108-61069-8

Cambridge University Press

gamma rays high-energy rays produced when radioactive atoms decay; they have a very short wavelength and can cause cancer

Global Positioning System (GPS) a system of satellites that transmit microwaves and are used to find the precise location of objects on the Earth

hertz a unit for measuring the number of cycles that happen every second (frequency); abbreviation is Hz

incident ray a ray of light arriving at a surface

infrared a form of electromagnetic radiation that lies between microwaves and visible light; also known as heat radiation

iris the coloured circular part of the eye that surrounds the black pupil

lens a glass disc used to make images with light; a convex lens makes both enlarged and smaller images image and a concave lens makes a smaller image

lens (eye) a small disc of transparent tissue behind the pupil that allows near and far objects to be focused

longitudinal wave a wave with vibrations in the direction of travel instead of transversely. Sound waves are examples.

long-sighted able to see distant things clearly, but not things that are close

medium substance that allows waves to travel in it

microwaves electromagnetic radiation used for cooking, communications and Wi-Fi; lies between radio waves and infrared radiation

normal an imaginary line that is at right angles to a surface

opaque blocking light completely

percussion instrument a musical instrument that is struck to make a sound; often has a vibrating surface to make the sound (e.g. a drum)

pitch how high or low a sound seems to our ears

plane mirror a flat reflective surface

prism a piece of glass with a triangular cross-section that can be used to separate white light into its colours

pupil the circular black area in the centre of the eye, through which light enters

radar a system that uses radio waves to show the position of objects that cannot be seen

radio waves electromagnetic radiation that has the longest wavelength

rarefaction the part of a sound wave where the air molecules are spread apart

reflect to throw back the energy of a wave (e.g. heat, light, sound) without absorbing it

reflected ray a ray of light that is reflected off a surface

refraction the bending of light as it passes from one medium to another

refractive index a measure of how much the speed of light changes as it passes from a vacuum into a particular substance

retina an area of tissue at the back of the eye that contains cells that can detect light and colour

short-sighted able to see close things clearly, but not things that are far away

standing wave a wave that is trapped between two fixed ends and moves backwards and forwards, reflecting from each end in turn

subtractive colour mixing a way of forming new colours by combining different coloured paints or pigments, e.g. mixing red and yellow paint to make orange

translucent allowing some light through, but no clear image can be seen through the substance

transparent allowing light to pass through, and a clear image can be seen through the substance

transverse wave a wave moving through a substance in which the particles are vibrating at right angles to the direction of motion of the wave

ultraviolet radiation that lies between visible light and X-ray; is needed by our bodies to make vitamin D; short wavelength UV can cause sunburn and cancer

vibration movement backwards and forwards or side to side in a regular way

visible light the part of the electromagnetic spectrum that we can see

visible spectrum the part of the electromagnetic spectrum that we can see; includes all the colours of visible light

wavelength the distance from one wave crest to the next

wind instrument a musical instrument that relies on air vibrating inside a tube to make sound; includes brass and woodwind instruments

X-rays short wavelength electromagnetic radiation that can pass through flesh to give images of bones; hazardous and can cause cancer

ISBN 978-1-108-61069-8

Index

ISBN 978-1-108-61069-8 Cambridge University Press

ISBN 978-1-108-61069-8 Cambridge University Press

ISBN 978-1-108-61069-8 Cambridge University Press

ISBN 978-1-108-61069-8 Cambridge University Press

ISBN 978-1-108-61069-8

Cambridge University Press

ISBN 978-1-108-61069-8 Cambridge University Press

ISBN 978-1-108-61069-8

Cambridge University Press

ISBN 978-1-108-61069-8 Cambridge University Press