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GRADE 9

Investigating Science for Jamaica

Integrated Science

June Mitchelmore

Advisors:

Willa **Dennie**

Richard **Johnson**

Peta-Gay **Kirby**

With online support

OXFORD

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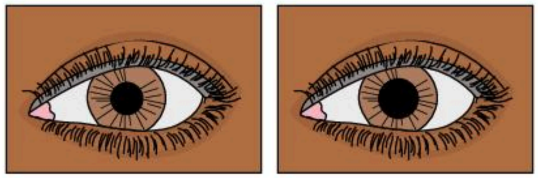
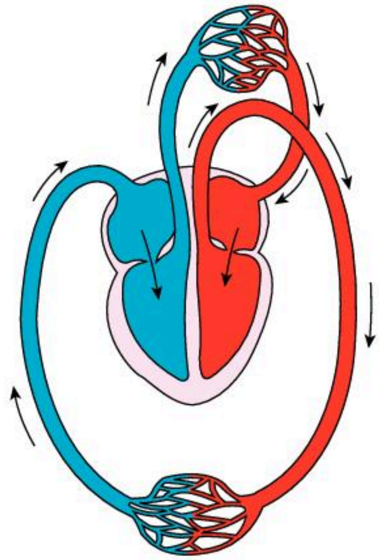
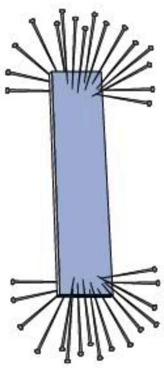






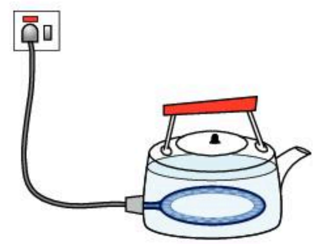
Introduction for students

Your Science programme is changing. You will still cover the science content of:

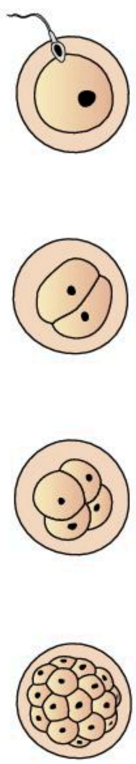
- life processes and the environment,
- matter and how it changes,
- and energy and forces.

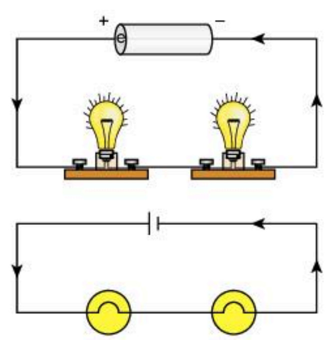
But you will find that Technology and Mathematics are integrated with the Science topics and you will investigate using:

- the Scientific method,
- and the Engineering Design Process (EDP).



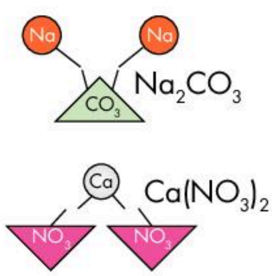
Your Science topics are presented as part of STEAM (Science, Technology, Engineering, Art and Mathematics).

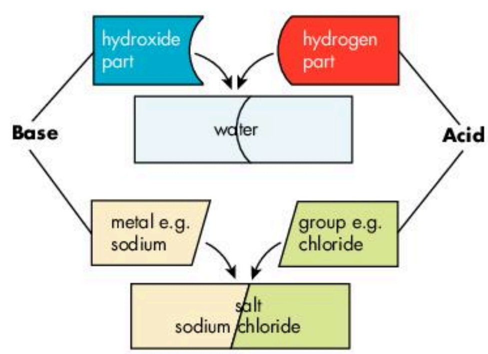




You will also:

- be more involved with deciding what you will investigate and how you will do it,
- do more Problem-Based Learning (PBL),
- use Information and Communication Technology (ICT) to research, present and share the results of your investigations,
- carry out the activities in the Workbook and do the puzzles, questions and Worksheets,
- play a part in evaluating how well you are achieving the objectives.





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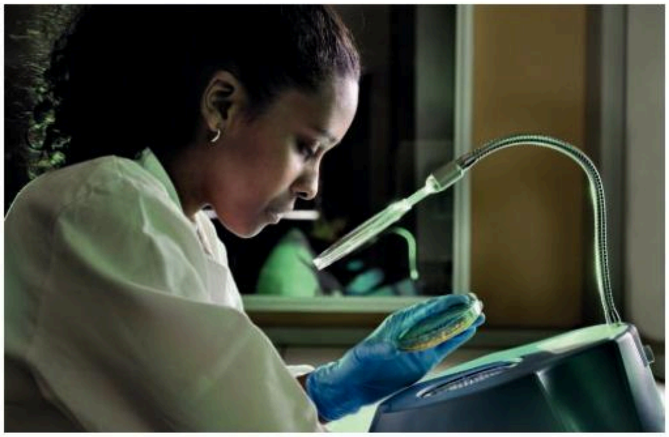
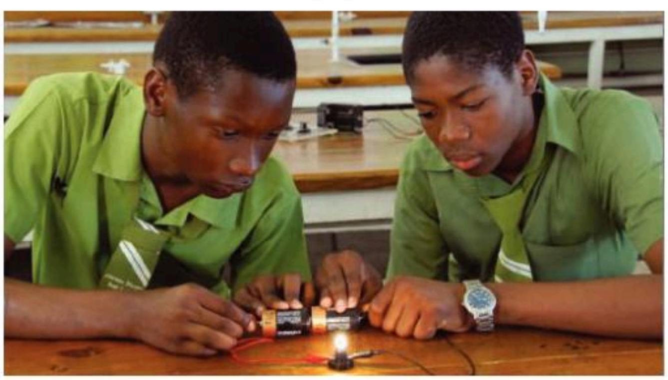
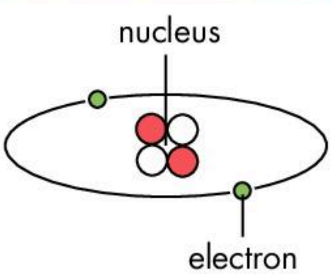
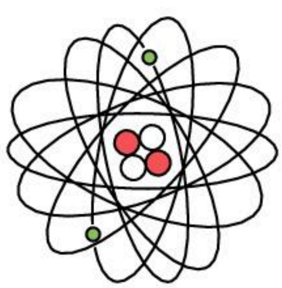








UNIT 19 Sensitivity and co-ordination

UNIT 20 Acids and alkalis

UNIT 21 Embryo development and birth control

For teachers

This book has been specially designed to cover the Jamaican National Standards Curriculum (NSC) for grade 9 (form 3) for Integrated Science. The book will also be useful with other secondary science syllabuses in the Caribbean. The text, activities and questions have been chosen to give a good foundation for the study of integrated and separate science syllabuses for CSEC®.

In keeping with the objectives of the NSC the series is strongly based on investigations and inquiry-based learning and students are encouraged to develop their science process skills. Work is arranged under profiles, similar to those used by CSEC®. Unit and topic objectives are given and there are related summaries, questions, key ideas and 'Fun facts' about science.

Science is presented as part of STEAM (Science, Technology, Engineering, Art and Mathematics). Investigations use science process skills and the Scientific method, ICT to assist with the retrieval, handling and communication of data, the Engineering Design Process (EDP) for research and design, and Mathematics for the description of physical quantities and analysis of data.

A specially designed Workbook accompanies this book. The Workbook is an integral part of the programme and it contains tables for students to use during their science investigations and design projects. There are also extra practical activities, crossword puzzles, fill-in sheets, questions, summaries, checklists and self-evaluation.

Further information on methodology can be found in the National Standards Curricula and videos supplied by the Ministry of Education. There is also an accompanying Teacher's Guide to this Student's Book that helps with the setting up of activities, further background material, additional tests and answers to selected questions.

This is an exciting opportunity to guide students to learn for themselves.

Access your support website here:
www.oxfordsecondary.com/9780198426820

Introduction

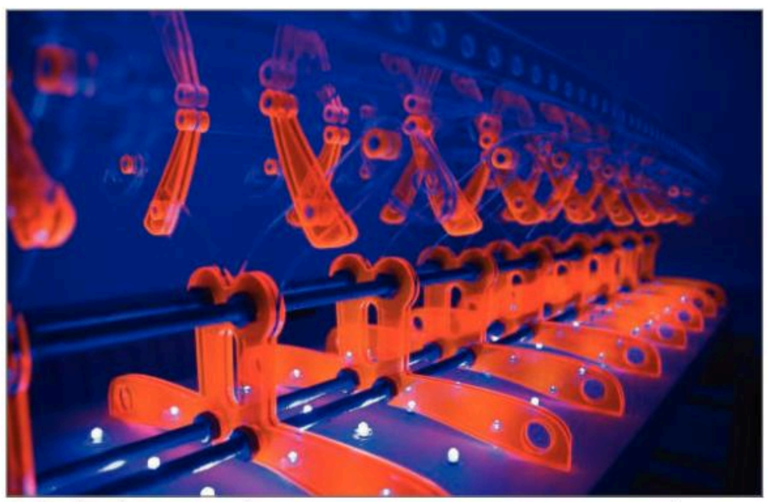
Working like a scientist (3)

1 *Students using ICT for the research and analysis of data and for communicating results.*

This unit will help you to:

- describe what is meant by STEAM
- use the thinking and doing skills of scientists
- use the scientific method and the engineering design process to solve problems
- use instruments to measure physical quantities
- name the SI units and use prefixes correctly
- use mathematics and ICT to present and analyse results
- plot graphs and find the gradients.

2 *Scientists find out about the living world. This environmentalist is collecting water samples for analysis in the laboratory.*



3 *Technologists, such as engineers, use computer-assisted design (CAD) in the creation and improvement of designs for solving problems.*

Science, technology, engineering, art and mathematics (STEAM)

Your science programme, and the investigations that you do, will include more technology, engineering, art and mathematics in a package that is called STEAM. For example, where you need some mathematics skills in your programme they will be included for you. Studying with STEAM will help prepare you for new challenges in your future work and everyday life.

Science: this has three parts:

- Content or concepts: the structure and functioning of living things and of non-living materials, as well as forms of energy and forces, and how everything is related and interacts.
- Process skills for thinking and doing: for example, observation and recording will help you solve problems, including using the scientific method, see pages 4–7.
- Attitudes: for example, working well together and being curious, imaginative and enthusiastic, will help you in your work at school and elsewhere.

Technology: in this programme, you will use:

- ICT (Information and Communication Technology): this is used for handling of data, research and analysis and for sharing information with others, see pages 10–11.
- Engineering: Engineers are technologists. They use raw materials to make new things to help solve problems. They work using the Engineering Design Process (EDP).

Engineering: You will use the Engineering Design Process (EDP) to solve problems and make new things. Engineers use their science and mathematics knowledge, assisted by ICT and art, to explore lots of options and produce design ideas. Early solutions may be small models to see if their ideas work, see pages 8 and 9.

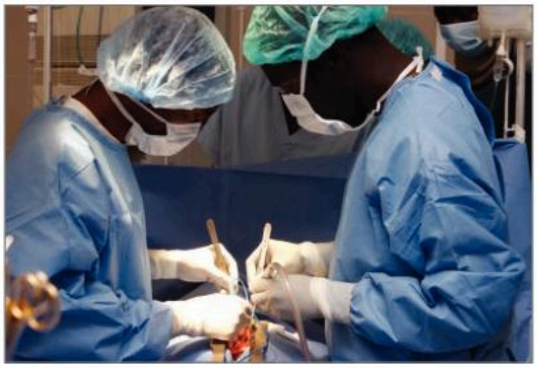
Art: This plays a critical role during the design process. You will make sketches of alternative ideas, detailed scale drawings of the model you will make, and labelled, annotated drawings of final models. You will also use art in advertising and to make products attractive, appealing and marketable.

Mathematics: Whenever you count, use numbers, measure or calculate, you are using mathematics. It is so basic to your work in science that you may barely notice it. You also use mathematics when you display information, for example in bar charts, histograms and line graphs, and interpret the results, see pages 12–21.

Mathematics also links with ICT, as the binary code used in computer language is made up of just two digits (0 and 1). You can find how to count and write in binary code on page 10.

Objectives

- Describe what is meant by STEAM.
- Understand how mathematics and ICT are used to analyse, present and share results.
- Identify how the scientific method and the Engineering design process are similar and different.



Scientists (doctors) carrying out heart surgery

Technologist (a chemical engineer) in the laboratory designing new chemicals

Your programme will be:

- active and hands on
- problem-based and enquiry-based
- group-based and research-based
- supported by ICT and mathematics.

Ways of working

Problem-based learning (PBL)

- Choose a real-life problem.
- Work in groups of about six students.
- One person is the leader, another is the secretary.
- Everyone is involved in deciding the tasks needed to answer the question.
- Then, work alone or in pairs using study skills to research answers from people, your textbook, other books and the internet. ICT
- Return to the group and share your results, and agree on conclusions.
- Prepare reports and visual displays.

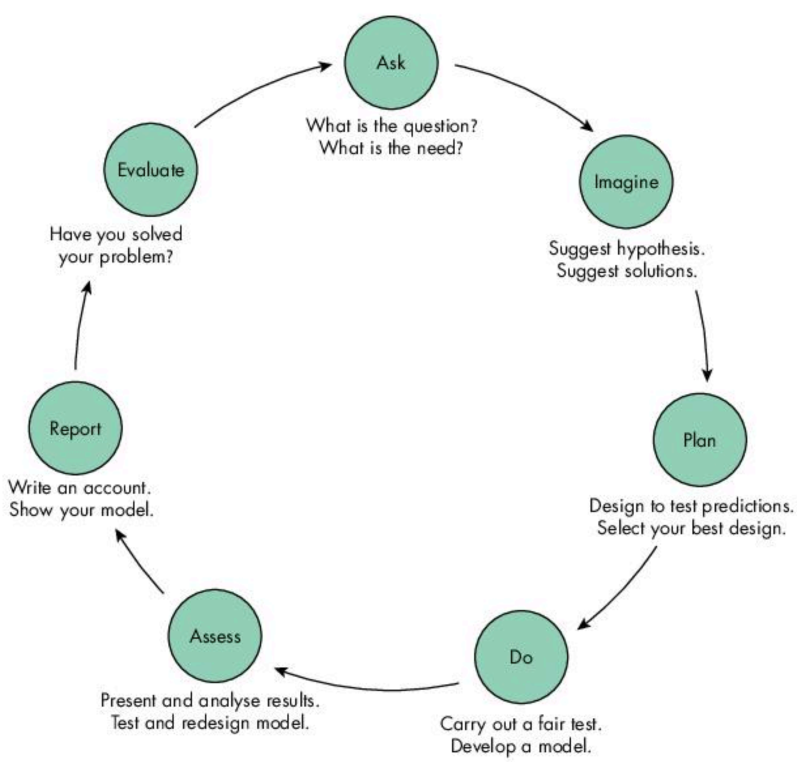
Inquiry-based learning (IBL)

You take a big role in finding out for yourself. Your textbook is just one of your resources and your teacher guides your work rather than telling you what to learn.

Inquiry-based learning can be:

- Structured: The teacher chooses the question and gives you the steps to follow.
- Guided: The teacher chooses the question but you then use a variety of sources to find answers and share results. ICT
- Open-ended: You can choose the question and how you will answer it.

Scientific method		Engineering design process
Identify the problem: What is the question you want to answer?	**Ask**	Identify the problem: What is the need you want to satisfy?
Do background research. Decide the hypothesis. ICT	**Imagine**	Do background research. Suggest solutions. ICT
Suggest predictions and identify variables. Design the experiment and what you will do.	**Plan**	Decide on what you are going to make. Draw your ideas and alternative solutions.
Test your prediction by doing a fair test.	**Do**	Choose your best design and develop a model.
Present and analyse your results.	**Assess**	Test and redesign as necessary.
Write an account of your experiment.	**Report**	Show your model and drawings.
Have you solved your problem?	**Evaluate**	Have you solved your problem?



▶ **See Workbook Introduction.**

Overview on science and technology

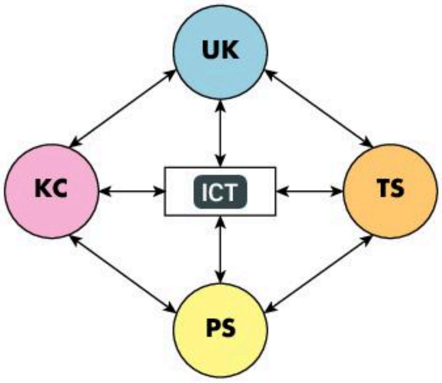
KC (Knowledge and comprehension). This is the science information that you need to know and understand.

UK (Use of knowledge). These are the *thinking* skills you use for problem solving and to make use of your information.

PS (Practical skills). These are the *doing* skills you use to carry out activities and test your ideas.

TS (Technological skills). These are the skills to design and make useful new things using knowledge and materials.

ICT (Information and Communication Technology). This is to find and analyse data, and share information with others.



Knowledge and Comprehension

Information base: remembering and understanding science information

Remember (ICT)
- Remember information you have been taught or recorded.
- Pick out the right answers from several choices.
- Write about a given topic using ICT.

Understand
- Show you understand something by explaining it.
- Give examples to illustrate what you have learned.

Use of Knowledge

Thinking skills: applying and interpreting information, and dealing with data

Apply information
- Make use of your knowledge in new situations.
- Use mathematics in solving problems and modelling ideas.
- Show how things are related, for example, in a food web.
- Say how one thing may cause another, for example, when investigating a pollution problem.
- Put together information, for example, parts of the water cycle.
- Make use of information to help guide you to live in a safe and responsible way, without harming the environment.

Interpret (ICT)
- Interpret information by explaining its meaning and importance.
- Make inferences (explanations) from observations and data.
- Notice patterns in your results and make predictions.
- Use ICT to help you find information from tables, bar charts, pie charts and line graphs.
- Draw conclusions based on your results.

Evaluate
- Say if your conclusions can be trusted. (Was there a fair test?)
- Take account of both sides of an argument.
- Make recommendations for action based on the information.
- Take account of the possible outcomes of your suggestions as they affect other people and the environment.

Practical Skills

Practical skills: planning, carrying out and reporting on activities; work and study skills

Plan / Design
- Identify a problem and ask questions about it.
- Plan an activity to test a prediction based on the hypothesis.
- Suggest controls where these are important.
- Identify equipment and materials to carry out a fair test.

Manipulate / Measure
- Handle and care for equipment, chemicals and living things.
- Use measuring instruments safely and take accurate readings.
- Carry out certain activities such as filtering and using a Bunsen burner and microscope with due regard to safety.

Draw
- Make large, clear drawings of living things, apparatus or models, and label them correctly.

Working methods
- Follow instructions carefully and in the correct order.
- Keep your workplace tidy and uncluttered.
- Be economical in the use of materials and work in a safe way.

Observe / Record / Report ICT
- Use your senses and instruments to observe accurately.
- Repeat and take the average of several readings.
- Record your observations in tables, diagrams, bar charts, histograms, pie charts and line graphs using ICT.
- Present your findings clearly in a written or spoken report.

Study skills ICT
- Use a range of resources including ICT for research.
- Keep accurate records of what you find out.
- Be self-reliant and independent of teacher supervision.
- Carry on with a task until it is finished properly.

Group work ICT
- Express your own opinions, but also listen to and respect the different ideas of others.
- Work with others by sharing ideas, information and materials.
- Assist in coming to group decisions.
- Show co-operation and responsibility to the group.
- Show concern for the safety of other people, other living things, property and the environment.

Technological Skills

Designing and making skills: making new things to solve practical problems

Make new things ICT
- Apply scientific ideas to design and make models or machines. Make products attractive and appealing.
- Follow the Engineering Design Process (EDP) to solve a problem or make something for a particular use. Use Art as part of design.

Use technology
- Investigate the use of familiar tools e.g. tin opener, egg whisk.
- Investigate the effects of inventions on people or the environment, for example, the aerosol can or penicillin.

The scientific method

Now you will see how you use the thinking and practical skills of scientists. They work in a step-by-step way that is called the **scientific method**. This is a systematic method of working that allows scientists to test their hypotheses and draw their conclusions. You can also work like a scientist!

Ask, imagine and plan

ICT

- Identify the problem and ask questions about it.
- State possible solutions as statements (hypotheses) that can be tested.
- Predict answers to your questions. (What do I think will happen?
- Identify variables and how you will control them to set up a fair test for your predictions.
- Identify the method to follow, and materials and apparatus you will need.

Carry out

ICT

- Put your plan into action, using materials safely.
- Follow good working methods on your own or in a group.
- Make observations and measurements.
- Find things out from people, books and computer sources.

Assess: Record results

ICT

- Record your observations and measurements.
- Notice and re-check any unexpected results.
- Make labelled drawings of specimens and equipment.
- Make tables, bar charts, pie charts and line graphs of your results.

Assess: Interpret

ICT

- Discuss your results with others.
- Look for patterns in your results.
- Decide what your results might mean. (Interpret them.)
- Draw conclusions based on your results.

Report

ICT

- Write up your report to show what you did and what you found out. You can use ICT.
- Record the aim or hypothesis, equipment and materials, method, results and conclusions.
- Show and talk about what you did.
- Find out if other people understand you, and answer questions.

Evaluate

- Do your results support or disprove your prediction or hypothesis?
- Decide if you have solved your original problem or achieved your aim.
- Do you need to repeat or change any part of your experiment?
- Are there new questions you want to discuss or test?

Setting up a fair test

Scientists work in a step-by-step way.

Identify and state the problem

- What do I want to find out? What is the problem?

For example:

- Can seeds germinate in the light?
- Does mould grow more quickly when it's warmer?
- Does more sugar dissolve in hotter water?
- Does using more cells make a bulb shine more brightly?

State or formulate hypotheses e.g.

- Light affects the germination of seeds.
- Temperature affects how much sugar dissolves in water.

Make predictions based on the hypothesis e.g.

- If I leave seeds in the light, they will not germinate.
- If I increase the temperature, more sugar dissolves.

Plan and design experiments (fair tests)

List the possible variables and identify which are the independent, dependent and control variables. Decide how to deal with each of them as you set up your fair test.

0.1 Setting up a fair test

Choose one of the four questions above, or one of your own. Work in a group to:

1 State hypotheses and predictions that can be tested.
2 Identify all of the variables that might be important.
3 Choose which of the variables are
  (a) the one you will vary (the independent variable). Decide how you will vary it, for example: which temperatures or numbers of dry cells will you use?
  (b) the results you will expect (the dependent variable). Decide how you will observe or measure the results, for example: how will you decide if a seed has germinated?
  (c) control variables – ones that might affect your results and therefore will upset your test. Decide how you will control each of them, for example, using the same number of seeds and damp cotton wool or the same volume of water.
4 Prepare a table that shows how you will deal with each of the independent, dependent and control variables, so that you can set up a fair test.
5 Choose the materials and equipment you will need.
6 Set up the parts of your experiment and carry out a fair test.
7 Record, interpret and report on your results.
8 Evaluate what you have done. Do your results agree or disagree with your prediction? Is your hypothesis supported or disproved ? Do you need to repeat your test?

▶ **See Workbook Introduction.**

What does it mean?

Variable: The conditions in the experiment, such as water and size.

Independent variable: The one variable you change, to find its effect.

Dependent variable: The results you observe or measure and that depend on the independent variable.

Control variables: Variables that might affect the experiment and that you should keep constant.

Fair test: One where only the independent variable has been allowed to affect the dependent variable.

Fun facts

When preparing a graph, the independent variable is recorded on the horizontal x-axis and the dependent variable on the vertical y-axis.

0.2 Scientific method

1 Work in a group to plan and create your own flow diagram of the steps in the scientific method. Discuss each of the steps and make your own drawings to illustrate each one.
2 As a class identify a problem in your school or community. Discuss and formulate a hypothesis, then list the predictions you will test.
3 List all of the possible variables that might be involved and classify them as independent, dependent and control variables.
4 State how you will deal with each variable in order to set up a fair test.
5 Select materals and equipment and carry out your test.
6 Record your data / observations and display them appropriately.
7 Explain and draw conclusions supported by data.
8 Do your results support or disprove your original hypothesis?

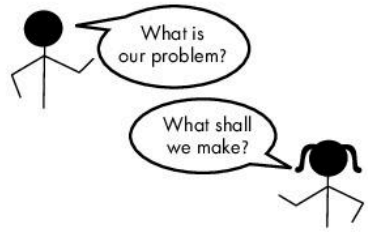
Engineering design process

Technologists, for example engineers, make new things and materials to solve practical problems. They use similar practical skills of scientists but their aim is to make something rather than to carry out a fair test. They follow steps that are called the **Engineering design process (EDP)**.

Engage: Ask questions

- Identify the problem and ask questions about it.
- Describe the challenge to be solved.
- What are the requirements and constraints?
- How have others tried to solve it?
- How long do you have, what materials might you need?

ICT



Explore: Imagine

- What are some solutions?
- Brainstorm ideas in your group.
- Write descriptions and make sketches of your ideas.
- Select the best two designs and compare them.

ICT

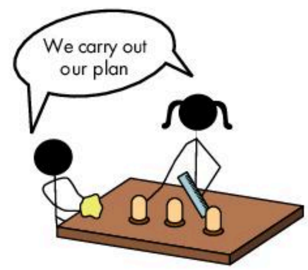
Elaborate: Plan

- Choose the option that is likely to be the best one.
- Make a neat and detailed drawing of your design.
- List the materials and supplies you will need.
- Gather the necessary materials.
- Find a place to work.

ICT

Execute: Create

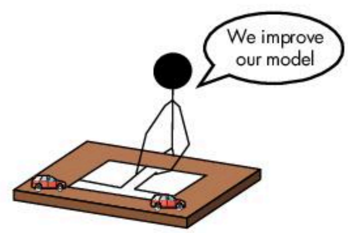
- Follow your plan.
- Write any problems you have and how you changed your design.
- Make labelled drawings of your model.
- How did it work?



Explain: Assess, improve and report

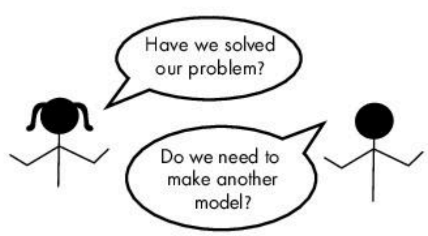
- Does your design meet the requirements?
- Does your design meet your constraints?
- Make changes to your model to improve it.
- Report to others about your model and drawings.
- Take their comments into account and make changes.

ICT



Evaluate: Have you solved your problem?

- Repeat the 'Assess' step to improve your model as many times as necessary.
- Use art to make it attractive and appealing.
- When you have your final model, decide if you have made something to solve your original problem.



Using the Engineering design process

Engineers work in a step-by-step way, but can also go backwards and go around the steps several times as they try out new designs. Let us look at an example.

Problem: The students were asked to understand the principles of heat energy transfer and design a model to minimise or maximise how heat energy is transferred.

Engage: Ask questions

Each group:

- Chooses a device, for example refrigerator, radiator, electric jug, vacuum flask, air conditioner.
- Discusses how they think the device works; how does it use the principles of heat energy transfer?
- Records the main points.

Explore: Imagine

- Groups research how their device works: they use books, ask other people, use the internet. ICT
- They use their information to refine and improve their understanding of how their device works.
- They brainstorm ideas about how they can make a model that minimised or maximised heat energy transfer.

Elaborate: Plan

- They suggest alternative designs, for example an insulated box or a solar water heater or solar cooker.
- They make drawings, discuss and decide on the best alternative, taking constraints of time and materials into account.
- They decide on what they will need. ICT

Execute: Create

- They follow their plans to construct a model.
- They make labelled drawings of their device and how it works.

Explain: Assess, improve and report

- They test their device and make improvements as necessary.
- They explain to the class how their model works.
- They identify the heat energy transfer principles they have used.
- They report to the class on its operation: success, failures and lessons learnt.

Evaluate: Has the problem been solved?

- Have the students solved their original problem?
- Does the class agree, using a prepared checklist, that their model illustrates heat energy transfer?

STEAM

Art is integrated into the engineering design process, for example:

- for choosing suitable materials, based on their characteristics
- for making sketches and detailed scale drawings that assist in the design and choice of alternatives
- for artistic flair for choosing colours, style and visual appeal
- for making final models and products attractive and marketable.

0.3 Making an indicator

Materials: several solutions including acids and alkalis, litmus paper, various coloured flowers, pestle and mortar, knife, water, alcohol

Method

The problem is to make an indicator from coloured petals and show that you can use it to distinguish between acids and alkalis.

1 Engage: Ask questions in your group about acids and alkalis and how indicators change colour. Record what you know.
2 Explore: Use research from books, the internet and other people to find out about indicators in flowers. Brainstorm ideas about which flowers you might use. ICT
3 Elaborate: Suggest alternative plans on how to get the colours out of the flowers in order to use them. Make a plan on the materials you will use.
4 Execute: Carry out your plan and make some indicators.
5 Explain: Assess. Use the litmus paper to identify an acid, then find the colour of your indicator with the acid. Repeat for an alkali. Improve your indicators if necessary, and report on your findings.
6 Evaluate what you have done. Have you solved your problem? Were the results as you expected? Do all the flowers give the same results?

▶ **See Workbook Introduction.**

Information and Communication Technology

Our usual way of counting is in groups of ten: this is called base ten or the decimal system. We use 10 digits: 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9. In base ten, each column to the left of the units is ten times bigger than the one before. Where a digit is placed tells us its value, for example, 7 = 7 units, 70 = 7 tens or seventy, 700 = seven hundred and 7000 = seven thousand.

The processing of information in electronic circuits is done with just two digits: OFF for 0 and ON for 1. This is called the base two or binary system. In the binary system, each column to the left of the units is two times bigger than the one before. Where the 0 or 1 is placed tells us its value.

Using ICT in grade 9

ICT

For example:

- Visit websites and research information.
- Use email and smartphones for communicating information.
- Use word processing, spreadsheets and presentation software.
- Take photos and transfer them into a report.

2^6	2^5	2^4	2^3	2^2	2^1		
2×2×2×2×2×2	2×2×2×2×2	2×2×2×2	2×2×2	2×2	2		
sixty four	thirty two	sixteen	eight	four	two	one	Value in base 10
			1	0	1	1	= eleven
		1	0	1	0	1	= twenty one
	1	1	0	0	1	0	= fifty

Counting in base 2 (binary system)

Bits and bytes

Strings of eight binary digits (bits) make a byte. Different bytes are used to code for numbers, letters, punctuation marks, etc. The bytes make up the instructions, numbers and words used by the computer, for example, see the letter codes below:

Capital letters		Lower-case letters	
A	01000001	a	01100001
B	01000010	b	01100010
C	01000011	c	01100011
D	01000100	d	01100100
E	01000101	e	01100101
F	01000110	f	01100110
G	01000111	g	01100111
H	01001000	h	01101000
I	01001001	i	01101001
J	01001010	j	01101010
K	01001011	k	01101011
L	01001100	l	01101100
M	01001101	m	01101101
N	01001110	n	01101110
O	01001111	o	01101111

ICT

What are these numbers in base ten?
(a) 1010 (b) 11100 (c) 101101
(d) 010110 (e) 101001 (f) 0100110
(g) 1000101

▸ See Workbook Introduction.

ICT

You can use binary code to show numbers and letters.

1. Use binary code to count from one to ten. As an example 'five' is one lot of 4 and one unit, so it would be written 101 in binary code.
2. Using the base two shown, what is
   (a) the code of the largest number that could be shown, and
   (b) what is its value in base ten?
3. Look at the binary code for capital 'A'. If this code were used for a number, what would the number be in base ten?
4. (a) How do the binary codes for the capital and lower case letters differ from each other? Hint: compare 'A' and 'a'.
   (b) Is this the same difference for every pair of letters?
5. Complete the binary codes for all the capital and lower case letters.
6. Think about how long it has taken you to do this activity. How long do you think it would have taken a computer to do it?
7. What is the ASCII code and why is it important?

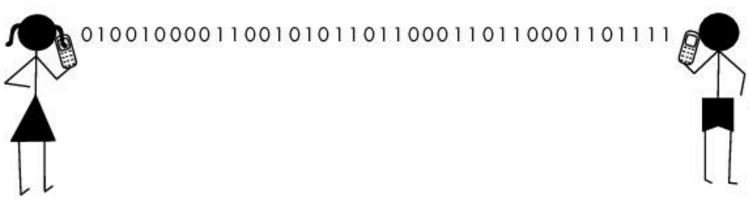
Important areas of ICT

ICT

These cover the knowledge, understanding and skills needed by students.

Digital literacy	Skills	
• Identify computer parts • Interpret binary code • Use the internet for emails and social networking • Use online identities • Use ICT for learning • Find and assess information online • Appreciate the impact of the scale of ICT on society	• Use word processing • Edit documents • Use spreadsheets • Use programs to prepare different kinds of graph • Retrieve required information from the net • Communicate online • Use DTP for flyers • Prepare presentations	 *ICT on the move*

Technology in the world	Technical understanding	Safety, security and the law
• Appreciate the ICT base of business activities • Appreciate the transfer of skills to business software • Design a web page • Use e-commerce for buying and selling things • Explore ICT use locally and internationally • Know about ICT-specific jobs and ICT-based jobs	• Identify and use a range of electronic devices • Use networks for working and storage • Use data storage, e.g. in the cloud • Make flow charts and explore systems design • Explore principles of simple programming • Create simple games	• Show respect online • Practise online safety • Do not believe everything you are told online • Only agree to meet people met online in public places • Practise health and safety • Respect copyright of material • Realise that hacking is illegal • Everything you send, access or save can be retrieved by the law – even if you delete it



Sonja   Lee

Write a message from Lee to Sonja in binary code.

What is Sonja saying to Lee?

Quick check ☑

Scientists use the scientific __________ and engineers use the engineering __________ process to solve __________.
ICT stands for __________ and __________ technology and it makes use of a __________ code.

Use these words to fill in the spaces as you write the sentences in your Exercise book.

binary **information** **method**
communication **design** **problems**

Units and physical quantities

The SI system (Systeme International d'unités) is **a standard** international system of units used for measuring. A **physical quantity** is anything that can be measured. The measurement is described using a unit. The SI system uses the metric system with the units related by powers of ten, for example:

$$10\,\text{cm} \times 10^2\ (100) = 1\,\text{m}$$

The SI system has seven fundamental quantities (see box). You will be working with five of these: mass, length, time, temperature and electric current (see Unit 17 on Electricity and magnetism). All other units can be made up (derived) from the fundamental quantities. For example:

$$\text{Speed} = \text{distance/time} = \text{metres/second or ms}^{-1}$$

Each fundamental quantity has a **base unit** (see box). This is the standard measure of the quantity. The base unit can be multiplied by powers of ten (for larger measurements) or divided by powers of ten (for smaller measurements). You use prefixes to do this (see bottom of page and page 13).

Mass A measure of the amount of matter in an object – this determines how easy or difficult it is to get the object moving when it is pulled or pushed. The base unit is the kilogram (kg), but you will often use grams (g).

Length The distance between two points. The base unit is the metre (m), but you will often use centimetres (cm). The units for area (cm^2) and volume (cm^3) are derived from this. (See pages 14 and 15.)

Time How long something takes to happen. The base unit is the second (s), but you will also use minutes (60 s), hours (60 × 60 s = 3600 s) and days (3600 s × 24 hours).

Temperature This is a measure of the average movement (kinetic energy) of the particles in a substance. The SI base unit is the kelvin, where absolute zero (where particles would stop moving) is –273 K. You will use thermometers marked with the Celsius scale (°C). A temperature of 0 °C = 273 K. So water boils at 100 °C or 373 K. Note that we do not use ° for 'degree' when using the kelvin scale.

Objectives

- List the base units for physical quantities used in the SI system.
- Use prefixes correctly and convert from one unit to another.
- Find the area and volume of regular and irregular objects.
- Express numbers using significant figures and standard form.

What does it mean?

Physical quantity: Something that we can measure.

Fundamental quantity: A quantity defined in the SI system.

Base unit: The basic value of a physical quantity as defined in the SI system.

Derived quantities and **units**: These have been made up from the fundamental quantities and units.

Prefixes: Descriptions with a certain value that are added in front of a unit to make it bigger or smaller.

SI base units

Fundamental quantity	*Base unit*
Mass	kg (kilogram)
Length	m (metre)
Time	s (second)
Temperature	K (kelvin)
Electric current	A (ampere)
Amount of substance	mol (mole)
Luminous intensity	cd (candela)

10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{-1}	
÷ 1000 000 000 000	÷ 1000 000 000	÷ 10 × 10 × 10 × 10 × 10 × 10 ÷ 1000 000	÷ 10 × 10 × 10 ÷ 1000	÷ 10 × 10 ÷ 100	÷ 10	Length base unit
pm picometre	nm nanometre	µm micrometre	mm millimetre	cm centimetre	dm decimetre	m metre

Prefixes for quantities smaller than the base unit

0.4 Measuring physical quantities

Materials: a glass of water, a length of wire, various measuring instruments, for example, balance, ruler, thermometer, measuring cylinder, Vernier caliper, micrometer, stopwatch

Work in a group:

Discuss what each of the instruments can measure and how they can be useful in your activity. ICT

Water

1 Use the instruments to measure and record the values of as many things as possible about water.
2 List some things about water, for example, colour, that could not be measured.
3 State, giving reasons, which of the set of things (measured/not measured) are physical quantities. Decide in your group on a definition of 'physical quantity'.

Wire

4 Look at the Vernier caliper and micrometer and examine the scales. Discuss how the instruments are used.
5 Use the Vernier caliper to find the diameter of the wire. Record your result. How accurate is your reading?
6 Use the micrometer to find the diameter of the wire. Record your result. How accurate is your reading?
7 Compare the readings you made.

Vernier caliper: measures internal and external distances to the nearest 0.1 mm

Micrometer screw gauge: measures thickness to the nearest 0.01 mm

To change from one unit to another: move the digits relative to the decimal point	
Multiply by 10 e.g. cm to mm	Move the digits left one place
Multiply by 100 e.g. m to cm	Move the digits left two places
Multiply by 1000 e.g. g to mg, km to m	Move the digits left three places
Divide by 10 e.g. mm to cm	Move the digits right one place
Divide by 100 e.g. cm to m	Move the digits right two places
Divide by 1000 e.g. g to kg, mm to m	Move the digits right three places

Prefixes and conversions

1 What fraction of a metre rule is a (a) decimetre, (b) centimetre, (c) millimetre?
2 The mass of a stone is 30 g. What would this be in (a) milligrams, (b) kilograms?
3 Radio frequency is measured in megahertz (MHz). How do you convert this to (a) hertz (b) kilohertz (kHz)?

	10^3	10^6	10^9	10^{12}
Length base unit	× 10 × 10 × 10 × 1000	× 10 × 10 × 10 × 10 × 10 × 10 × 1000 000	× 1000 000 000	× 1000 000 000 000
m metre	km kilometre	Mm megametre	Gm gigametre	Tm terametre

Prefixes for quantities bigger than the base unit

▶ **See Workbook Introduction.**

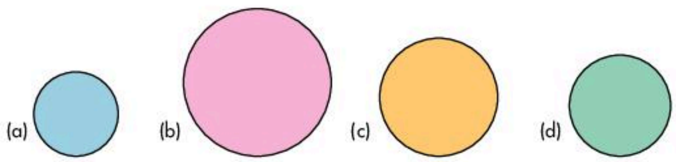
Length, area and volume

Length

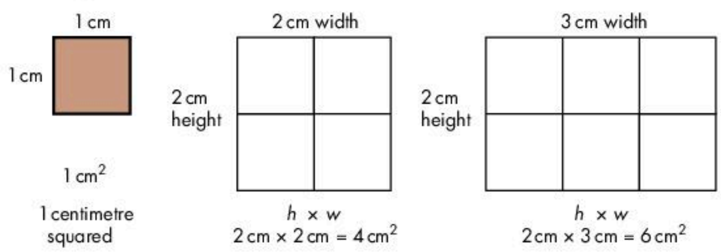
This is a fundamental quantity and its base unit is the metre (m). 100 cm = 1 m. You use cm to measure in one dimension: the length of a line or the distance along one side or edge of a shape. You should measure accurately using a 30 cm ruler or metre rule.

Area

This is a measurement of the surface of an object. Compare the objects below and list them in order of increasing area, also called the surface area.



You can find the area of regular rectangular shapes by multiplying height by width. Regular shapes have formulas for finding their area. Area is measured in cm^2.



To find the area of regular and irregular objects, such as a leaf, you lay the object on squared paper (where each square is $1\,cm^2$). You count the number of whole squares and add to it the $\frac{1}{2}$ and $\frac{1}{4}$ squares to get a full total of the area in cm^2.

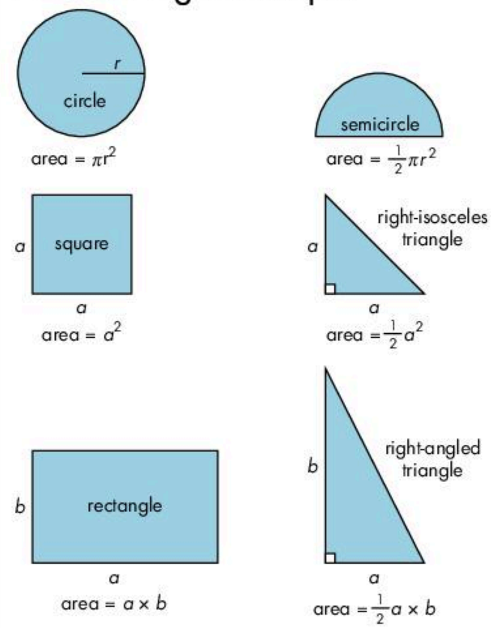
0.5 Measuring length and area

Materials: desk, 30 cm ruler, metre rule, sheet of writing paper, diagrams of shapes with dimensions marked

Work in a group:

1 Measure the width across a desktop using your hand-span. Record all the measurements. What is your unit? How accurately can you measure with your hand? How much variation is there in the group measurements?
2 Now measure the width of the desk using your ruler. Record your measurements. What is your unit? How accurately can you measure with the ruler? How much variation is there in your group? Discuss the importance of using the ruler and of standardisation.
3 Use a ruler to measure the length and width of a sheet of paper. Work out its area.
4 Work out the areas of figures (a)–(d) on the right.

Areas of regular shapes



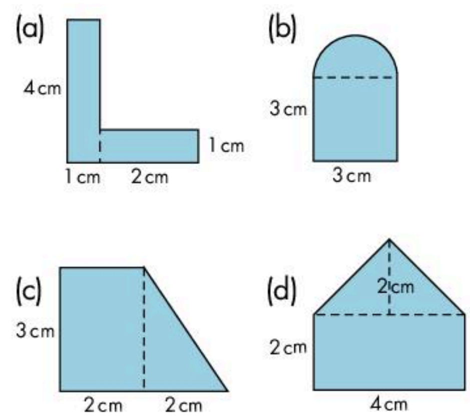
What does it mean?

Diameter: Widest measurement across a circle through the centre.

Radius: Half of the diameter.

π: 'Pi' Used to calculate the area of a circle; it is approx. 22/7 or approx. 3.14.

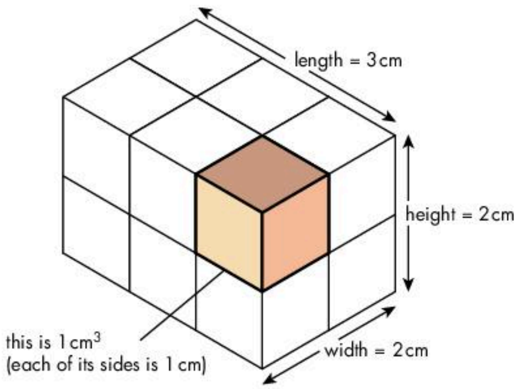
Find the areas of each shape



▶ See Workbook Introduction.

Volume

This is a measurement of the amount of space taken up by a solid object. You find the volume of cuboids by multiplying length × height × width. It is measured in cm^3.



volume = length × height × width
= 3 cm × 2 cm × 2 cm = 12 cm^3

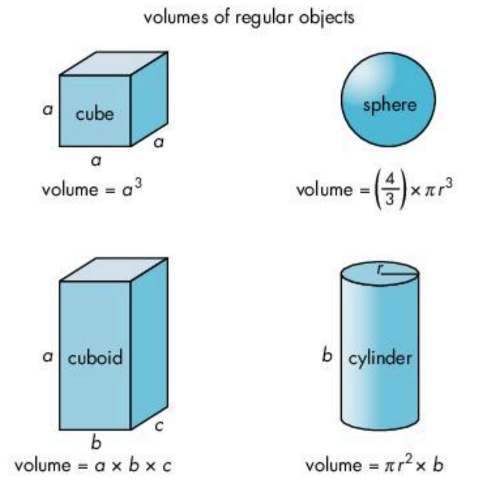
The volumes of regular solids can be found using formulas. The volumes of regular and irregular solids are also found by using water in a measuring cylinder or a displacement (Eureka) can. You find out how much extra space your object takes up.

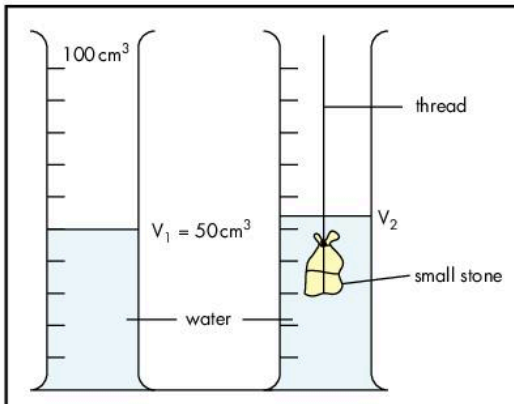
0.6 Measuring volume

Materials: measuring cylinder, water, cube, rectangular block, sphere, cylinder, ruler, displacement can, thread, small stone

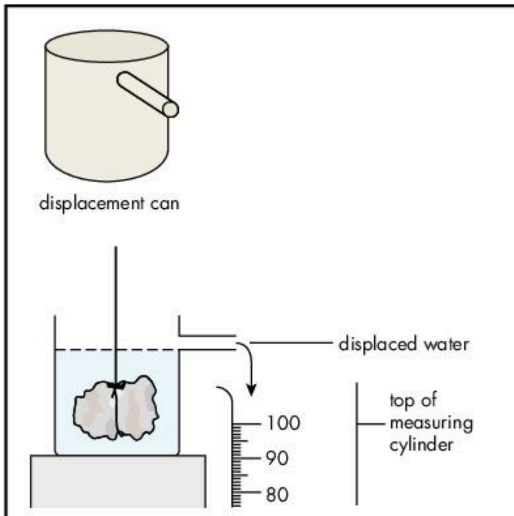
1. Half fill the measuring cylinder with water and record the volume. Submerge a small solid object and record your observations. Repeat two more times using larger objects. Suggest a definition for volume.
2. Your group has been provided with regular solid objects. Identify them from the picture on the top right. Take measurements and work out the volume of each one.
3. Half fill the measuring cylinder with water and record the volume (V_1).
4. Tie thread around a solid shape and gently lower it into the water. Record the new volume (V_2).
5. Enter your results in a table and calculate the change in volume as $V_2 - V_1$.
6. Repeat for the other regular objects.
7. Alternatively, fill a displacement can completely with water. Submerge an object in the water and collect the volume of water that is displaced.
8. Compare the volumes you have found for each of the objects using the calculation method with the displacement method.
9. You have also been given a small stone. Which method – calculation or displacement – would be best for finding its volume? Justify your choice. Find its volume.

Volumes of regular objects





Volume of the small stone = $V_2 - V_1$



Volume of the small stone = volume of water displaced from the can

▶ **See Workbook Introduction.**

Precision, significant figures and standard form

You will now make precise and accurate measurements and record them with a certain number of significant figures. You will also express figures in standard form and do calculations with them. ICT

0.7 Making precise measurements

Materials: small object, e.g. rectangular block, cylinder, sphere; ruler, Vernier caliper and micrometer screw gauge

Work in a group:

1 Measure one dimension of the small object with (a) the ruler, (b) the caliper and (c) the micrometer. Record your results in a table. What do you notice? Which of the measurements is the most precise (is nearest to the real value as it tells you most about the measurement)?
2 Repeat your measurements for the same dimension three more times to make sure you have accurate readings (similar when repeated, with little variation).
3 How many significant figures are there in each of the measurements that you recorded? With which measuring instrument can you make the most precise measurements?

Significant figures

The significant figures of a measurement are the digits that carry meaning contributing to its precision. For example, a reading of 5 cm (one significant figure) could be anything from 4.5, 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3 to 5.4 cm. If, instead, the measurement was recorded as 5.0 cm, then this is more precise and it has two significant figures.

Different measuring instruments allow us to make readings with different degrees of precision. For your work in science, you will usually use a ruler for measuring length. But for greater precision, you need a caliper or micrometer.

In the decimal system we use ten digits: 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9. In a particular numeral how do we know which are the significant figures?

- All non-zero digits are significant, for example, 5461 m has four significant figures.
- Zeros that are between significant figures are significant, for example, 704 g has three significant figures.
- 'Leading' zeros that come before a significant figure are not significant, for example, 0.0001706 m, the '1' is the first significant figure, and the numeral has four significant figures.
- If there is a decimal point, 'trailing' zeros after significant figures are significant: 6.40 cm has 3 significant figures.
- If there is no decimal point, 'trailing' zeros after significant figures are not significant: 640 cm has two significant figures.

Using a caliper

Precision and significant figures

1 Which of these measurements is the most precise? (a) 4 cm, (b) 4.1 cm, (c) 3.90 cm, (d) 4.0 cm
2 How many significant figures are there in each measurement listed in 1 above?
3 Which of these measurements is the most precise? (a) 41.4 g, (b) 63 g, (c) 41 g, (d) 63.15 g
4 How many significant figures are there in each measurement listed in 3 above?
5 Write a numeral with three significant figures.

What does it mean?

Digits: In the decimal system the digits are 0 and 1 to 9. We write the digits to make the numeral.

Numeral: How we represent a number, e.g. 8, VIII and 1000 (base two) are numerals that show the number eight.

Number: What similar sets of objects have in common: four bananas, four cars, four books – they all have the idea of the number 'four' in common.

Significant figure: A digit in a numeral that is important to determine the value of the numeral, abbreviated to sig. fig.

Rounding: Rules for making an approximation in value.

Standard form: Writing large and small numbers with a numeral between 1 and 10 multiplied by a power of 10.

Rules for rounding

For your work in science you usually measure to or approximate your answers to two or three significant figures. The process by which you do this is called **rounding**.

- Round-up if the next digit is 5, 6, 7, 8 or 9, for example, 51.264 expressed to three significant figures is 51.3; 0.1649 rounds to 0.16 to two significant figures (it is closer to 0.16 than it is to 0.17); and 557 to the nearest 10 is 560
- Round-down if the next digit is 1, 2, 3 or 4, for example, 21.93 expressed to three significant figures is 21.9; and 452 to the nearest 10 would be 450

Calculations using significant figures

- To add or subtract, the result should have the same precision as the least precise measurement, for example, 34.23 g + 17.4 g = 51.6 g (not 51.63 g)
- To multiply or divide, do this in a similar way, for example, 49.24 cm ÷ 2.0 = 24.6 cm (not 24.62 cm)

Rules for standard form

Large and small numbers are written with two parts: a numeral between 1 and 10, multiplied by a power of 10.

- The powers of 10 are positive for numbers larger than ten, for example, $4.2 \times 10^6 = 4200000$
- The powers of 10 are negative for numbers smaller than one, for example, $1.78 \times 10^{-9} = 0.00000000178$

Calculations using standard form

- To add or subtract, change to ordinary numbers, do the calculation, then change back to standard form, for example, $4.2 \times 10^4 + 1.78 \times 10^5 = 42000 + 178000 = 220000$, which in standard form is 2.2×10^5
- To multiply or divide, work with the two sides of the numeral separately. You may need to adjust the powers at the end.
  – To multiply, add the powers together, for example, $(5 \times 10^3) \times (3 \times 10^5) = (5 \times 3) \times (10^3 \times 10^5) = 15 \times 10^8$ then this is 1.5×10^9 in standard form. **ICT**
  – To divide, subtract the powers, for example: $10^6 \div 10^2 = 10^4$

Rounding up and down

1 Round the following numerals to three sig, figs. (a) 6.172, (b) 3.615, (c) 0.3693, (d) 0.01486
2 Round the following numerals to two sig, figs. (a) 4.16, (b) 29.8, (c) 0.739, (d) 0.03671
3 Round the following numerals to the nearest 10 (a) 63, (b) 21.7, (c) 39.5

Calculations using significant figures

1 (a) 71.4 + 52.31, (b) 8.3 + 0.07
2 (a) 45.09 – 2.16, (b) 72.6 – 38.42
3 (a) 0.08 × 42, (b) 0.005 × 9
4 (a) 71.5 ÷ 5, (b) 614 ÷ 2.3

Using standard form

1 Express these numerals in standard form (a) 57000, (b) 63460000, (c) 0.439, (d) 0.00000736
2 Change these numerals from standard form to ordinary numbers (a) 5.9×10^5, (b) 4.8×10^7, (c) 2.7×10^{-6}, (d) 1.8×10^{-9}

Calculations using standard form

1 (a) $5.5 \times 10^5 + 7.3 \times 10^7$,
(b) $6.8 \times 10^{12} + 1.5 \times 10^3$
2 (a) $9.4 \times 10^6 - 5.8 \times 10^5$
(b) $7.1 \times 10^8 - 9.2 \times 10^6$ **ICT**
3 (a) $(4.0 \times 10^4) \times (8.2 \times 10^8)$
(b) $(1.7 \times 10^6) \times (5.9 \times 10^7)$
4 (a) $(8.2 \times 10^4) \div (4.1 \times 10^2)$
(b) $(9.0 \times 10^8) \div (1.2 \times 10^5)$

Quick check ☑

We measure ________ quantities using units. We can add ________ to change the value of ________ units. We use a ________ unit (cm²) to measure ________ . The ________ of a numeral is given in significant figures.

Use these words to fill in the spaces as you write the sentences in your Exercise book.

physical **base** **prefixes** **area** **precision** **derived**

Graphs and gradients

Graphs

Graphs are diagrams or pictures you can draw to show the relation between two or more variables, or sets of data. You may have been given the values or have found them from an experiment. You can then interpret the graphs.

Which kind of graph you draw depends on the kind of data:

- If one of the variables is numerical and the other is words:
  - (a) Write the words along one axis and then show the values as columns – vertically: draw a **bar chart** (or bar graph), or horizontally: draw a **column graph**.
  - (b) Draw a **pie chart**. Change the numbers into sectors that are parts out of 360° at the centre of a circle. The angle of each sector is proportional to the value of the part.
- If both the independent and dependent variables are numerical, then you can make a histogram or line graph.
  - (a) In a **histogram**, on the x-axis you mark equal intervals of the independent variable; on the y-axis you record the corresponding frequency (as bars).
  - (b) In a **line graph**, you record the independent variable along a scale on the x-axis and plot the values of the corresponding dependent variable up the y-axis.

Objectives

- Identify the correct kind of graph to use for showing your data.
- Plot and interpret line graphs.
- Calculate gradients of line graphs and determine their units.
- Create and interpret distance–time and velocity–time graphs.

What does it mean?

Data: Can be numerical or words.

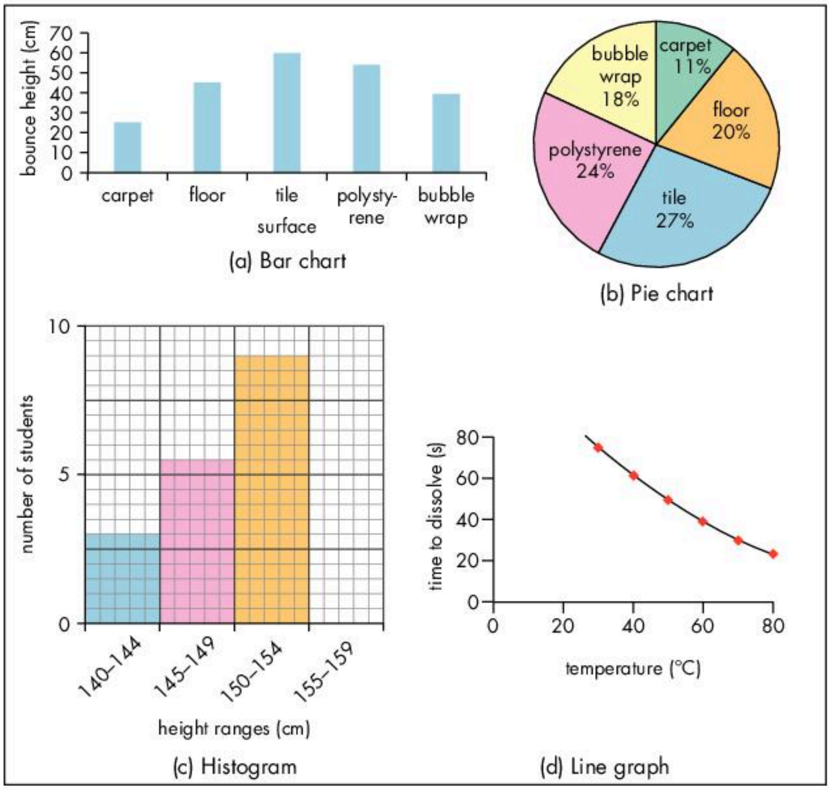
Continuous data: Can have any value, for example length or temperature.

Discrete data: Can have only whole-number values, for example, the number of students or rulers.

Categoric data: These are description words, for example, green or Tuesday.

Plotting a line graph

- Use a sharp pencil and a ruler.
- Plan your graph to take up the space available.
- When you draw your axes, leave space to label them clearly.
- If possible, use increments of 2, 5 or 10 (or their multiples) for your scales.
- Mark and label the values of the independent variable on the x-axis, for example, time.
- Mark and label the values of the dependent variable on the y-axis, for example, height.
- Label the axes with the quantity being measured and the unit, such as 'time(s)'.
- Refer to your table of results: record on the graph, with a small cross (or dot inside a circle), where each reading on the x-axis corresponds to one on the y-axis.
- Check your points.
- Draw a line of 'best fit' using a ruler (have as many points above as below the line). Ignore results that look wrong (check them again and record what you have done).
- Alternatively, draw a curved line to connect the points, for example if the graph is showing growth.



- Add a title above or below your graph, such as 'Increase in mass (g) of seedlings against time(s)'. Note that the change in the dependent variable is written first.

Gradients

A line graph shows the relationship between two variables. The line you draw through the corresponding points expresses this relationship. We call this the slope or **gradient**. Look at the diagrams on the right.

(a) If for each increasing value of A, B also increases: this is shown by a line that rises to the right. This shows a positive relationship.

(b) If for each increasing value of A, B decreases: this is shown by a line that falls to the right. This shows a negative relationship.

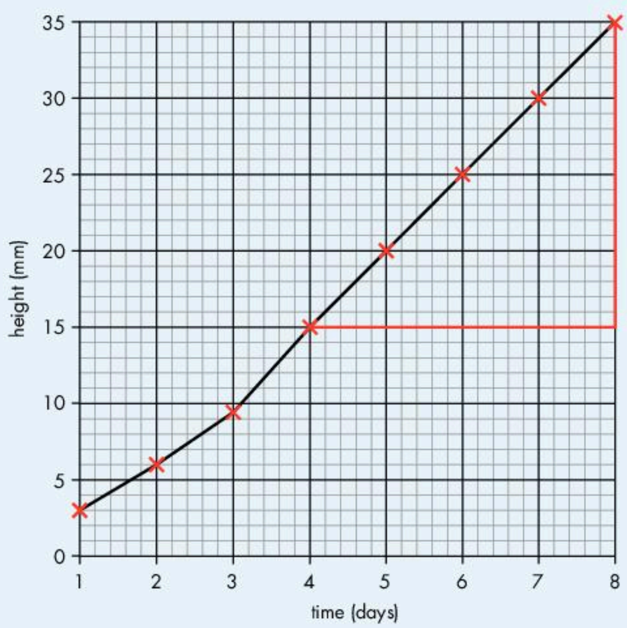
(c) If for each increasing value of A, B stays the same: this is shown by a straight flat line.

0.8 Plot a graph and find the gradient

Materials are provided by your teacher, or you can use the results below, graph paper, pencil, ruler.

1 Plot your graph of the growth of seedlings.

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
3 mm	6 mm	9.5 mm	15 mm	20 mm	25 mm	30 mm	35 mm



2 Calculate the gradient:

(a) Select two points on the best line of fit, where the slope is uniform, and draw a large triangle.

(b) Gradient is defined as $= \dfrac{\text{change on the y-axis}}{\text{change on the x-axis}}$

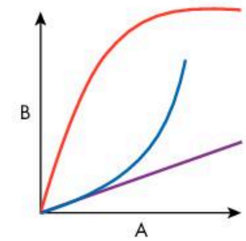
(c) Change on the y-axis = 35 – 15 = 20 mm

(d) Change on the x-axis = 8 – 4 = 4 days

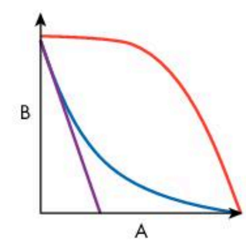
(e) So the gradient (growth rate) $= \dfrac{20\,\text{mm}}{4\ \text{days}} = 5\,\text{mm/day}$

Looking at line graphs

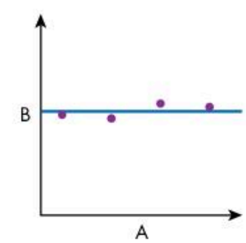
(a) As A increases, so does B



(b) As A increases, B decreases



(c) As A increases, B does not change



0.9 Find the growth rate

1 Use the data to plot a line graph.

Seedlings	Height (mm)
Day 1	2
Day 2	3
Day 3	4
Day 4	7.5
Day 5	13
Day 6	19
Day 7	25

2 How do the independent and dependent variables relate to each other?

3 Find a suitable place on the graph, draw a triangle and find the gradient.

4 In what units should you express the gradient?

▶ **See Workbook Introduction.**

Derived units and gradients

Density

Density describes how tightly packed a substance is. Density is the mass per unit volume of a substance. We make up (derive) density from the fundamental quantities of mass and volume:

$$\frac{\text{Mass (kg)}}{\text{Volume (m}^3\text{)}} = \text{Density (kg/m}^3\text{). Also written as kgm}^{-3}$$

Every cubic metre of pure water at room temperature has a mass of 1000 kg. Its density is therefore 1000 kg/m^3 or 1000 kgm^{-3}. This is the same as 1 g/cm^3 or 1 gcm^{-3}

Distance–time graphs

When we measure the distance an object travels (in metres) in a certain time (in seconds) we can use those fundamental quantities to find (derive) the speed.

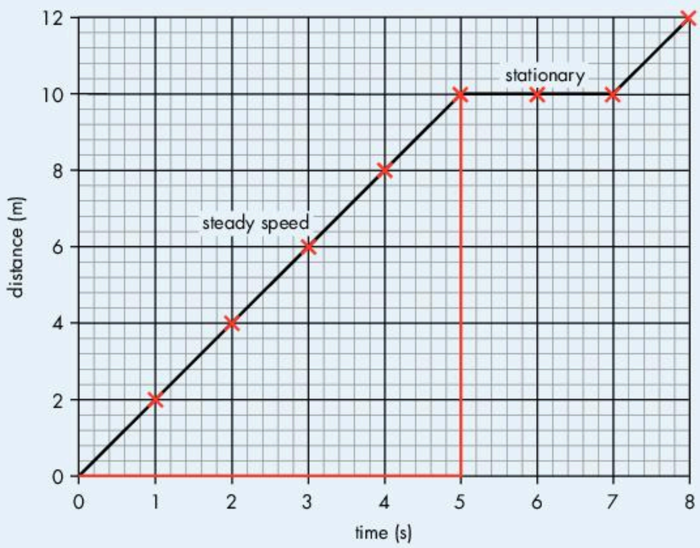
$$\frac{\text{Distance (m)}}{\text{Time (s)}} = \text{Speed (m/s). Also written as ms}^{-1}$$

0.10 Distance–time graph

Materials Table of results, graph paper, pencil, ruler.

1 Plot your graph of distance against time.

2 m	4 m	6 m	8 m	10 m	10 m	10 m	12 m
1 s	2 s	3 s	4 s	5 s	6 s	7 s	8 s



2 Draw a large triangle on the graph.

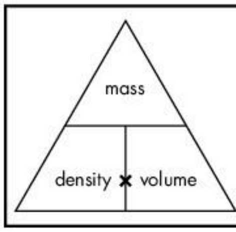
3 Calculate the gradient that shows the speed during uniform motion. So, between 0 and 5 seconds:

(a) Gradient (speed) $= \dfrac{\text{change on the y-axis}}{\text{change on the x-axis}}$

$$= \frac{10-0}{5-0} = \frac{10\text{ m}}{5\text{ s}}$$

(b) Speed = 10 m/5 s = 2 m/s or 2 ms^{-1}

4 What is the speed between (a) 5 and 7 seconds and (b) 7 and 8 seconds?



Density = Mass/Volume

Mass = Density × Volume

Volume = Mass/Density

Density triangle

Calculations with density

1 Which of these things would sink in water? Why? (a) gold ring: density 19.3 gcm^{-3}, (b) ice: density 0.92 gcm^{-3}

2 If a 2 cm^3 block has a mass of 10 g, what is its density?

3 The density of silver is 10.5 gcm^{-3}. Would a silver ring have a smaller or greater mass than a similar gold ring?

4 A sheet of glass (density 7.9 gcm^{-3}) has a mass of 1 kg. What is its volume?

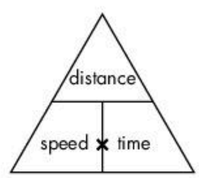
What does it mean?

Speed: The distance an object moves (in metres) in a certain time (in seconds): measured in m/s or ms^{-1}.

Velocity: Speed in a certain direction. It is also measured in m/s or ms^{-1}.

Acceleration: The rate at which velocity changes with time. It is measured in m/s/s or m/s^2 or ms^{-2}.

▶ **See Workbook Introduction.**



Speed = Distance/Time

Distance = Speed × Time

Time = Distance/Speed

Speed triangle

Calculations with speed

1 An object travels 2 metres in 5 seconds. What is its speed?

2 If I drive for 30 minutes at a speed of 50 km/h, how far do I travel?

3 How long will it take to travel 250 m at a speed of 50 km/h?

Velocity–time graphs

A velocity–time graph shows how the velocity of an object (y-axis) changes over time (x-axis). When we measure the velocity (in m/s) and time in seconds (s); the gradient is acceleration.

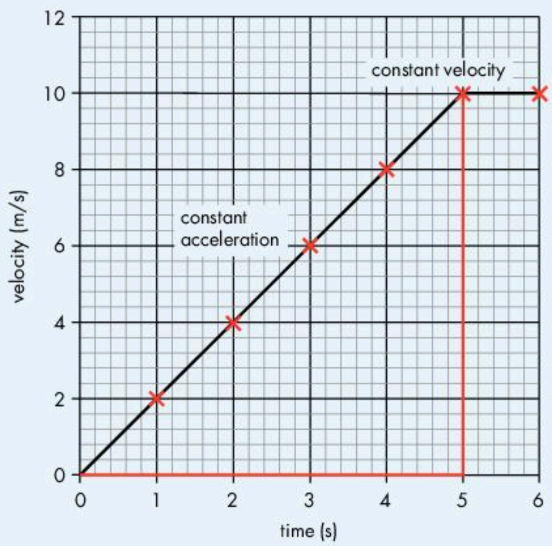
$$\frac{\text{Velocity (m/s)}}{\text{Time (s)}} = \text{Acceleration (m/s/s). Also written as } ms^{-2}.$$

0.11 Velocity–time graph

Materials Table of results, graph paper, pencil and ruler.

1 Plot your graph of velocity (ms^{-1}) against time (s).

Velocity	0	2	4	6	8	10	10
Time	0	1	2	3	4	5	6



2 Calculate the gradient that shows the acceleration:

(a) Draw a large triangle between 0 and 5 seconds.

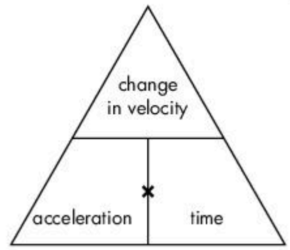
(b) Gradient (acceleration) $= \frac{\text{change on the y-axis}}{\text{change on the x-axis}}$

(c) In what units do you express the acceleration?

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time}}$$

$$\text{Change in velocity} = \text{Acceleration} \times \text{Time}$$

$$\text{Time} = \frac{\text{Change in velocity}}{\text{Acceleration}}$$



Acceleration triangle

Calculations with acceleration

1 If an object is accelerating at $20\,ms^{-2}$ for 20 seconds what is its change in velocity?

2 If the velocity of an object has changed by $10\,ms^{-1}$ during 5 s, what is its acceleration?

3 On the distance–time graph what is shown when the line (a) is rising and (b) is flat?

4 On the velocity–time graph what is shown when the line (a) is rising and (b) is flat?

Force

A force, for example, a push, pull, the force of gravity or magnetic force can change the motion of an object. The force needed to accelerate a mass of 1 kilogram at an acceleration of 1 metre per second per second is a 1 newton (N) force.

Mass (1 kg) × Acceleration (1 ms^{-2}) = Force (1 $kgms^{-2}$: 1 newton)

What does it mean?

Steady speed: On a distance–time graph, the line you plot is at an angle.

Stationary: Stopped. On a distance–time graph where the line is straight and flat.

Acceleration How quickly velocity increases. The gradient on a velocity–time graph where the line is at an angle.

Steady velocity: On a velocity–time graph, where the line is straight and flat.

Quick check ☑

The ________ variable is on the x-axis. The slope of a graph is the ________ . Speed is distance over ________ and is measured in ________ . ________ is speed in a certain direction. Acceleration is measured in ________ .

Use these words to fill in the spaces as you write the sentences in your Exercise book.

time **independent** **velocity**

ms^{-2} **ms^{-1}** **gradient**

Questions

Answer these questions in your notebook

For questions **1–40** answer **A**, **B**, **C** or **D**.

1 Which of these subjects is NOT included in STEAM?
A Science **B** Engineering
C English **D** Mathematics

2 ICT involves
A information **B** communication
C binary code **D** all of the above

3 What does the 'P' stand for in EDP used by engineers for solving problems?
A Process **B** Procedure
C Program **D** Principle

4 Computer programs work using:
A base two digits **B** decimal code
C base ten digits **D** powers of 10

5 When doing experiments with seeds, why do we use large numbers?
A so we will get the answers more quickly
B because plants grow more quickly than animals
C to make sure the results are not just due to chance
D so there will be more plants to use later

6 Which of the variables does an experimenter change during a fair test?
A dependent variable
B independent variable
C control variables **D** all of the above

7 You could use the EDP to do which of these?
A Identify a new kind of animal
B Describe a chemical reaction
C Build a rabbit hutch
D Discover a new plant

8 You would use the scientific method to do which of these?
A Find the best food for rabbits
B Write a software program
C Design a pair of crutches
D Build a model plane

9 The binary code for a number is 101100. What is this in base ten?
A Ten **B** Three
C Forty four **D** Thirty six

10 How would you write the number seventeen (base ten) in binary code?
A 11111 **B** 2000
C 10001 **D** 2001

11 How many digits are in a byte?
A 2 **B** 8
C 10 **D** it varies

12 The base unit of mass is:
A m **B** g
C kg **D** cm^3

13 Which of these would NOT be used for measuring length?
A microscope **B** micrometer
C Vernier caliper **D** metre rule

14 How many milligrams are there in a gram?
A 1 **B** 10
C 100 **D** 1000

15 How many millimetres are there in a centimetre?
A 1 **B** 10
C 100 **D** 1000

16 The mass of a stone is 45 g. What would this be in kg?
A 450 kg **B** 4.5 kg
C 0.45 kg **D** 0.045 kg

17 Radio frequency is measured in megahertz (MH). How do you convert this to kilohertz?
A $\times 10^3$ **B** $\times 10^6$
C $\div 10^3$ **D** $\div 10^6$

18 What is $\times 10^6$ equal to?
A 10 000 **B** 100 000
C 1 000 000 **D** 10 000 000

19 What does 10^{-3} mean?
A $\div$ 10 **B** $\div$ 100
C $\div$ 1000 **D** $\div$ 10 000

20 Which of these quantities is NOT derived from metres (m)?
A cm^3 **B** cm^2
C m^3 **D** kg

21 Which of these is the formula for finding the area of a rectangle of sides a and b?
A $\frac{1}{2}\, a \times b$ **B** $2\, a \times b$
C $a \times b$ **D** $a + b$

22 Which of these is the formula for finding the area of a semicircle?
A πr^2 **B** $\frac{1}{2}\pi r^2$
C $2\pi r^2$ **D** $\frac{4}{3}\pi r^2$

23 The diameter of a circle is:
A the widest measurement across the circle through the centre
B half the widest measurement across the circle
C any line that goes across a circle
D any line that touches the circumference of the circle

24 The approximate value for π is:
A $\frac{7}{22}$ **B** $\frac{22}{7}$
C 3.44 **D** 0.314

25 What is the volume of a cuboid whose sides are 2 cm, 3 cm and 4 cm?
A 9 cm^3 **B** 12 cm^3
C 24 cm^3 **D** 48 cm^3

26 A measuring cylinder is used to measure the:
A mass of a liquid **B** volume of a liquid
C mass of a gas **D** volume of a gas

27 The level of water in a measuring cylinder is $60\,cm^3$. When a stone is added the new volume is $100\,cm^3$. What is the volume of the stone?
A $160\,cm^2$ **B** $100\,cm^2$
C $60\,cm^3$ **D** $40\,cm^3$

28 How many significant figures are there in 4.30?
A 1 **B** 2
C 3 **D** 4

29 How many significant figures are there in 0.00453?
A 6 **B** 5
C 4 **D** 3

30 What is 0.0346 rounded to **two** significant figures?
A 0.036 **B** 0.035
C 0.034 **D** 0.03

31 What is 35 000 in standard form?
A 35×10^3 **B** 35×10^4
C 3.5×10^3 **D** 3.5×10^4

32 What is 0.00892 in standard form?
A 89.2×10^{-3} **B** 89.2×10^{-4}
C 8.92×10^{-3} **D** 8.92×10^{-4}

33 What is $(5 \times 10^3) + (2 \times 10^5)$?
A 7×10^{15} **B** 3×10^{-2}
C 2.05×10^{15} **D** 2.05×10^5

34 What is $(3 \times 10^{-3}) \times (4 \times 10^5)$?
A 1.2×10^3 **B** 7×10^{-2}
C 12×10^{-2} **D** 7×10^2

35 When making a column graph, how do we show the numbers of our results?
A by the lengths of the columns
B by the widths of the columns
C by the lengths and widths of the columns
D by the numbers on the horizontal axis

36 On a line graph, on which axis do we record the results obtained by the experimenter?
A vertical axis **B** horizontal axis
C either axis **D** both axes

37 Which of these does NOT describe speed?
A m/s **B** $m\,s^{-2}$
C ms^{-1} **D** km/hr

38 Which of these does NOT describe density?
A $1000\,kg/m^3$ **B** $1000\,kg\,m^{-3}$
C $1\,g/cm^3$ **D** $1\,g\,cm^{-2}$

39 Which statement is NOT true?
A Velocity is speed in a certain direction
B Both speed and velocity are measured in ms^{-1}
C Speed is distance multiplied by time
D Change in velocity is equal to acceleration multiplied by time

40 On a line graph the change in velocity on the y-axis is $10\,ms^{-1}$, during a time of 5 seconds. What is the acceleration in the correct units?
A $10\,ms^{-2}$ **B** $15\,ms^{-2}$
C $2\,ms^{-2}$ **D** $2\,ms^{-1}$

For questions **41–52** write the answers in your notebook.

41 Describe three similarities and three differences between the scientific method and the engineering design process.

42 (a) Write five sentences about how you can use ICT in your work. **ICT**
(b) Complete a project using ICT.

43 What skills and attitudes are needed by (a) scientists, (b) computer programmers, (c) engineers, (d) artists, (e) mathematicians? Which would you prefer to be?

44 Write an account for a younger child to explain (a) the importance of the binary code, and how it is used to code for (b) numbers and (c) letters.

45 Prepare and send an email to a friend describing the five most interesting things you have found out in the unit. **ICT**

46 Consider the precautions to follow when using the net and social media. Prepare a list of suggestions to use in class. **ICT**

47 Explain the importance of the following: (a) SI units, (b) ASCII codes, (c) the decimal system.

48 Describe how each of the following is derived from the base units of metres (m) and time (s): (a) speed, (b) velocity, (c) acceleration.

49 (a) When is it useful to prepare and interpret a line graph? (b) Make a list of the steps to follow when preparing a line graph. (c) From your work in the unit, describe how one particular line graph was used.

50 How well have you developed the skills of science that were listed on pages 4 and 5?
(a) Use of knowledge: Apply information: Interpret; Evaluate
(b) Practical skills: Plan/Design; Manipulate/Measure; Draw; Working methods; Observe/Record/Report; Study skills; Group work
(c) Technological skills: Make new things; Use technology

51 Give three examples, from within the unit, where you have used lab safety (you can include your use of the internet).

52 Do you now have a better idea of why it is useful to study science as part of STEAM?

Key ideas

- Science is presented as part of STEAM (science, technology, engineering, art and mathematics).
- Science includes content or concepts, process skills for thinking and doing, and attitudes.
- Scientists and technologists/engineers use a stepwise method to solve problems.
- Scientists find out using the scientific method in which they set up fair tests to test hypotheses.
- Technologists/engineers make new things to solve practical problems.
- The variable a scientist controls is the independent variable; its effect on the dependent variable is found, while controlling other variables.
- Engineers use the engineering design process (EDP) to make new things to solve problems.
- ICT helps us to research and handle data and to share information with others.
- Computers work using the binary code (base two) of 0s and 1s to represent data.
- Sets of eight binary digits make a byte, with a meaning based on the ASCII coding system.
- There are precautions to be aware of and to avoid in the use of computers and the internet.
- In mathematics, we work with numbers and the displaying and interpreting of graphs.
- Physical quantities, e.g. length and mass are characteristics that we can measure.
- Measurements are described using units.
- The SI system has seven fundamental quantities, each with a base unit.
- Prefixes (using powers of 10) are used to increase or decrease the value of a base unit.
- We use measurements and formulae to derive area (amount of surface: cm^2) and volume (amount of space taken up: cm^3).
- Significant figures are the digits that carry meaning for the precision of a measurement.
- We can round up or round down to a certain number of significant figures.
- Standard form is a numeral between 1 and 10 multiplied by a power of ten.
- Graphs (e.g. bar charts, pie chart, histogram or line graph) show the relations between two or more things (descriptions or numerical data).
- Speed (ms^{-1}) is found from the gradient of the graph of distance (m) against time (s).
- Acceleration (ms^{-2}) is found from the gradient of changes in velocity (ms^{-1}) against time (s).

▸ **See Workbook Introduction.**

Problems

1 (a) Choose a corridor in your school and measure its length and width. Find out the area.
(b) How many flooring tiles each 1 m^2 would you need for the corridor?
(c) Would you get a better fit to the dimensions if you chose smaller tiles?

ICT

2 You want to paint the walls and door in a room. Work in a group:
(a) Choose a room in your school.
(b) Find the height and width of each of the walls (including the windows) and work out the area of each wall and the total area.
(c) Find the height and width of the windows and calculate their area. Take this away from your first number.
(d) Visit a hardware store and find how many m^2 could be painted by a gallon of paint. Work out how many gallons you need and the total cost.
(e) Ask your ICT teacher if you could enter your data in a spreadsheet to do the calculations.

3 In groups:
(a) Find out the distance of the Sun from the Earth. If this is given in km, then change it to metres.
(b) Find out the speed of light (in m/s).
(c) Calculate the time it takes for light to travel from the Sun to the Earth. (Hint: first change all your numbers into standard form).
As a class, discuss the degree of difficulty in carrying out the task. How did using standard form help you?

4 In groups, find out:

ICT

(a) The distance that light travels in a year (this is called a light-year).
(b) The meaning and measurement of an astronomical unit (AU).
(c) The distance, in light-years and in AU of the star, Alpha Centauri from the Earth.
(d) How long does it take light to reach us from Alpha Centauri?
(e) Check your answers online.

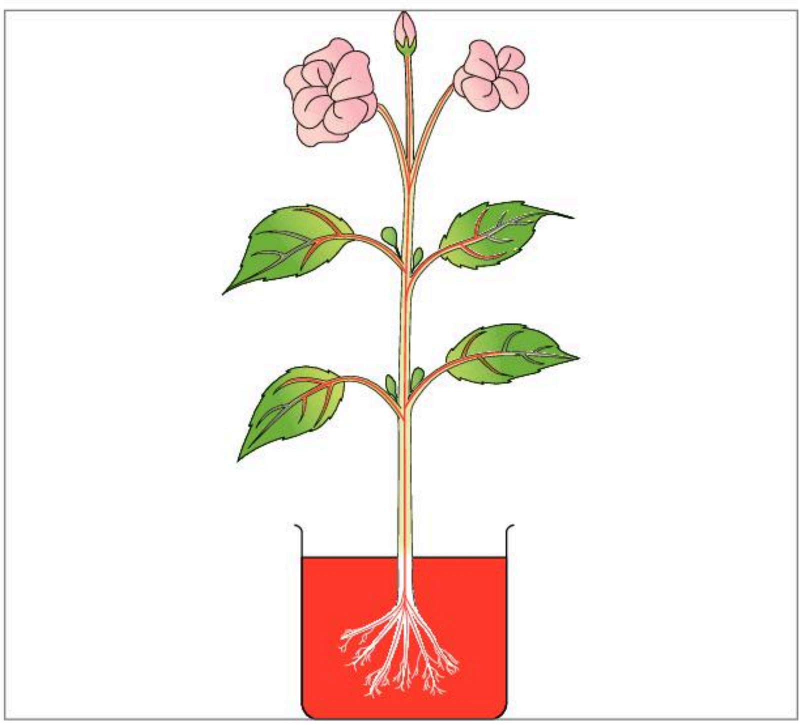
Unit 16

Transport in living things

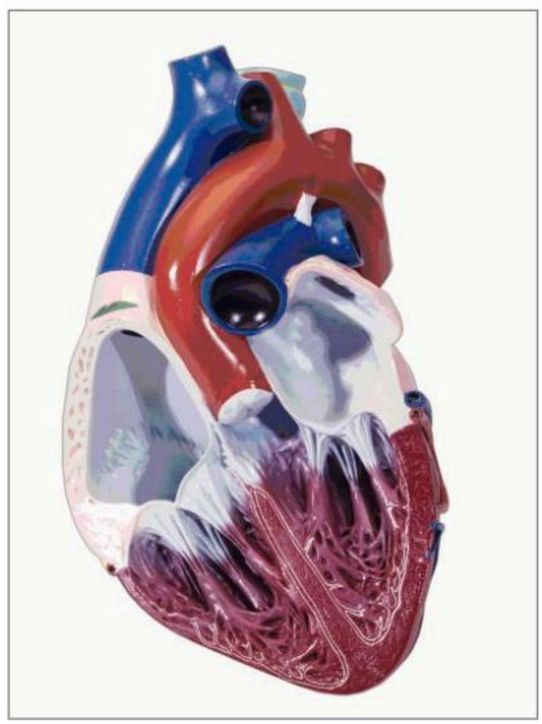
1 *A scientist at the Jamaica National Transfusion Service checks the haemoglobin level of blood from a donor.*

This unit will help you to:

- appreciate how diffusion and osmosis are important for movement of substances
- describe the tissues and transport system in flowering plants
- describe the structure of the blood and how it functions as a transport system
- describe the structure of the blood vessels, heart and circulatory system
- identify some problems of the circulatory system, their causes and how they might be reduced or prevented.



2 *The diagram shows the transparent stem of balsam, which has been left in coloured dye. The pathway of red lines in the xylem is the same pathway that is taken by water and salts.*



3 *The model shows a section of the human heart. The top parts (the atria) receive blood and the lower parts (the ventricles) pump blood out to the lungs and body.*

Diffusion and osmosis

The cells of all living things need to:
- take in oxygen and food to carry out respiration
- get rid of carbon dioxide, other wastes and excess heat.

Diffusion and osmosis are important for these to occur.

Objectives
- Investigate movement of particles by diffusion and osmosis.
- Compare diffusion and osmosis and how they are important in living things.

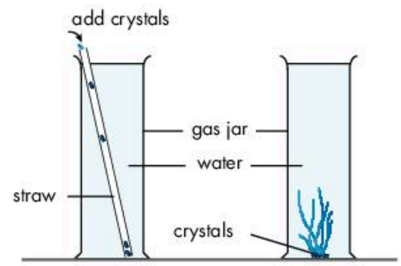
16.1 Movement of particles: diffusion

Materials: air freshener, newspaper, matches, jam jar with a lid, plastic glass, water, spoon, instant coffee
Method
1. Your teacher will spray some air freshener near the front of the room. As each student smells it, they should raise their hands. What do you notice? Why?
2. Light a piece of newspaper. Trap some of the smoke in a jam jar and quickly put on the lid. What happens? Why?
3. (a) Three-quarters fill a plastic glass with water. What colour is the water?
   (b) Add a quarter spoonful of coffee grains to the water.
   (c) Observe and record what happens for two minutes.
   (d) Then stir the mixture. What happens? What colour is the mixture? Has the coffee dissolved in the water? How do you know?

▶ **See Workbook Diffusion and osmosis.**

16.2 Measuring diffusion

Materials: copper sulphate, water, gas jar, straw, marker
Method
1. Fill the gas jar with water. Put the straw into the water and carefully drop ten small crystals of copper sulphate down to the bottom of the water.
2. Do not use a spoon or move the gas jar. Leave it for 10 days.
3. On each day, use your marker to record how high the colour of the copper sulphate has risen.
4. Explain what has happened.



Questions
What differences would there be if:
1. The crystals of had been bigger?
2. The crystals had been smaller?
3. The water had been warmer?
4. The water had been cooler?

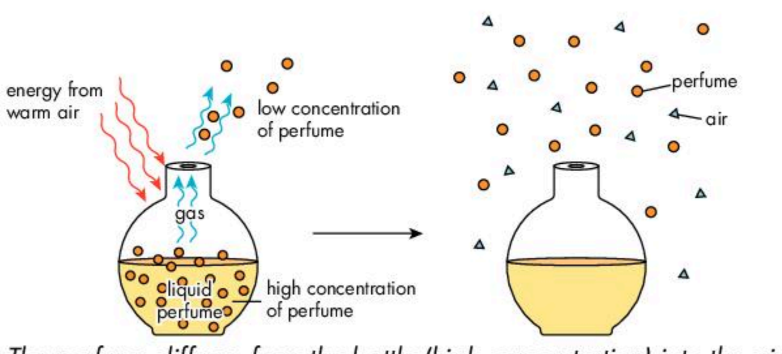
16.3 Setting up a fair test

1. Choose one of the questions above.
2. Use it to design a fair test to find the answer. Make sure you identify the one variable you will change and the variables you will keep constant.
3. Check with your teacher; then carry out and record your investigation.

Particles spread apart: diffusion

In solids the particles can only jiggle around; they cannot move from place to place. In gases and liquids, the particles can move from place to place. This means that the particles can spread out – we call this **diffusion**.

Diffusion is the movement of particles from a place where there are lots of them (where they are in high **concentration**). The particles move to a place where there are only a few of them (where they are in low concentration). Can you explain how each of the parts of the activity above shows diffusion?



The perfume diffuses from the bottle (high concentration) into the air where it was in low concentration. It becomes spread in the air.

16.4 Surface area and volume

Materials: knife, clean surface, ruler, dilute hydrochloric acid, forceps, stop watch. Your teacher will make solid agar by mixing 2 g of plain agar powder in 100 cm^3 of water and stirring and heating this in a water bath. A few crystals of potassium permanganate are stirred in to colour the agar. The agar is poured into ice cube trays to cool.

Method

Work in groups:

1 Carefully use a sharp knife to cut two cubes each with sides 1.5 cm, 1 cm and 0.5 cm. Work out and record in a table the surface areas and volumes.
2 Use forceps to place the coloured cubes into a 250 cm^3 beaker of hydrochloric acid. Record the time for each size of cube to become colourless.
3 In class, determine the average time for each cube size and plot a suitable graph of the results.
4 Discuss the results and complete your report.

Questions

1 Under what conditions is diffusion quickest?
2 Do you think diffusion would be adequate for the movement of substances for (a) a unicellular organism (b) a multicellular organism? Why?

Osmosis: movement of water

Osmosis is a special case of diffusion. It is the movement of water across a partially or selectively permeable membrane.

16.5 Osmosis

Materials: citrus fruit, two plastic bags and ties, raisins, ruler, water, medium Irish potato, knife, two dishes, brown sugar, salt

Method

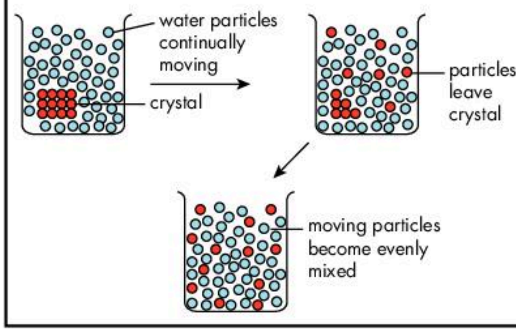
1 Put one peg of citrus fruit into a plastic bag with a tablespoon of salt and another in a second bag but without salt. Close and shake the bags. Leave for 10 minutes.
2 Measure ten raisins and find the average length. Feel their texture. Put them in water for 10 minutes and re-measure. Put them back in water for 2 hours and re-measure.
3 Cut the potato in half and carve out a hollow in each part. Cut the base of each half flat and stand them in dishes with the same amount of water. Place one teaspoon of brown sugar into one potato half. Leave for 30 minutes.

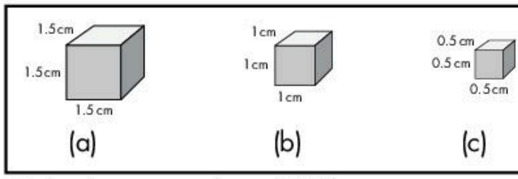
Questions

1 Record and explain what happens in each case.
2 Relate your observations to the concept of osmosis.

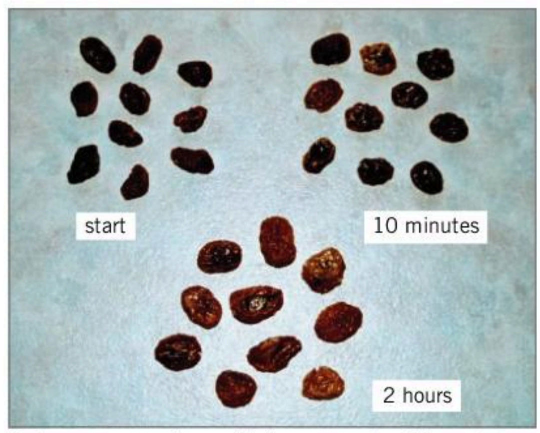
Diffusion in a liquid

Here is a model of what happens in diffusion.





Make the agar cubes of different sizes



Water enters the cells by osmosis. The raisins become larger.

What does it mean?

Diffusion: Movement of different particles among each other so that they become evenly mixed.

Osmosis: Movement of water through a partially or selectively permeable membrane such as the cell membrane in living cells.

Concentration: The amount of a certain substance in a mixture.

Partially or selectively permeable: Describes a membrane, such as the cell membrane, that allows water through but not solutes.

16.6 More activities with osmosis

Materials: chocho, salt, seeds or beans, knife, dishes, ruler, string, strong sugar solution, spoons. Your teacher will also prepare de-shelled eggs by covering them with dilute hydrochloric acid overnight until the shells have dissolved.

Method

Work in groups:

1 (a) Carefully cut a 1 cm slice of chocho or other vegetable. Cut a square of 2 cm x 2 cm.
(b) Place the chocho in a dish and sprinkle salt over it. Label it with your group's name.
(c) Record your observations and measurements after 10 minutes and after 2 hours.

2 (a) Choose five seeds or kidney beans. Measure their dimensions to find the average length, breadth and width.
(b) Add enough water to cover them. Label the dish.
(c) Record your observations and measurements after 10 minutes and after 2 hours.

3 (a) Carefully wash the two de-shelled eggs you have been given. These are raw eggs so handle them gently.
(b) Record the mass of each egg and measure the circumferences using string and a ruler.
(c) Put one egg into a beaker of water and the other into strong sugar solution. Cover and leave until next day.
(d) Wash the eggs in tap water and repeat the mass and length measurements. Record your results.

▶ **See Workbook Diffusion and osmosis.**

Questions

1 How do your activities support the suggestion that water particles have moved?
2 In which direction has water moved in each part 1–3?
3 Can you suggest any reasons for your results?

Movement of water

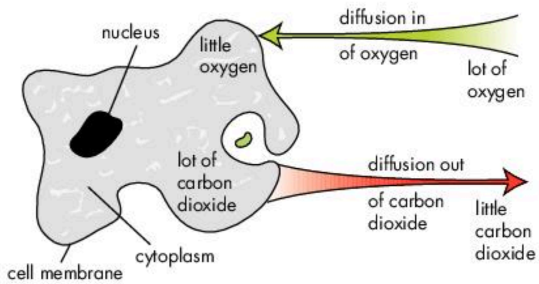
Diffusion and osmosis both occur because of the continual movement of particles from places where they are in high concentration to places of lower concentration. Osmosis is a special example of diffusion and it is the movement of water particles across a partially or selectively permeable membrane, such as the cell membrane in living plant and animal cells.

When citrus fruit, chocho, potato or de-shelled eggs are placed in strong sugar or salt solution, water particles move out of the living material into the surroundings.

When raisins, seeds or de-shelled eggs are placed in water, there are more particles of water outside the living material than inside, so water enters and swells the living cells.

An amoeba is a very small unicellular organism. It lives in water and has a large surface area in relation to its volume. No part of its cell is far from the water. The amoeba is not very active, and the rate of diffusion of oxygen and carbon dioxide is fast enough for its needs. It does not need a transport system as is required in large multicellular plants and animals

- Oxygen is at a high concentration in the water and a lower concentration inside the cell. So oxygen diffuses in.
- Carbon dioxide is produced during respiration. Carbon dioxide is at a high concentration in the cell and a lower concentration outside. So carbon dioxide diffuses out.



Amoeba exchanges gases by diffusion.

What does it mean?

Concentration gradient: Describes the direction of movement of particles from a region of high concentration to a region of lower concentration. It is important in diffusion and osmosis.

Isotonic: Describes two solutions of the same concentration separated by a partially or selectively permeable membrane. There is no overall (net) movement of water between the two solutions.

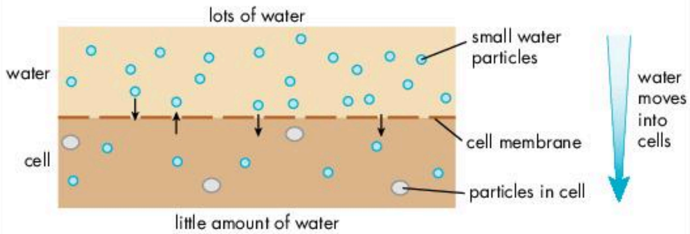
Hypertonic: Describes a solution that is more concentrated than another for a particular substance, e.g. sugar. *Note:* a strong sugar solution is high in sugar particles but low in water particles.

Hypotonic: Describes a solution that is less concentrated than another for a particular substance. *Note:* a weak sugar solution is low in sugar particles but high in water particles.

Making a model of osmosis

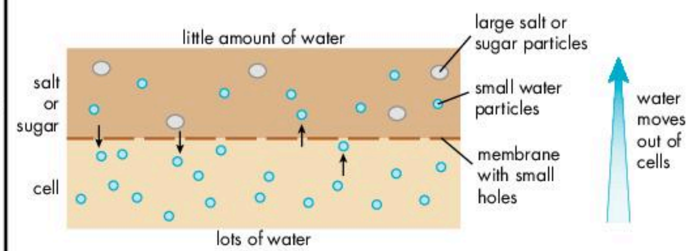
The cell membrane allows allows water particles to go through, but not other, larger, particles that are in the cell sap or cytoplasm. The cell membrane is said to be partially or selectively permeable.

When living material is placed in water, it gains water, becomes larger and less wrinkled.



There is more water outside the living material than inside. Water particles move from their high concentration to their lower concentration.

Living material placed in salt or sugar loses water, becomes smaller and more wrinkled.

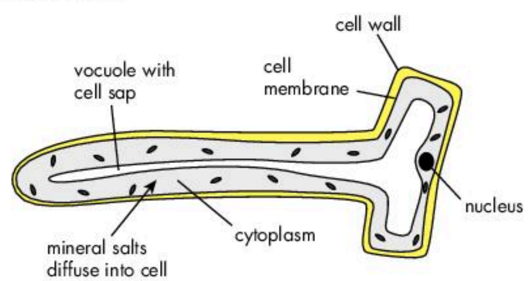


There is more water inside the living material than outside. Water particles move from their high concentration to their lower concentration.

Diffusion and osmosis compared

Diffusion

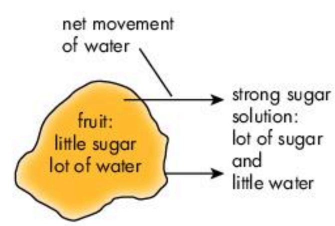
- Depends on movement of particles along their concentration gradients: from a higher concentration to a lower one.
- Occurs in any gas or liquid, and solids dissolved in water; both solute and solvent can move.
- Examples: diffusion of perfume or of particles of a crystal through a liquid. Also: diffusion of oxygen and carbon dioxide in or out of cells and in gas exchange; diffusion of food particles after digestion.
- Importance: allows movement of gases over short distances and is effective with large surface area to volume ratios.



A root cell: Mineral salts diffuse into the cell

Osmosis

- Depends on movement of particles along their concentration gradients: from a higher concentration to a lower one.
- Occurs only in liquids across a partially or selectively permeable membrane that only water (the solvent) can pass through.
- Examples of osmosis: plant root hairs taking in water; water passing from cell to cell in the root and leaf of a plant; water taken up by red blood cells put into water.
- Importance: movement of water between cells. Also used commercially to withdraw water, e.g. when preserving fruit in sugar solution.



Canned fruit: Water is withdrawn by osmosis

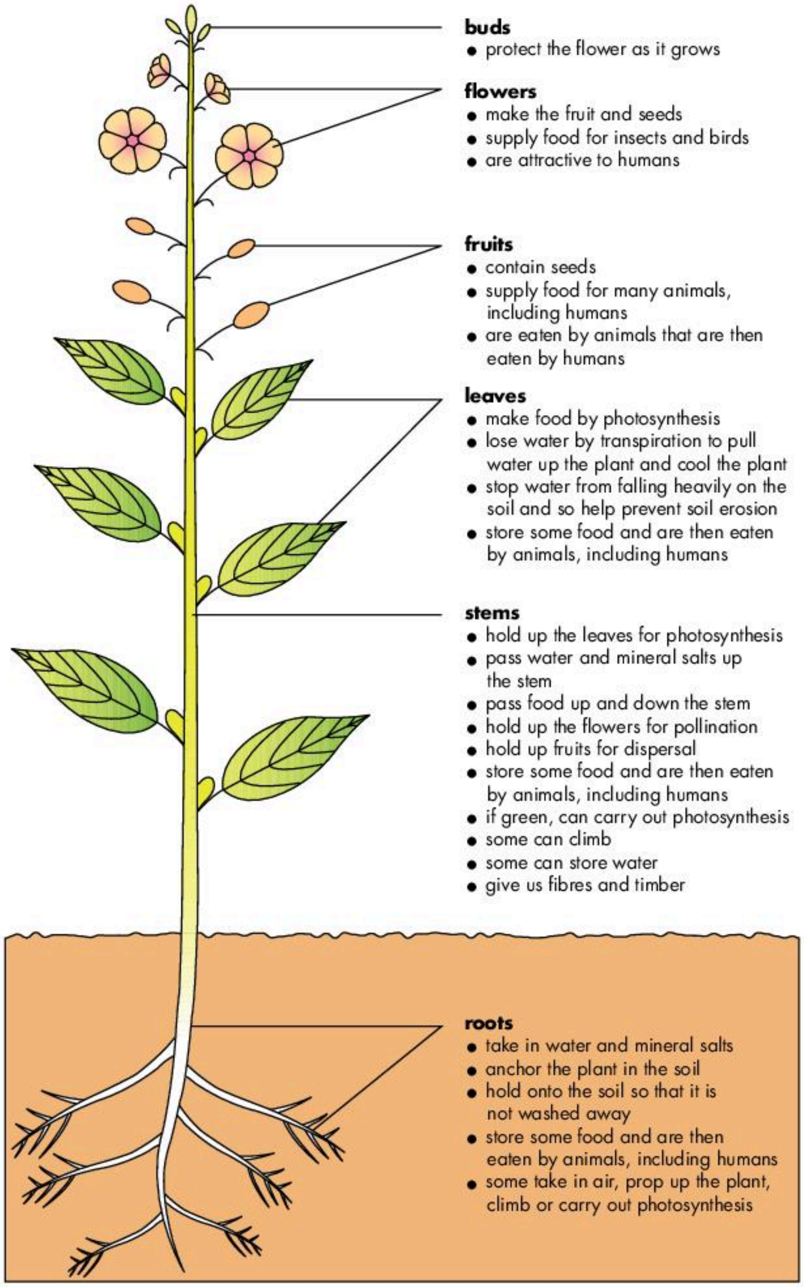
Quick check ☑

__________ occurs in gases, liquids and solids in solution. __________ is the movement of water particles through a __________ permeable membrane, such as the __________ membrane. A strong sugar solution would have __________ and pure water have __________ water particles.

Use these words to fill in the spaces as you write the sentences in your Exercise book.

cell	partially	osmosis
more	diffusion	fewer

Transport in plants



16.7 Parts of a flowering plant

Materials: the drawing of a flowering plant

Method

1 Flowering plants are multicellular organisms. In your group, use the drawing above to revise the structure and functions of the parts of flowering plants: their roots, stems, leaves and flowers.

2 Make up a quiz and ask another group your questions.

▸ **See Workbook Transport in plants.**

Objectives

- Revise the structure and functions of parts of flowering plants.
- Describe tissues in the roots, stems and leaves important for transport.
- Investigate the movement of water from the roots to the leaves.

16.8 Roots and root hairs

Materials: peas or beans, dish, damp tissue paper, hand lens, slides

Method

1 Soak the seeds in water overnight and then leave them on damp tissue paper in a covered dish for 2–3 days.

2 Use your hand lens to identify the main root and the very small root hairs.

3 Observe animations of root hairs or look at prepared slides from your teacher using a microscope.

4 Draw and label a root hair.

Questions

1 What shape are the root hairs?

2 How does their shape increase the surface area to volume ratio?

3 How does the structure of root hairs suit them to absorbing water and mineral salts from the soil?

16.9 Stems and transport

Materials: whole balsam plant, stalks with white flowers, dye solution

Method

1 Place the balsam plant and the freshly cut flower stalks into the dye.

2 Observe after a few hours and the next day.

Questions

1 What can you see in the stem?

2 What happens to the white petals?

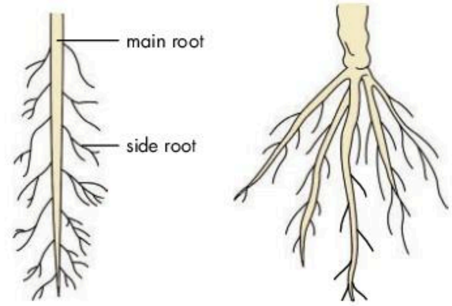
3 Why do these things happen?

4 How might this process be used commercially?

16.10 Looking at roots

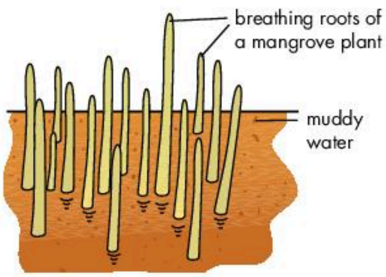
Materials: a whole grass plant, balsam or a herb, water

1. Wash the soil from the roots. Identify the characteristics of the roots and leaves of **dicotyledons** (the balsam or herb) from **monocotyledons** (the grass).
2. Discuss how the structure of the roots helps them to carry out their functions (check the previous page).
3. Research other functions of roots.
4. Research adaptations for different environments. ICT

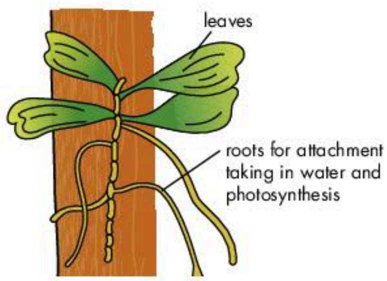


Dicotyledons	Monocotyledons
One main root	Many small roots
Branching veins	Parallel veins
Broad leaves	Narrow leaves
Two seed leaves (cotyledons) in seeds	One seed leaf (cotyledon) in seeds

Special roots



Roots need oxygen for their root cells to respire. There is little air in mangrove swamps, so the roots grow into the air.



Orchid roots help the plant to climb. They also take in oxygen, water and salts from the air and carry out photosynthesis.

Fun facts

- Plants die in waterlogged soils as the roots cannot get the oxygen they need for respiration to release energy.
- The deepest roots of a wild fig tree grew 120 m into the soil.
- A rye plant (a monocotyledon), can grow more than 620 km of roots.
- Raffia and bamboo palms have leaf blades up to 20 m long.
- The Venus flytrap and Pitcher plant have leaves that are modified to catch insects that are then digested.
- After rain, a large cactus can take in one tonne of water in a day.
- The *Saguaro* cactus of Arizona is 20 m tall and 1 m thick.

16.11 Looking at leaves

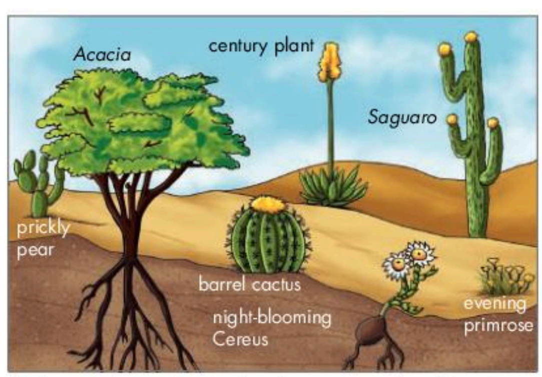
Materials: a variety of leaves

1. What do the leaves have in common? Check colour, thickness, veins, texture and appearance of top and bottom surfaces.
2. Discuss how the structure of the leaves helps them to carry out their functions (check the previous page).
3. Research other functions of leaves.
4. Research adaptations for different environments. ICT

Special leaves

Water hyacinth has swollen leaf bases to help it float in water.

In many cacti the leaves are just spines (to reduce loss of water); the stems are swollen and green, and they carry out photosynthesis.



What adaptations do plants need to live in a desert? Identify some adaptations of these desert plants.

Roots and the plant's transport system

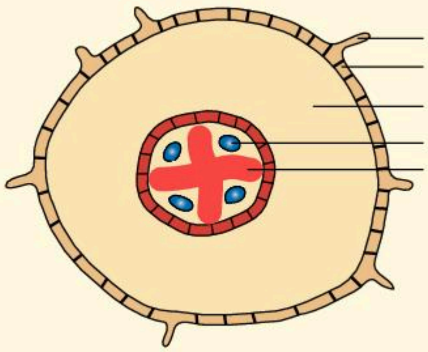
Look at a cross-section of the balsam root that you left in the dye. You should be able to see a central red area. This shows where the dye and the xylem vessels are in the root.

16.12 Transport tissues in roots

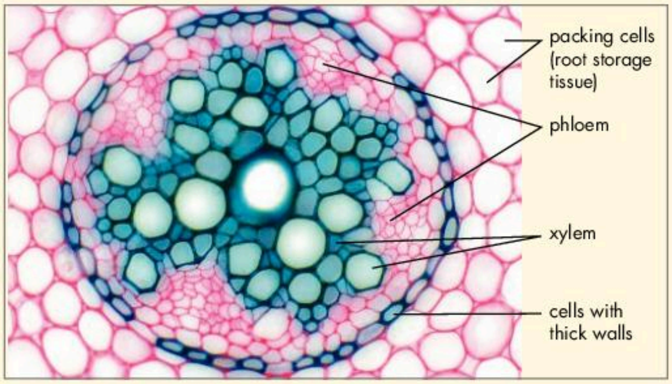
Materials: your cross-section of the balsam root, hand lens, prepared slide of a cross-section of a flowering plant root, microscope

Method

1 Examine and draw your own cross-section of the root.
2 Observe the cross-section of the root set up by your teacher. Draw a plan diagram **(a)** below. Then draw a few of the cells from the centre of the root **(b)**. Label your drawings.



(a) Diagram of cross-section of a root



(b) Photograph of a cross-section of a root. Note that the xylem is dyed blue and the phloem is red.

3 Remember that your drawings should be in pencil, with continuous smooth lines. Use a ruler and pencil to draw the label lines (which should not cross). Use all lower case letters to add your labels neatly in script.

Questions

1 How does the position of the red dye in your cross-section show that the xylem vessels transport water and mineral salts?
2 Why was it easier to see the xylem vessels in the prepared slide, rather than in your section?
3 Did you see any stored food in the packing cells? Does the root make food? If not, then where did this food come from?
4 How are xylem and phloem arranged in the root? How do their cell walls differ from each other?
5 List all the tissues you have seen in the root. List the main functions for each one.
6 Which of the tissues you have seen do you also expect to see in the stem and the leaf? Explain your answer.
7 Are there any tissues in the stems and leaves that are not present in the roots? Explain the reason for your answer.

What tissues are involved?

- Each part of the root has a covering of long **root hairs**. These have a very large surface area to their volume. They grow in amongst the soil particles, close to the water and mineral salts.
- In the centre of the root are the **xylem** vessels. These are tubes connecting the root to all parts of the plant. They carry the water and mineral salts up the plant.

▶ **See Workbook Transport in plants.**

What processes are involved?

- Water enters the roots by **osmosis** (see previous section). Water enters from outside (where it is in high concentration) to inside the cells (where there is a lower concentration).
- Mineral salts **diffuse** into the roots, from a higher to a lower concentration.
- The water passes from the root hairs across the root by **osmosis**. It travels into the centre of the root where the xylem vessels are.
- As more and more water is taken in, this pushes up water that is already in the root. The water rises in the xylem vessels. This is called **root push**. It is a push on the water from below.

Stems and the plant's transport system

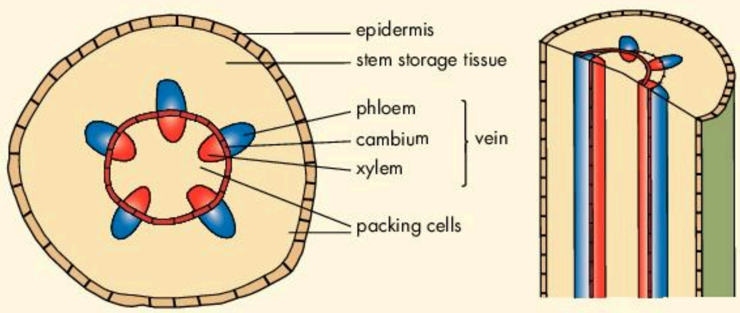
Look at sections of the balsam stem that you left in the dye. In a cross-section you will see red dots and in a longitudinal section long red strands. These show where the dye and the xylem vessels are in the stem.

16.13 Transport tissues in stems

Materials: your sections of the balsam stem, hand lens, prepared slide of a cross-section of a young dicotyledon stem, microscope

Method

1 Examine and draw your own sections of the stem. Draw and label plan diagrams as shown in **(a)** below.
2 Observe the cross-section of the stem set up by your teacher. Draw a few of the cells from each kind of tissue **(b)**. Label your drawings.

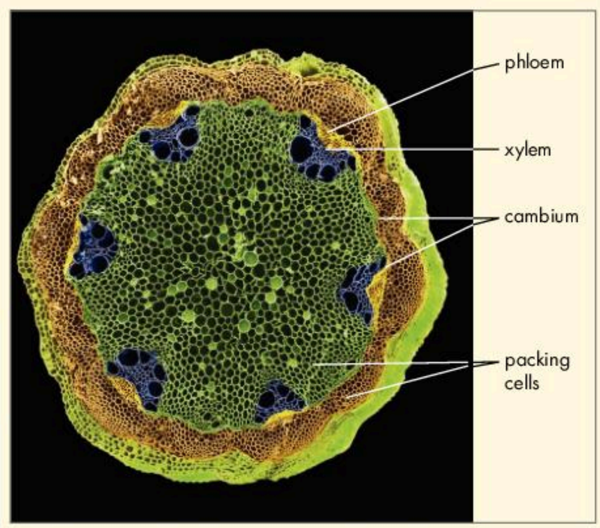


(a) Diagrams of cross-section and longitudinal section of a stem

▶ **See Workbook Transport in plants.**

What are the tissues and processes?

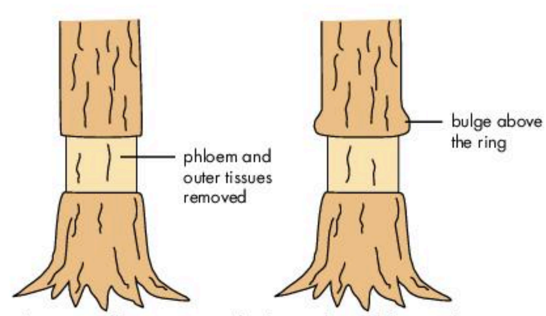
- The covering of the stem is one cell thick. This **epidermis** has small holes in it. Through these holes, oxygen and carbon dioxide can **diffuse** in and out of the stem as needed.
- The inner part of the veins contain **xylem** vessels. These are very narrow and water rises up in them by **adhesion** and **cohesion**.
- Water is lost from the xylem in the leaves during **transpiration**. As the water evaporates, it pulls more water up from below. This is called transpiration pull.



(b) Photograph of a cross-section of a stem. Note that the xylem is dyed blue and the phloem is yellow.

Questions

1 How are xylem and phloem arranged in the stem?
2 How does the position of the red dye in your sections show that the xylem vessels transport water and mineral salts? Is there any red dye in the phloem?
3 List all the tissues you have seen in the stem. List the main functions for each one.
4 Did you see any stored food in the packing cells? Did you see any green chlorophyll in the cells? Do you think the stem makes food? If not, then where did this food come from?
5 The diagram on the right shows a tree trunk that has been damaged. The outer tissues, including the phloem, have been removed. Why do you think the trunk is bulging above the ring?
6 How could you find out if the bulge contained food? What do you think will happen to the tree below the ring?



A ring of tissue, including the phloem has been removed. What will be the effect on the plant in the short- and long-term?

Leaves and the plant's transport system

16.14 Looking at veins

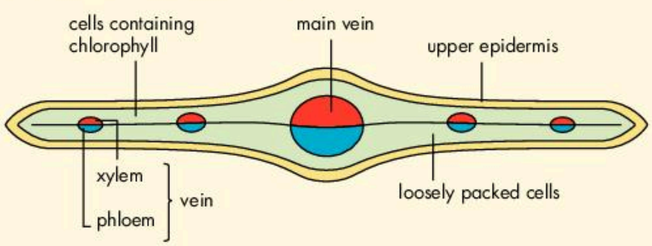
1 Collect leaves from a variety of plants.
2 Use a hand lens to help find the veins. Draw the leaves.

(a) Grass (b) Hibiscus (c) Sweet potato (d) Sensitive plant

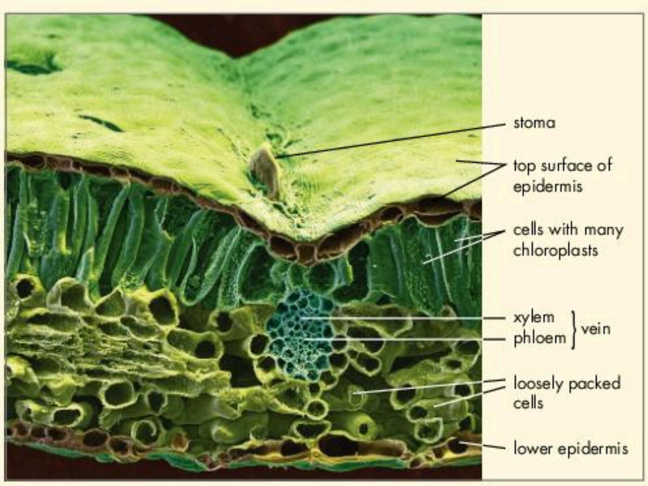
16.15 Transport tissues in leaves

Materials: your section of a leaf, hand lens, prepared slide of a cross-section of a dicotyledon leaf, microscope
Method

1 Examine and draw your own section of the leaf. Notice how the veins have become stained with the dye. Draw and label a plan diagram as shown in **(a)** below.
2 Observe the cross-section of the leaf set up by your teacher. Draw a few of the cells from each kind of tissue **(b)**. Label your drawings.



(a) Diagram of cross-section of a leaf



(b) Photograph of a cross-section of a leaf

What are the tissues and processes?

- The covering of the leaf (**epidermis**) has small holes called stomata. Oxygen and carbon dioxide **diffuse** in and out of the stomata as needed by the leaf.
- Water is also lost from the **xylem** in the leaves during **transpiration**. As the water evaporates, it pulls more water up from below (**transpiration pull**).
- Carbon dioxide (from the air) and water (from the soil) combine in **photosynthesis** in the leaf. Other foods are made by the addition of mineral salts. The food is transferred to the **phloem** and distributed around the plant.

▶ **See Workbook Transport in plants.**

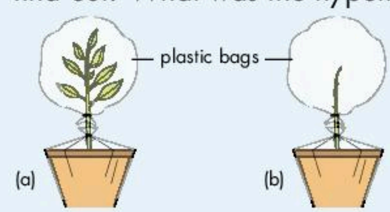
Questions

1 List all the tissues you have seen in the leaf. List the main functions for each one.
2 How could you show that the leaf makes food?
3 Prepare your own overall diagram showing the transport tissues and labelling the processes involved in transport in a plant.

16.16 Leaves and transpiration

The activity below was set up.

1 What did the experimenter want to find out? What was the hypothesis?



2 What do you think will happen?
3 Carry out research to find out about transpiration in flowering plants. ICT
4 Plan and design an experiment to find out the effect of light on the rate of transpiration.

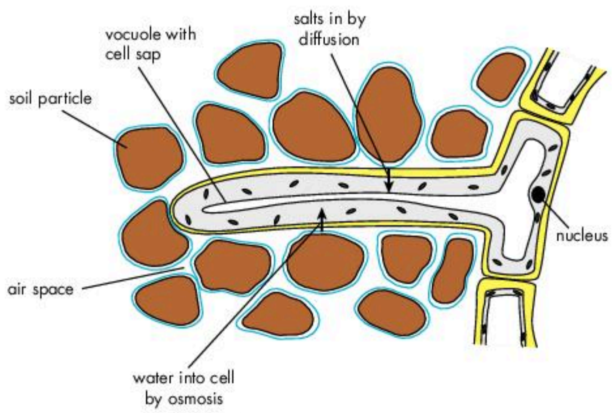
The water pathway

We can now trace the pathway of water from the soil, through the plant and out into the air. As it travels through the plant, water is used to transport materials, support the stem and some is combined with carbon dioxide to make sugars. As water evaporates into the air in transpiration, it cools the plant.

The root

Each root hair cell is elongated so it has a large surface area to volume ratio. It is also closely surrounded by soil particles. Water, containing mineral salts, forms a layer around the soil particles.

The water is at a higher concentration outside the cell than inside, so it enters through the cell wall and the partially permeable cell membrane by osmosis into the cell. Mineral salts are also usually at a higher concentration in the soil and so diffuse into the cell.



How water and salts enter the root

As water enter a root hair cell, it dilutes the cell sap. There is therefore more water in the root hair than in the cell next to it so water passes by osmosis into the next cell. This continues all the way across to the xylem vessels. As more water enters the root, this causes a root push from below.

The stem

Water and mineral salts rise up in the xylem vessels.

16.17 Adhesion of water molecules

Materials: two glass slides, water
Method
1 Place a drop of water on one glass slide. Place another slide on top of it.
2 Try to separate the slides. Observe what happens.

Explanation: You will find that the glass slides are very difficult to separate. Water molecules have become firmly attached to the slides. This force between water molecules and a surface is called **adhesion**. It helps the water in the xylem vessels to hold onto the surface of the wall.

What is transported in plants?

Water transports:
- Mineral salts in the xylem from the roots to the leaves where they are used to make a variety of food substances.
- Food substances in the phloem to storage areas in the roots, stems, leaves, seeds or fruits.
- Plant hormones needed to control flowering and growth.

Gases diffuse themselves:
- Oxygen is made in photosynthesis and used in respiration.
- Carbon dioxide is used in photosynthesis and produced in respiration.
- Water evaporates from leaves in transpiration.

What does it mean?

Vascular tissue: Xylem and phloem.

Veins: Contain the transport tissues: xylem and phloem. A vein is also called a vascular bundle.

Xylem: Dead vessels on the inner side of veins and the centres of roots; transport water and mineral salts **up** the plant (one-way system).

Phloem: Living vessels that take food substances **up** and **down** the plant (two-way system).

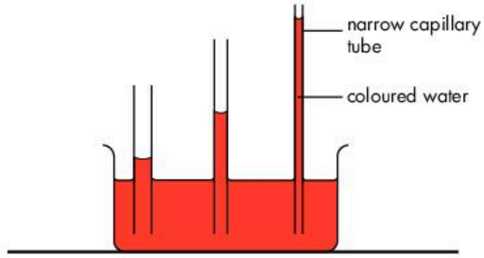
16.18 Xylem and phloem

Materials: Circles of two different colours and size (10 to represent xylem and 10 for phloem), chalk
Method
1 Using the chalk, draw two large circles on the floor (one representing a cross-section of a root and the other a stem).
2 Arrange the xylem and phloem circles to show how the transport tissues in a dicotyledon root and stem are arranged.

16.19 Cohesion of water molecules

Materials: narrow glass tubes, beaker, coloured water
Method
1 Select three very narrow glass tubes. Stand them upright in the coloured water.
2 Notice that the coloured water rises higher in the tubes than the surface of the water in the beaker. The water rises highest in the narrowest tube.

Explanation: Molecules of water adhering to the side of the glass pull on other water molecules, which in turn pull on other ones. The force between water molecules is called **cohesion**. Water can rise up in the narrow xylem vessels.



Water rises in very narrow tubes

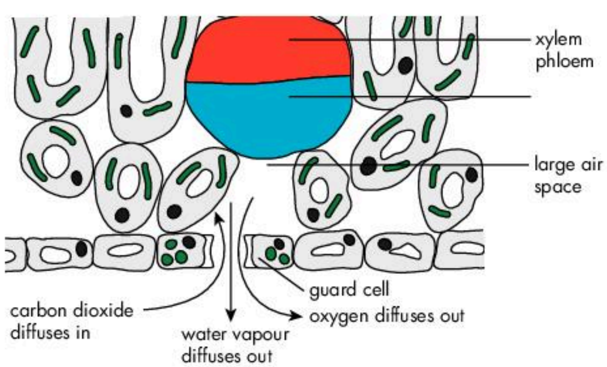
The leaves

16.20 Structure of leaves

Materials: hibiscus leaf, hand lens, hot water, string, prepared slide showing stomata, microscope
Method
1 Use the hand lens to look at the lower surface of the leaf. You may be able to see small openings, the **stomata**.
2 Look at the slide of the leaf surface under the microscope. Identify the stomata.
3 Tie a piece of string around the stalk of the leaf and dip it into hot water. You will see air bubbles coming out. Which surface produces more air bubbles?

Explanation: The leaf has many air spaces and when the air is heated it comes out through the stomata. There are more stomata on the lower surface of the leaf. Water evaporates from the cell surfaces inside the leaf and it diffuses along its concentration gradient to come out of the leaf through the stomata.

The stomata on the leaf are open during the day so that the plant can exchange gases during photosynthsis. So water changes to vapour and also diffuses out of the leaf.



Structure of a leaf to show diffusion during the daytime

16.21 Self-watering system

You are going away for two weeks. You have an expensive potted plant that needs to receive constant watering.
- Design a system so that your plant could be supplied with water.
- Explain how your system works.
- Set up your system with a potted plant and evaluate if it works.

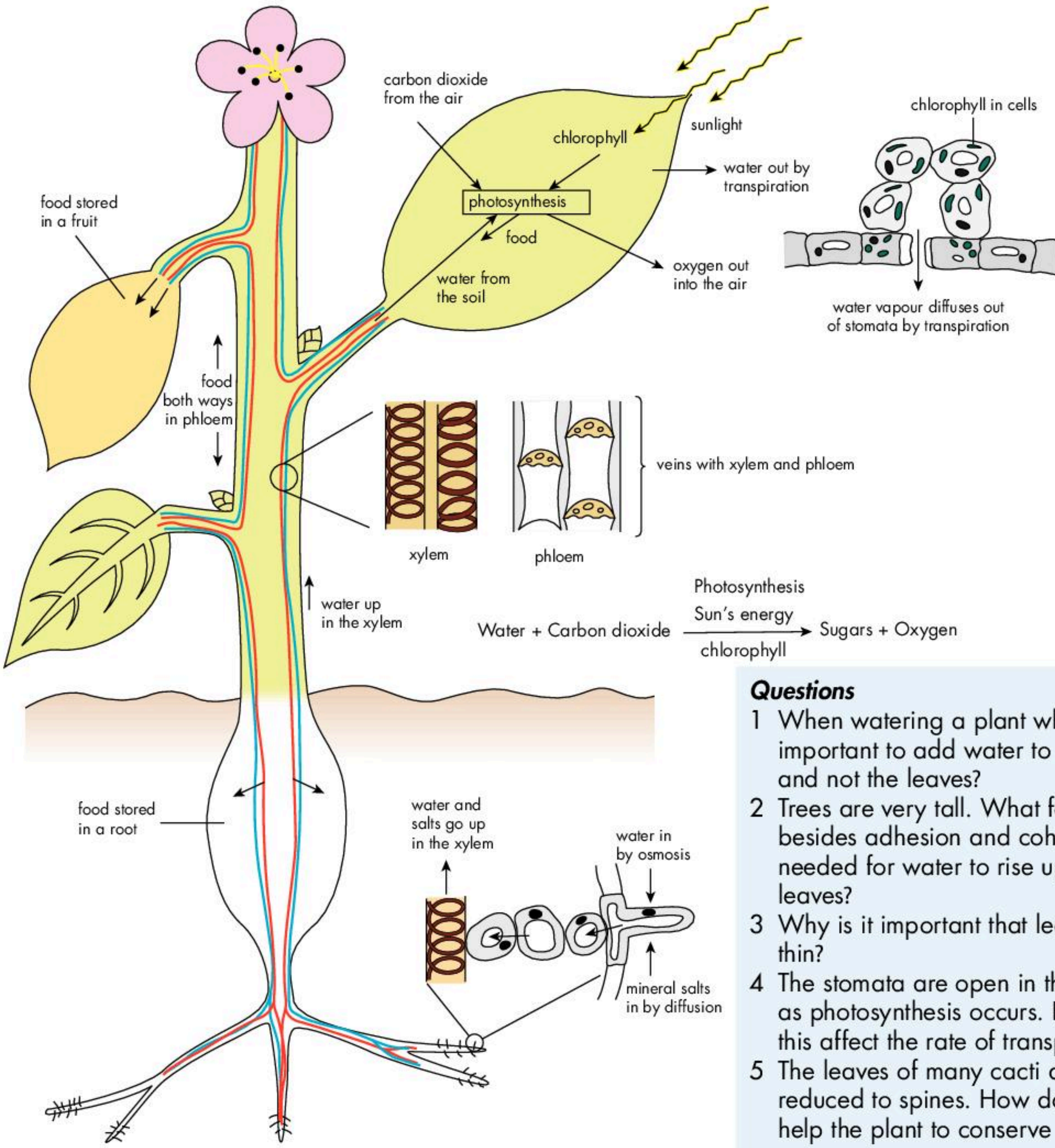
Transpiration is important

- Transpiration pull. Plants are continually losing water from their leaves. As water is lost, because the water molecules attract each other by cohesion, more water is pulled upwards. So the water in the xylem vessels is pulled up from above at the same time that it is being pushed from below. As a result, water rises up the plant.
- Evaporation. Heat energy is needed to change a liquid into a gas. When liquid water changes to water vapour inside the leaf, it takes heat from its surroundings. Transpiration therefore cools the leaf. It is a similar process to the sweating of animals.

16.22 Transpiration

Think of a factor that might affect the rate of transpiration. Make a prediction and state your hypothesis.
- Design a fair test to find out.
- Include instructions on how you will measure the rate of transpiration.

Transport system of a flowering plant



Questions

1 When watering a plant why is it important to add water to the soil and not the leaves?
2 Trees are very tall. What forces, besides adhesion and cohesion are needed for water to rise up to the leaves?
3 Why is it important that leaves are thin?
4 The stomata are open in the daytime as photosynthesis occurs. How does this affect the rate of transpiration?
5 The leaves of many cacti are reduced to spines. How does this help the plant to conserve water?

▶ **See Workbook Transport in plants.**

Quick check ☑

_________ is a special case of _________ and is the process by which water enters the plant. Flowering plants contain _________ : transports water and salts up the plant and _________ : distributes _________ around the plant. _________ is the process by which water leaves the plant.

Use these words to fill in the spaces as you write the sentences in your Exercise book.

osmosis **diffusion** **xylem** **transpiration** **food** **phloem**

Transport in humans

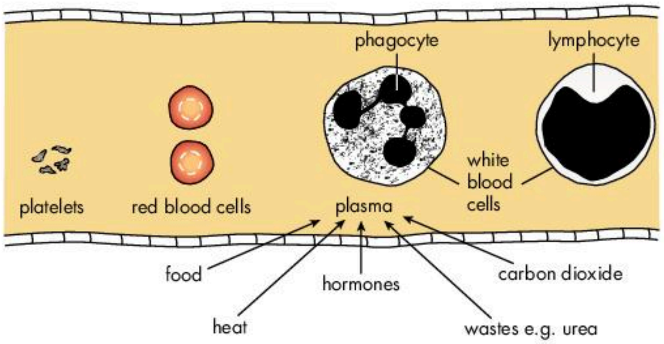
Animals are also multicellular but more active than plants. They have to move around to get food and to escape from enemies. They have more complex tissues and organs. Every cell has to be continually supplied with food and oxygen, and carbon dioxide and other waste materials taken away. A transport system of blood vessels, blood and a beating heart are needed to keep each cell supplied with what it needs.

Functions of the blood

- Picking up digested (soluble) substances from the intestines and taking them (via the liver and heart) to the cells.
- Picking up oxygen in the lungs and taking it to every cell.
- Picking up carbon dioxide from every cell and taking it dissolved in the plasma to the lungs where it is breathed out.
- Transporting chemical substances (e.g. hormones and enzymes) around the body.
- Distributing heat around the body and losing excess heat, especially by the process of sweating by the skin.
- Picking up waste from the cells and taking it to organs to be removed, e.g. urea, made in the liver, is taken to the kidneys to be excreted.
- Sealing wounds, by the formation of clots.
- Defending the body from disease organisms.

Structure of the blood

- Plasma is the liquid part. It is 90% water. It is in the plasma that all the cells and the substances are carried.
- Red cells. These are flat and hollowed in the centre. They do not have a nucleus. There is a lot of space for haemoglobin and a large surface for picking up oxygen in the lungs and carrying it to the cells.
- White cells. These are larger than red cells. They help the body fight disease organisms. Lymphocytes make antibodies and antitoxins. Phagocytes are like amoebae and they surround and digest germs.
- Platelets. These are small pieces of cells. Together with chemicals in the plasma, they help the blood to clot and seal up any small cuts. A scab forms and the skin repairs itself.



Objectives

- Identify the parts of the blood and their functions.
- Relate the structure of different blood vessels to their functions.
- Draw and label the heart and the circulatory system.
- Research selected diseases and their possible causes and prevention.

Fun facts

- An adult contains about five litres of blood; a child has half of this.
- There are about 5000 million red cells and 5 million white cells in each cubic centimetre of blood.
- A blood spot the size of a pinhead contains 5 million red cells, 8000 white cells and 350 000 platelets.
- Your heart muscles never rest. The heart beats about 100 000 times a day.

Blood doping

This is used illegally in sports. It is a method of increasing the number of red cells and therefore increasing the haemoglobin. More oxygen can be picked up, the muscles work more efficiently and the athlete achieves improved stamina and performance.

- The blood may have previously been withdrawn from the athlete and then the red cells injected again just before the race.
- Alternatively, red blood cells from another person could be injected.
- Now, genetically engineered drugs can be taken that make the body produce extra red cells.

Dangers

- The blood is thicker and clots more easily so a heart attack or stroke is more likely.
- Storage or use of other people's blood can pass on infections.

How is our blood important?

Parts of our blood are important in our fight against disease.

1 Red cells

The haemoglobin in red cells allows blood to carry 60 times more oxygen than could be dissolved in the plasma. Iron is part of the haemoglobin molecule. If there is an iron deficiency, less haemoglobin is made. The person becomes pale, tired and weak and more likely to become ill. This is called **anaemia**. A diet rich in iron is important, especially for girls and women who lose blood monthly during their periods, and for pregnant women. Good sources of iron are bread, liver, meat and green leafy vegetables.

2 Chemicals and platelets

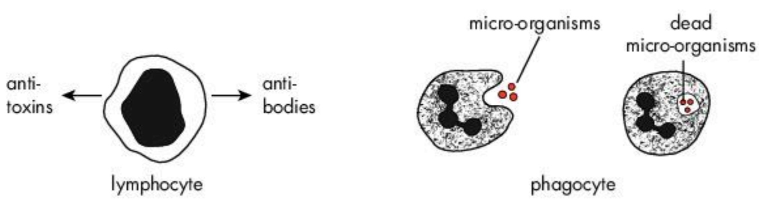
If the skin is cut, then for a few moments blood comes out. We need to wash the cut to try and stop micro-organisms getting in. After a short time a **clot** is made and the bleeding stops. Chemicals in the blood, together with platelets, make the clot to seal up the hole. A small cut can be left uncovered and a scab forms and dries. This protects the skin underneath, which repairs itself. A larger wound should be cleaned and covered, usually with the addition of an antiseptic cream.

3 Attack by the white cells

If micro-organisms get into the blood they are attacked by the immune system. This is the system made up of the white cells in the blood.

- Lymphocytes. These have a clear cytoplasm and a large nucleus. Some bacteria produce poisonous substances called **toxins**. The lymphocytes produce **antitoxins** to neutralise these, so the person does not become ill.

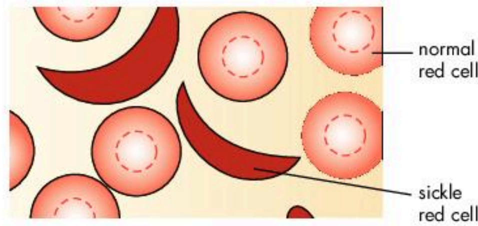
  All viruses and some bacteria have chemicals on their surfaces, called **antigens**. The lymphocytes produce corresponding **antibodies**. These make the micro-organisms clump together and they can be engulfed by other white cells. The body can make antibodies to that same kind of micro-organism much more quickly another time: you are immune to that disease. This is called **natural** immunity.
- Phagocytes. These are white cells that resemble *amoebae*. They can surround the micro-organisms and digest them.



▶ **See Workbook Transport in humans.**

Sickle cell anaemia

This is a disease of the haemoglobin. The red cells become crescent or sickle-shaped. The disease is caused by two faulty genes inherited from the parents.



The haemoglobin does not carry oxygen properly. The person is therefore weak and likely to catch infections. Afro-Caribbean and Indian people are most at risk.

ICT

- A person with sickle cell disease needs to take special care not to get cold and wet and should drink a lot of water.
- A person with only one faulty gene has sickle cell trait. They may not have any ill effects and they have an increased protection against malaria.

What else can we do?

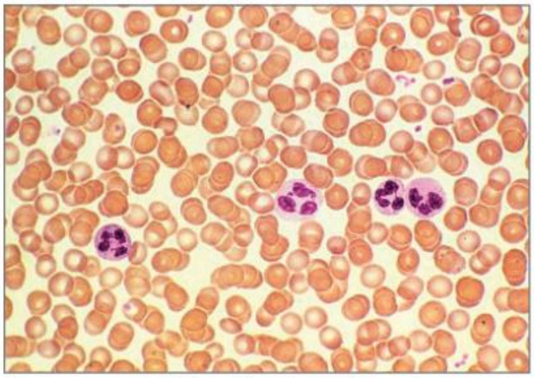
1. If we are ill and not getting better, the doctor may give us **antibiotics**. These kill bacteria but not viruses (which is why you cannot treat, e.g. a common cold with antibiotics). It is important to take the full course of pills, otherwise some bacteria will escape and may produce a resistant strain.
2. We can also be given **vaccinations**. These contain dead or harmless micro-organisms. They alert the lymphocytes to make antibodies. This is **artificial** immunity.
3. We can get help to be healthy. For example, some diabetics need to take daily insulin injections. We can also use supplements such as iron to overcome anaemia.
4. We can exercise to become fit. This improves our circulation and muscular systems so we are less likely to become ill.

16.23 Looking at blood

Materials: prepared slide of blood, microscope

Method

1 Look at the slide. Find the more numerous red cells. Describe their shape. How does this shape help them to pick up and transport oxygen?
2 Find the large white cells. Which kind is present? How does the structure of a phagocyte suit its function?
3 In what ways are an amoeba and a phagocyte (a) similar and (b) different? Why are the differences important?



Composition of the blood: 55% is plasma, 45% is made up of cells and platelets

Blood groups and blood transfusions

Not all blood is the same. There are four main blood types. These are called **A**, **B**, **AB** and **O**. People can also carry the Rhesus factor (Rh+) or not (Rh-). Each blood type contains slightly different chemicals in the plasma or on the red cells.

If a person is in an accident they may bleed. They may need to be given blood. This must be matched carefully to their own. If the wrong blood is given, it could cause blood clotting and possible death.

A **blood donor** is someone who volunteers to give blood. This can be stored by a blood bank or hospital, to be used in operations or emergencies. About half a litre of blood is taken from a vein in the arm. The donor replaces the plasma in a few hours, and the red cells in a few weeks. The blood is treated to remove any possible infections and is then stored carefully.

A **blood transfusion** is usually between similar blood groups, e.g. both patient and donor's blood could be Rh+ Group A. Blood group O blood is most useful, as it can be given to all patients. People with blood group AB can receive blood from any group.

A person donating blood

16.24 Blood groups and blood banks

Method

1 Research the differences between blood groups. ICT
2 Ask a nurse, a clinic or the blood bank for information on how they test blood and how it is made safe for use. Find out the special problems of storing blood and how this is done.
3 If possible invite a guest speaker, such as a medical person or someone from the blood bank, to come to your class. They may be able to show you how blood groups are tested.
4 Find out the problems from the past with infections, for example with the virus causing AIDS, which was given to some patients. Find out how these problems have now been solved.
5 Research the advantages and disadvantages of using artificial blood.

Artificial blood

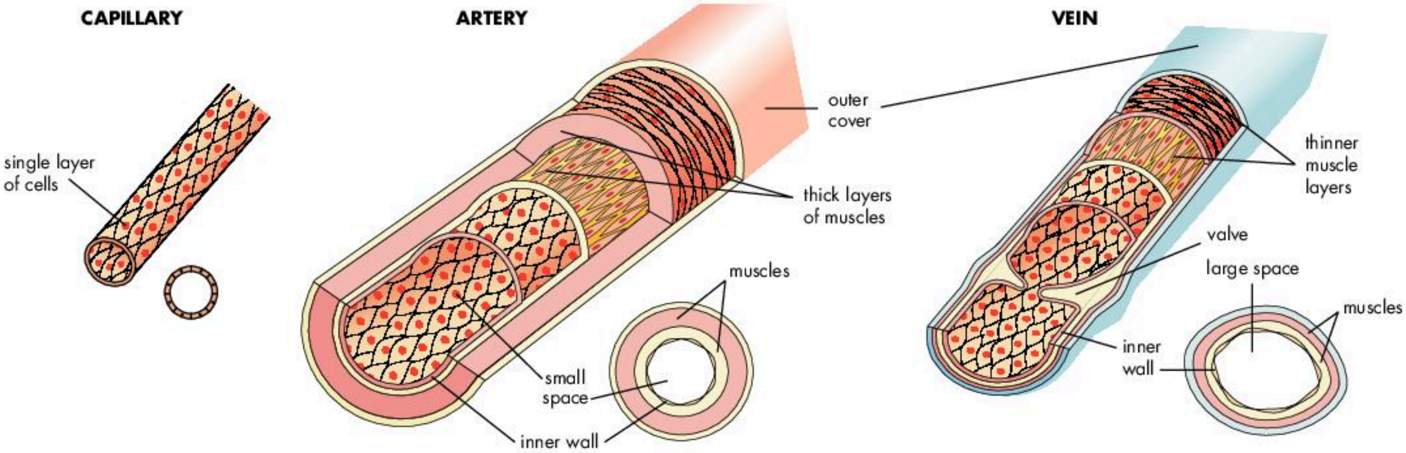
- Blood serum is blood plasma from which all the clotting factors have been removed. This can be used in some types of blood transfusions.
- A special salt or starch solution can be given as a blood substitute.
- Some artificial blood being tested contains stem cells that can grow into different blood cell types.

Bone marrow transplant

This is an operation to replace damaged or destroyed bone marrow with healthy bone marrow stem cells.

- Bone marrow is the soft, fatty tissue inside your bones that produces blood cells.
- Stem cells are immature cells in the bone marrow that give rise to all of your different blood cells.

Blood vessels



The structure of a capillary, artery and vein

Arteries carry blood away from the heart at high pressure. They therefore have thick muscular walls. Most arteries carry blood rich in oxygen. Arteries take blood to the body parts.

Capillaries are the link between arteries and veins. Capillaries are very narrow and have a wall one cell thick. Red blood cells squeeze along them in single file. Capillaries go close to every cell, taking substances to them and removing wastes.

Veins carry blood back towards the heart at low pressure. They therefore have thinner walls with less muscle. Veins also contain one-way valves to help keep the blood flowing back to the heart. Most veins contain blood rich in carbon dioxide.

Fun facts

- The length of all the arteries, veins and capillaries is about 100 000 km.
- The main artery in the body, the aorta, is about 3 cm across.
- Ten capillaries held together would be thinner than a human hair.

PS 16.25 Arteries and veins

Materials: watch with a second hand
Method

(a) Feeling the pulse

1 Blood flows through your arteries in spurts. These are caused by the beats of the heart. You feel this as a pulse. Put your first two fingers to one side of the wrist (see diagram). Push gently to feel the pulse.

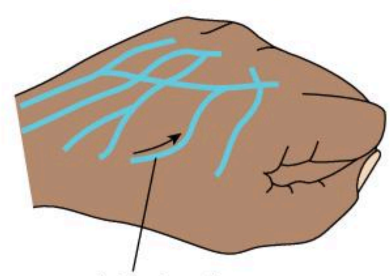
2 Record the number of beats in 30 seconds. Repeat this three times and find the average. Multiply this by two, to find the pulse rate per minute.

(b) Looking at veins

3 Lift one arm above your head and let the other hang down by your side for two minutes. Then look at the back of both hands. You should find the veins are more clearly seen on the hand that was held downwards, as it was more difficult to pump the blood back up to the heart.

4 Use two fingers to stroke blood in a vein towards your fingers (see diagram). You can 'empty' a vein so it seems to disappear. When you remove your fingers, it quickly refills.

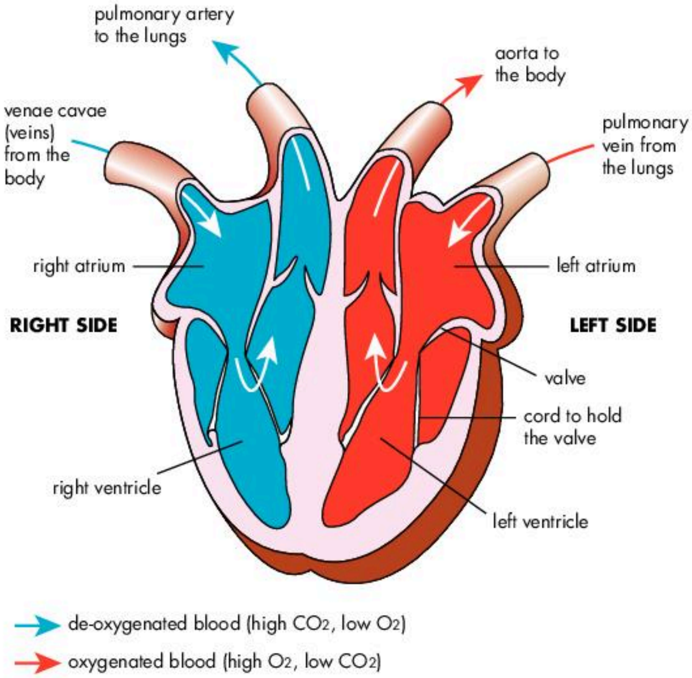
(a) Taking a pulse

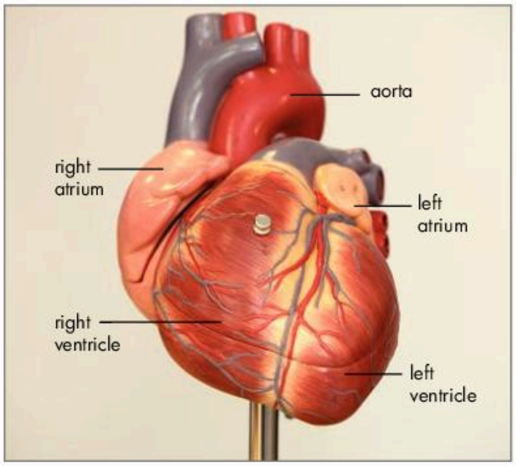


(b) Pushing blood out of veins.

▶ **See Workbook Transport in humans.**

The structure of the heart





An outside view of a human heart

How the heart works

- Blood returns to the right atrium from the body in veins. This is de-oxygenated blood. The blood has lost most of its oxygen and has picked up carbon dioxide from the cells.
- The blood is pushed from the right atrium to the right ventricle. It is pumped in the pulmonary artery to the lungs.
- In the lungs, the blood loses carbon dioxide and picks up oxygen. The oxygenated blood returns to the left atrium in the pulmonary vein.
- The blood is pushed from the left atrium to the left ventricle. It is then pumped into the aorta to go to the body.

TS 16.26 Making models

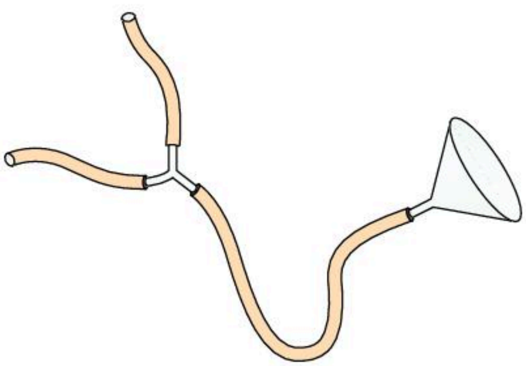
Materials: real stethoscope, rubber tubing, filter funnel, Y-glass tubing, shoe box, straws, card, scissors, sticky tape
Method
1 Use the real stethoscope to listen to your partner's heart. Place the disc near the breast, a little to the left of the centre of the chest. Move the disc around until you hear the heart.
2 You should hear two noises: lub-dub, lub-dub. These are caused by the valves closing as the heart beats.
3 Now design and make a homemade stethoscope. Use it to see if you can hear a heart beat.
4 Use the materials provided, or others of your choice, to design and make a model heart. Make it as realistic as you can. Discuss each other's models and try to improve them. Which would be the best materials to use?

PS 16.27 Heart structure

Materials: pig's or cow's heart
Method
1 Your teacher will show you the external and internal structure of a pig's or a cow's heart.
2 Identify the parts by comparison to the diagram and photograph above.
3 Annotate diagrams of the external and longitudinal sections of a heart.

Fun facts

- Your heart beats once almost every second. So blood gets right round the body every minute.
- An adult's pulse rate, at rest, is about 60–70 per minute.
- Each of the body's 600 billion cells gets fresh blood every minute.



A homemade stethoscope

The circulatory system

The circulatory system is made up of:

- the blood vessels that take blood to and from the cells, and
- the heart that pumps the blood.

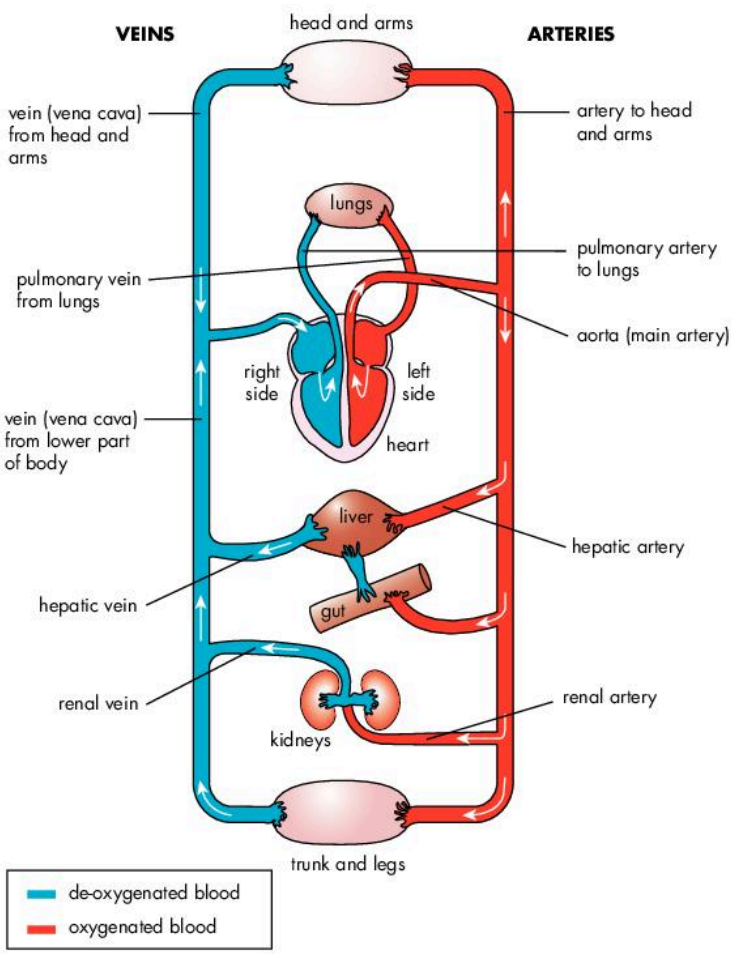
The diagram on the right shows a simple circulatory system. Blood passes *twice* through the heart on its pathway around the body. It is therefore called a **double circulation**.

Lungs These receive deoxygenated blood from the heart via the pulmonary artery. Oxygen breathed into the lungs enters the blood. Carbon dioxide, excess heat and water vapour are lost from the blood and breathed out.

Heart Oxygenated blood returns to the heart by the pulmonary vein to the left atrium. From the left ventricle it is pumped into the aorta and the arteries that take blood to the liver, alimentary canal, kidneys, trunk and legs, etc.

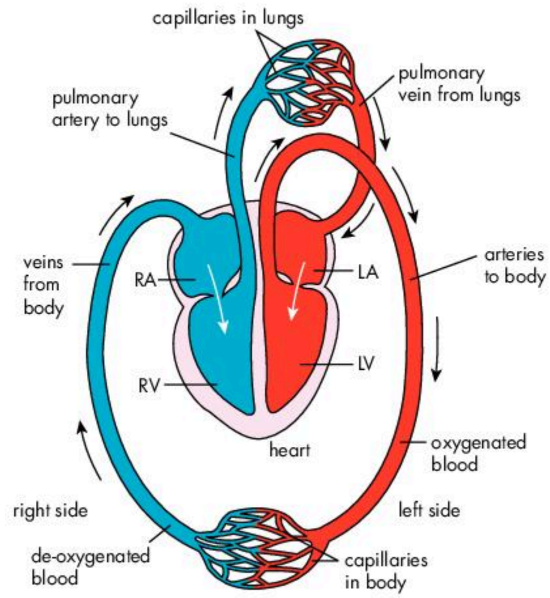
Body organs The arteries make smaller and smaller branches until they become capillaries. The capillaries take oxygen and food to every cell, and pick up carbon dioxide, wastes and heat.

Heart Veins return deoxygenated blood to the heart in the right atrium and the cycle continues.



The circulatory system

▶ **See Workbook Transport in humans.**



Simple diagram of the circulatory system

Fun facts

- Because of the central wall in the heart, it is really like two hearts. The blood does not mix.
- The atria both contract together. Then the ventricles beat to send blood to the lungs and the rest of the body.

PS 16.28 Blood circulation

Materials: cut-out shapes to represent the organs of the body, e.g. lungs, kidneys; an LS diagram of the heart, red and blue string, sticky tape, scissors

Method

1. Work on the floor or outside. Position the heart centrally.
2. Place the organs roughly where they would be in the body.
3. Use blue string to show vessels containing de-oxygenated blood. Stick these to the organs they connect.
4. Use red string to show vessels containing oxygenated blood. Stick these to the organs they connect.
5. Walk around the system, saying what happens to the blood in each organ and what happens when the heart rate increases.

Exchange of substances by the cells

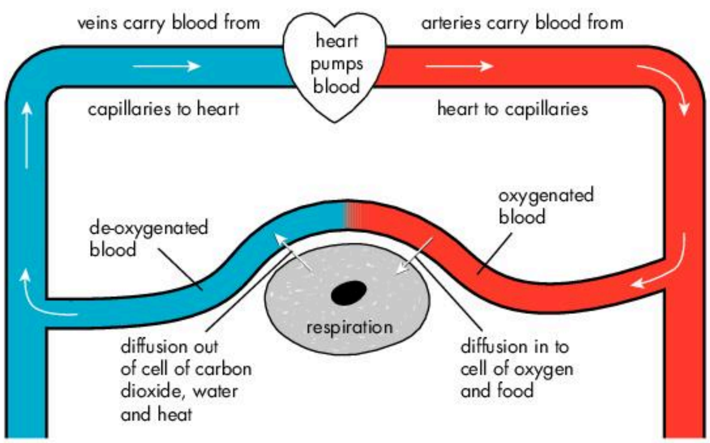
Each living cell in the body is supplied, all the time, by blood in the capillaries. Substances diffuse across the thin capillary walls along their concentration gradients.

From the capillaries the cells receive:

- Oxygen: picked up in the lungs and carried in the blood.
- Dissolved food: picked up in the villi of the small intestine.
- Other substances such as hormones and enzymes.

The cells carry out respiration and return to the capillaries:

- Carbon dioxide: to travel in the blood to the lungs.
- Other wastes: to be eventually excreted by the kidneys.
- Water: to be excreted in the kidneys, skin and lungs.
- Energy: used for life processes. Excess heat is lost from the skin and some in the air lost from the lungs.
- Any other substances, such as hormones or enzymes.



▶ See Workbook Transport in humans.

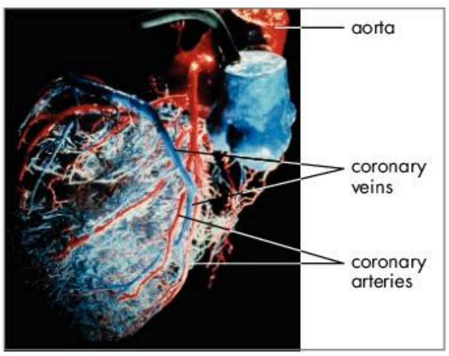
16.29 Tracing the pathways

Method

1. Use a diagram of the heart to trace the pathway of (a) de-oxygenated blood and (b) oxygenated blood through the heart. Why is it important that the heart is in two parts?
2. Use the diagram on the previous page to help you trace the following pathways. Name each vein, artery, compartment of the heart, and any other organs that the blood passes through for blood travelling:
   (a) from the head to the legs
   (b) from the intestines to the legs
   (c) from the liver and back again to the liver
   (d) from the kidneys to the liver.
3. Why can't blood go directly from the kidneys to the liver?
4. How is the blood changed in each of these organs:
   (a) the legs (b) the lungs (c) the intestines (d) the liver
   (e) the kidneys? (For example, what is lost and gained in each of the organs?)

Questions

1. How does the structure of (a) arteries, (b) capillaries and (c) veins suit them for their functions?
2. Do you expect the pressure to be greater in the capillaries or the veins? Explain why.
3. How does the structure of the (a) the atria and (b) the ventricles of the heart suit them for their functions?
4. How are valves important in (a) the veins and (b) the heart?
5. How are the heartbeat and the pulse related? Would you expect these both to increase with exercise? Why? How would you find out if they do?



How does the heart itself receive blood?

The muscles of the heart have to contract day and night throughout a person's life. They need to receive a continuous supply of blood. But the heart does not use the blood inside it for its own needs.

- Oxygenated blood is brought to the heart muscles in the coronary arteries.
- During exercise, the heart beats more quickly and receives additional blood.
- De-oxygenated blood is taken away by the coronary veins.

Research what happens if the blood supply in the coronary arteries is insufficient. ICT

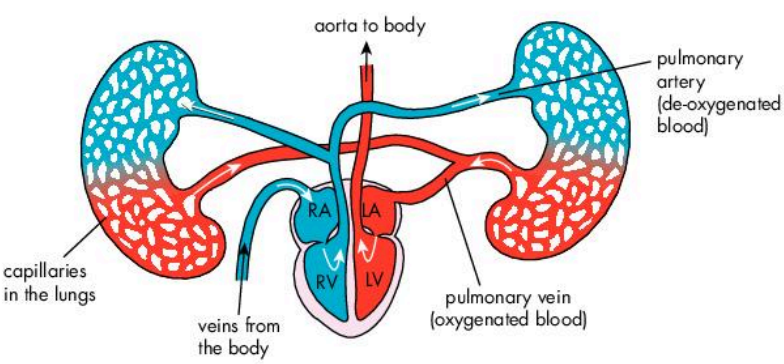
Respiration and the circulatory system

The lungs are where gas exchange occurs: the blood picks up oxygen and loses carbon dioxide.

- When we breathe in, we take in fresh supplies of air containing about 21% of oxygen and 0.03% of carbon dioxide.
- When we breathe out, the air has only about 17% of oxygen, but 4% of carbon dioxide.
- It is the blood system that links the lungs, the heart and the living cells. So oxygen is available for respiration. The products of respiration are also taken away from the cells by the blood.

How are the heart and the lungs linked?

- All arteries take blood away from the heart. Most arteries contain oxygenated blood. There is one exception: the pulmonary artery that goes from the heart to the lungs, which contains de-oxygenated blood.
- All veins take blood towards the heart. Most veins contain de-oxygenated blood. There is one exception: the pulmonary vein that goes to the heart from the lungs, which contains oxygenated blood.
- The pulmonary artery takes de-oxygenated blood to the lungs. The blood loses carbon dioxide and picks up oxygen in the alveoli. The oxygenated blood returns to the heart in the pulmonary vein.



How the heart and lungs are linked

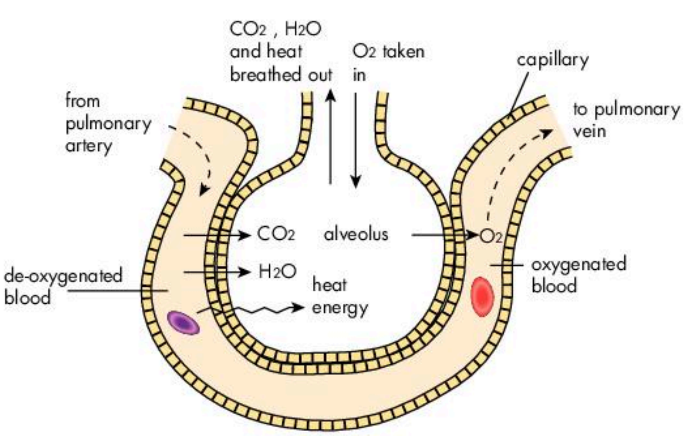


Diagram showing an alveolus and gas exchange

Fun facts

- There are 300 million alveoli in your lungs, each about 0.2 mm in diameter.
- There are more than 2000 km of blood vessels in your lungs.
- If you live to 80, you will have taken 600 million breaths.

Digestion and the circulatory system

During digestion food is broken down to produce soluble food molecules small enough to pass through the cell membranes.

- Food molecules diffuse through the wall of the villi in the small intestine, into the blood capillaries along their concentration gradients.
- The blood goes from the intestines to the liver. Here the food requirements for the body are sorted out.
- Food is sent on in the hepatic vein to the vena cava and then the heart.
- The blood is sent to the lungs where it picks up oxygen.
- When it returns to the heart it is pumped out in the aorta to the body.
- Each living cell can then receive food and oxygen along their concentration gradients.

Questions

1 (a) In which direction does blood flow in arteries? (b) What do arteries usually contain?
2 (a) In which direction does blood flow in veins? (b) What do veins usually contain?
3 What do the pulmonary arteries contain? Where do the pulmonary arteries (a) travel from (b) travel to?
4 What do the pulmonary veins contain? Where do the pulmonary veins (a) travel from (b) travel to?
5 How does the blood that goes from the lungs to the heart differ from that that travelled from the heart to the lungs?

The importance of exercise

Exercise has good effects on many parts of the body.

- **Heart and blood system:** Exercise makes the heart beat more strongly and helps to strengthen its muscles. It also improves the circulation of the blood around the body.
- **Lungs:** We breathe more deeply when we exercise, and so our lungs are strengthened. The blood takes more food and oxygen to our muscles so they can work harder.
- **Muscles:** Our muscles increase in size as we exercise. They become firm instead of flabby. They become stronger and allow us to exercise for longer.
- **Bones and joints:** With exercise the bones are strengthened and we can bend more easily at the joints. Exercise, together with a balanced diet, can keep the bones from getting thin and possibly from breaking when we get older.
- **Body mass:** Exercise helps us to use up more energy and so it can help us to keep our proper body mass and not get too fat. Exercise makes fat change into muscle. Because the muscles are strengthened, we also get into better 'shape'.
- **Reduces stress:** Exercise helps us to relax and, as lots of exercise is done outdoors, we also get fresh air and sunshine. Exercise helps the whole body to work better and helps us to relax and sleep more soundly.

What things make up fitness?

Different sports help to develop different kinds of fitness. We also need these kinds of fitness to be good at certain sports. But it is important to begin small and work up slowly. If an unfit person suddenly undertakes rigorous exercise, it could lead to a heart attack, straining of muscles, or broken bones.

- **Strength:** This is the amount of force that your muscles can exert. It can be developed, for example, by weightlifting, rowing, swimming or cycling hard, and digging in the garden.
- **Stamina:** This is what keeps you going for a long time. You need to develop a strong heart and lungs. Stamina can be developed, for example, by long-distance running, rowing, and swimming or cycling hard.
- **Suppleness:** This lets you move freely and easily. A supple person can change direction quickly and can bend, stretch and twist easily. Before beginning other exercises, people often 'warm up' by doing some bending and stretching exercises. Suppleness can be developed, for example, by gymnastics, judo, yoga and dancing.

▸ **See Workbook Transport in humans.**

Exercise

Exercise doesn't have to be an organised sport. You can exercise while walking, running, climbing stairs, gardening, or helping with the housework.

But the exercise should be:

- long enough
- hard enough
- often enough.

For example, a twenty-minute run that makes you breathe heavily and sweat, done three times each week, improves your fitness. Even walking 30 minutes a day can improve your health.

How much energy?

The table shows the amount of energy used in certain activities (in kJ/h).

Activity	Energy used
Sleeping	200
Reading / Watching TV	350
Darts / Snooker	450
Light work	600
Slow walk	1000
Gardening	1000
Cycling / Jogging	1500
Playing football	2000
Dancing (vigorous)	2000
Swimming	2200
Walking up stairs	3500

Questions

1 Make a bar chart of the information in the table. ICT
2 Which exercise is (a) best and (b) worst for all-round fitness?
3 Suggest suitable exercises for:
(a) a teenager who doesn't like sport
(b) a mother with a 2-month-old baby
(c) yourself.
4 Choose three sports. Discuss with a friend if they would be good at developing strength, stamina, or suppleness.

Diseases of the circulatory system

There are things that can go wrong with our circulatory system. Because of disease, one or more parts of the circulatory system may not function properly.

For example, **varicose veins**.

How do veins work? The veins return blood to the heart. For example, in the legs the valves direct the blood upwards. If any blood tries to flow the other way, the valves prevent it.

What are varicose veins? The valves in the veins do not meet properly (see diagram). So blood goes the wrong way. Blue, swollen veins are seen especially on the legs when standing up. The legs ache and the feet may swell.

Who is most at risk? Varicose veins are more common in women and in people who stand still a lot or who are very tall or fat.

What can be done for people with varicose veins? When sitting down, the legs can be raised to help circulation. Support stockings can also be worn. Varicose veins are a nuisance but not usually dangerous. They can also be operated on.

For example, **high blood pressure** (hypertension)

What is normal blood pressure? Doctors take two readings: systolic (as the ventricles contract to pump out blood) and diastolic (as the heart relaxes to take blood into the atria). A healthy young adult has a systolic pressure of about 110 and diastolic of 75. This is recorded as 110 over 75.

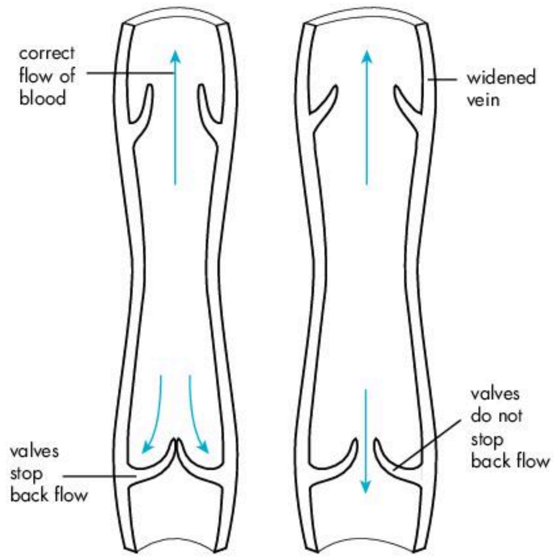
What is it? Blood pressure increases with age (130 over 90 may be normal for a 60-year-old). High blood pressure would be more than 150 over 100.

Cause: This includes the narrowing of the arteries due to fatty deposits (see diagram) and hardening of the arteries. Both of these make it more difficult for the heart to pump blood around the body.

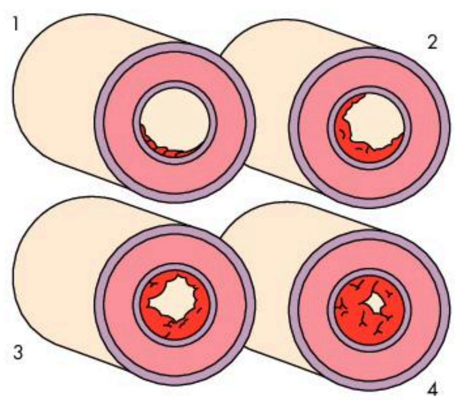
Symptoms: A person rarely knows when they have high blood pressure. It is therefore important to have your blood pressure taken at least every six months. This can prevent the pressure getting worse and causing other problems.

What can be done for people with high blood pressure? Exercise can help. There are also drugs such as diuretics, ace-inhibiters and statins that are prescribed by doctors.

Are there any other dangers? Untreated high blood pressure means that a **stroke** is four times more likely. This is when a blood clot blocks a narrowed artery to the brain. This cuts off its blood supply. If a large area is affected, the person may die. In other cases there may be loss of speech or of strength in the limbs. With treatment some of these problems can be overcome as other parts of the brain become activated.



Normal veins *Varicose veins*



A healthy artery (1) becomes 'furred-up' (2) & (3). It can become so narrow (4) that it can be blocked by a blood clot. Narrowing of the arteries is called atherosclerosis. Hardening of the arteries is arteriosclerosis

Questions

1 Explain how the normal functions of veins and arteries are upset to cause
(a) varicose veins and
(b) high blood pressure.

2 Prepare questions about problems with the circulatory system you would like to ask. Try to arrange for a nurse or doctor to come to class to answer them.

3 High blood pressure, diabetes and sickle cell anaemia all contribute to having a stroke. Research the reasons for this. ICT

Diseases of the circulatory system (cont.)

For example, **angina** and **heart attack**.

What is angina? Angina is not a disease, but is a symptom of a problem with the heart muscles. The pain is felt near the heart and may spread, especially to the left arm.

Cause: The coronary arteries have become narrowed. This means that not enough blood flows through them to the heart muscles. It often appears during exercise (when the heart needs extra blood) and goes away when the exercise stops.

Who is most at risk? People who smoke, are overweight or under a lot of stress. There are various self-help measures (see the next page).

What can be done for people with angina? One treatment is to reduce the heart's need for oxygen, by taking drugs such as beta-blockers. Another treatment is to use a pill that widens the coronary arteries so the muscles receive more blood.

What is a heart attack? The heart ceases to function properly. About one in three heart attacks can cause death.

Cause: Usually a clot in the coronary arteries. This reduces or blocks the flow of blood to part of the heart muscle.

Symptoms There is a heavy pressure in the centre of the chest spreading to the shoulders and arms. It can be for a few minutes and then return, or be a continuous pain for many minutes. The person may be faint or short of breath.

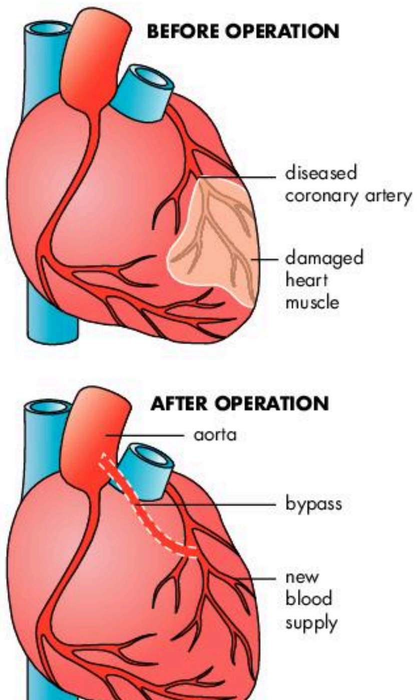
What can be done for people with a heart attack? A heart attack is a medical emergency. Treatment must be started as soon as possible. Most deaths occur in the first few minutes or hours. If a person survives those, the outlook is good.

Are there any other dangers? Yes, for example if a person has a heart attack while driving a car, there can be an accident. If the underlying cause is not treated, there may be another heart attack.

What about heart operations? A dye can be injected into the coronary arteries. On an X-ray, this will show where the arteries are narrowed or blocked. A coronary artery bypass operation can then be done. A piece of vein is taken from the patient's leg. This is attached to the aorta and used to bypass the damaged artery (see diagram).

What are other heart problems? The valves inside the heart may be damaged. This means that blood does not flow properly. It is possible for artificial valves to be put into the heart.

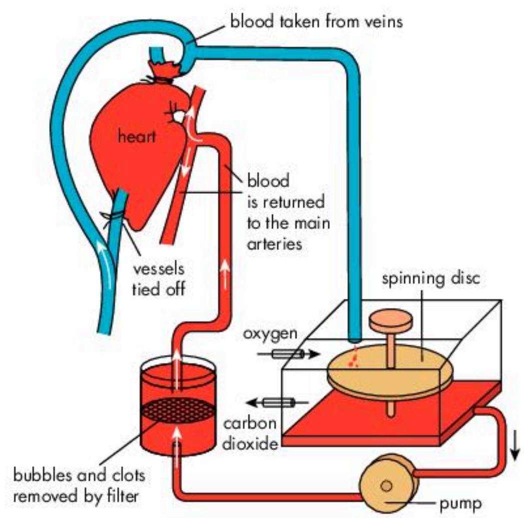
A healthy heart keeps a regular rate of heartbeat. If a person's heart cannot keep a steady pace, they may need an operation. An artificial pacemaker is fitted in the chest. This produces a supply of electricity to keep the heartbeat steady.



The heart before and after a bypass operation

Questions

1 What are the effects of some of the diseases of the circulatory system on the individual, family and society?
2 Visit, or request a speaker from, the Heart Foundation of Jamaica. Report on their work. ICT
3 Plan and design a 'working' model of the heart or circulatory system.



During an operation, the heart has to be stopped. A machine takes over the functions of the heart and lungs.

How to reduce circulatory problems

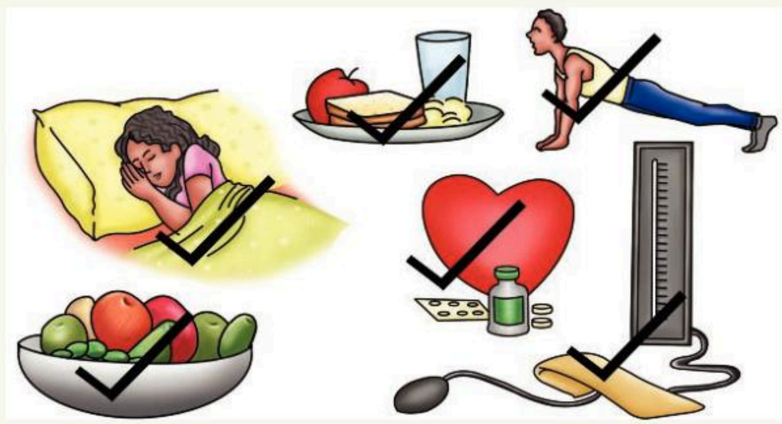
Some problems, such as inherited diseases or problems that run in the family, cannot be avoided. But we can still do a lot to reduce the likelihood of getting diseases of the circulatory system, or of reducing their effects. Our health and our life is our own responsibility.

▶ **See Workbook Transport in humans.**

Questions

1 Talk to your family and other adults about the Do and Don't hints.
2 In your class, prepare an illustrated chart of how to reduce the chance of suffering from circulatory problems.

Deficiency diseases	Inherited diseases	Parasitic diseases
• Do eat a diet rich in natural sources of vitamins and minerals • Do check out any unexplained tiredness. • Do have blood transfusions if these are essential.	• Do understand your disease and its effects. • Do follow instructions on how to reduce its effects. • Do, if necessary, have genetic counselling.	• Do take precautions against the parasites or the vectors that transfer them. • Do behave in a sexually responsible way, to avoid sexually transmitted infections.

Diseases of function	
• Do eat a balanced diet and avoid excess weight. • Do take regular exercise. • Do avoid stress and have regular sleep. • If you are a diabetic, control your blood sugar level by injections. • Do check your blood pressure regularly and take any necessary medicines to reduce it. • Do check your cholesterol level and take any necessary medicines to reduce it. • Do take medicines that have been prescribed for you. • Do take notice of warning signs, and take action.	
• Don't smoke, it can damage your arteries. • Don't eat too much salty food, it can raise your blood pressure. • Don't eat too much saturated animal fat. It can become cholesterol and help to fur-up your arteries. Take medicines if necessary. • Don't overeat. Excess weight puts a strain on the heart.	

Quick check ☑

Red cells transport _________; _________ is dissolved in the plasma. _________ blood returns from the body in veins to the _________ atrium of the heart. Blood leaves from the _________ ventricle into the aorta. We can exercise and eat a healthy diet to try and avoid _________ diseases.

Use these words to fill in the spaces as you write the sentences in your Exercise book.

right **de-oxygenated** **oxygen**
carbon dioxide **circulatory** **left**

Questions

Answer these questions in your notebook

For questions **1–35** answer **A**, **B**, **C** or **D**.

1 The particles of which of these would diffuse the quickest?
A liquid **B** solid
C gas **D** solution

2 Particles diffuse
A from an area where they are in higher concentration to an area of lower concentration
B from an area of lower concentration to an area of higher concentration
C against their concentration gradient
D only when they are in solution

3 What is the final result when a crystal is placed in water?
A the crystal remains at the bottom of the container
B water remains at the top of the container
C the crystal particles evaporate into the air
D the water and crystal particles become evenly mixed up

4 Which is the BEST definition of osmosis?
A diffusion of particles along their concentration gradients
B diffusion of water along its concentration gradient
C diffusion of water that occurs in plants only
D diffusion of water along its concentration gradient through a partially permeable membrane

5 When raisins are placed in water they change
A in appearance only
B in texture only
C in size only
D all of the above

6 The cause of what happens in Question **5** is
A diffusion **B** osmosis
C dehydration **D** all of the above

7 The structure in the living cell mainly responsible for what happens in Question **5** is the
A cell wall **B** cytoplasm
C cell membrane **D** nucleus

8 An amoeba can depend on diffusion for its needs because
A it is like an animal
B it lives in water
C it has a high surface area to its volume
D it has a high volume to its surface area

9 The reduction of leaves to spines in cacti has which of the following results?
A reduction in photosynthesis
B reduction in transpiration
C increase in protection for the plant
D all of the above

10 Which of these things is important for a water plant?
A a long tap root
B a lot of small roots
C big leaves that float
D small leaves like spines

11 How does water enter a root? By
A root push **B** osmosis
C diffusion **D** transpiration

12 How do mineral salts enter a root? By
A root push **B** osmosis
C diffusion **D** transpiration

13 How do root cells get food?
A from the phloem
B from the xylem
C they make their own
D all of the above

14 What is transported in the xylem of flowering plants?
A water only **B** water and salts
C carbon dioxide **D** oxygen

15 Which statement is NOT correct?
A water goes up a plant in the xylem
B water goes down the plant in the xylem
C food goes up a plant in the phloem
D food goes down the plant in the phloem

16 How does transpiration help the plant?
A it cools the plant
B it pulls up water from below
C it gets rid of excess water
D all of the above

17 The liquid part of the blood is
A plasma **B** pure water
C urine **D** haemoglobin

18 Which of the following produces antibodies?
A lymphocytes **B** phagocytes
C red cells **D** plasma

19 Which blood group can give blood to all other groups?
A group A **B** group B
C group AB **D** group O

20 What would be the result if the wrong blood group was given in a transfusion?
A no problem **B** clotting
C anaemia **D** sickle cell anaemia

21 Why can red blood cells transport oxygen?
A they have haemoglobin
B they have a large surface
C they have large nuclei
D they have haemoglobin and a large surface

22 Which blood vessels take blood away from the heart?
A capillaries **B** veins
C arteries **D** all of the above

23 Which kind of blood vessel contains blood at the highest pressure?
A capillaries **B** veins
C arteries **D** all of the above

24 How many chambers are in the heart?
A 4 **B** 3
C 2 **D** 1

25 Which heart chamber receives blood from the lungs? The
A right atrium **B** left atrium
C right ventricle **D** left ventricle

26 Which blood vessel has oxygenated blood?
A pulmonary artery **B** pulmonary vein
C vena cava **D** renal vein

27 What prevents blood flowing the wrong way in veins?
A valves **B** blood pressure
C the pulse **D** muscular wall

28 Blood from the intestines goes first to the
A heart **B** lungs
C liver **D** kidneys

29 What changes occur to the blood in the lungs?
A carbon dioxide and water are removed and oxygen added
B oxygen and water are removed and carbon dioxide added
C oxygenated blood changes to de-oxygenated blood
D the blood picks up food

30 Anaemia is caused by a lack of which of these in the diet?
A iodine **B** iron
C haemoglobin **D** amino acids

31 A varicose vein is likely to be
A the same size as an ordinary vein
B narrower than an ordinary vein
C wider than an ordinary vein
D narrower or the same as an ordinary vein

32 What is angina?
A a heart attack **B** a kind of stroke
C a heart disease **D** a pain

33 Atherosclerosis is
A narrowing of the arteries
B hardening of the arteries
C another name for a heart attack
D another name for a stroke

34 Which of these is used during a bypass operation?
A dialysis machine **B** heart-lung machine
C kidney filter **D** all of the above

35 Which things reduce the chance of having a problem with our circulatory system? Not
A eating too much **B** having stress
C smoking **D** all of the above

For questions **36–51** write the answers in your notebook.

36 Define (a) diffusion and (b) osmosis.

37 List all the places in the plant and human where (a) diffusion and (b) osmosis occur.

38 Why don't single-celled organisms need a transport system? How do they get rid of wastes?

39 List and explain the processes involved in taking in water and its transport to the leaves.

40 How are (a) salts and (b) food transported in a plant?

41 Describe what enters and leaves a leaf (a) in the daytime and (b) at night.

42 How is evaporation important to (a) plants and (b) animals?

43 How are blood groups important when giving blood transfusions?

44 (a) Name the four parts of the blood and give their functions. (b) For one part, describe how its structure suits it for its function(s).

45 (a) What is the pulse? (b) How does it vary at rest, immediately after exercise and a few minutes after exercise? Explain the differences.

46 Explain why (a) there is a wall down the centre of the heart (b) the atria only have thin walls and (c) the muscles of the left ventricle are thicker than those of the right ventricle.

47 How can you listen to the heartbeat? What exactly do you hear?

48 What is (a) oxygenated blood, (b) name two vessels that contain it.

49 How are the vena cava and the aorta different in structure, and direction and type of blood?

50 Draw a cell and a capillary. Show how the cell receives and gets rid of substances.

51 Write six hints for a healthy heart.

Key ideas

- Diffusion is the continual movement of particles from areas of higher to lower concentration.
- Osmosis is the net movement of water along its concentration gradient through a partially or selectively permeable membrane such as the cell membrane.
- Unicellular organisms can supply their needs and get rid of wastes by diffusion.
- Multicellular organisms, such as plants and animals, need a transport system.
- Plants take in water (by osmosis) and salts (by diffusion) through their roots and these are transported up in the xylem.
- The water is pushed up from below (root push) and pulled up from above (transpiration pull).
- Food that is made is transported up and down the plant in the phloem.
- Oxygen and carbon dioxide diffuse in and out, and water vapour diffuses out of the leaves.
- The blood plasma transports food, carbon dioxide, heat, hormones and wastes, such as urea.
- Red cells with haemoglobin transport oxygen.
- White cells (lymphocytes and phagocytes) help defend the body against micro-organisms.
- There are four main blood groups: A, B, AB and O.
- The structure of the blood vessels (arteries, capillaries and veins) suit them for their functions.
- Arteries have thick muscular walls and take blood away from the heart.
- Veins have thinner walls and valves. They take blood from the organs back to the heart.
- Capillaries have walls one cell thick and take substances to and from each individual cell.
- The heart has four chambers.
- The right atrium receives de-oxygenated blood from the body in the venae cavae.
- The right ventricle pumps de-oxygenated blood to the lungs in the pulmonary artery.
- The left atrium receives oxygenated blood from the lungs in the pulmonary vein.
- The left ventricle pumps oxygenated blood to the body in the aorta.
- Each organ receives blood with oxygen and food from an artery and returns blood with wastes, such as carbon dioxide, water and heat to a vein.
- The lungs add oxygen and the intestines add food to the blood.
- Some important functional diseases are high blood pressure and heart attacks.
- There are measures we can take to reduce the likelihood of diseases of the circulatory system.

▶ **See Workbook Transport in living things.**

Problems

1 Work in a group: (a) Recap the work you did on the structure of plant cells. Research and discuss how a root hair cell is similar to and different from a typical plant cell. ICT
   (b) Brainstorm in your group suitable materials you could use to represent each kind of structure in a root hair cell model.
   (c) Follow the steps of the Engineering design process to Engage, Explore, Elaborate, Execute, Explain and Evaluate.

2 Work in a group: (a) Research and discuss how a xylem vessel is similar to and different from a root hair cell. ICT
   (b) Identify all of the structures and make a large labelled drawing.
   (d) Follow the steps of the Engineering design process to make a model of a xylem vessel.

3 Work in a group: (a) Research structures of arteries, veins and capillaries. ICT
   (b) Make large labelled drawings to show the structure of an artery, vein and capillary and annotate to say why each structure is important for its functions.
   (c) Brainstorm suitable materials you could use to represent each kind of vessel.
   (d) Make models following the steps of the Engineering design process.

4 Work in a group: (a) Look again at the model of a human heart your group made and point out any major problems.
   (b) Discuss if you can improve your model using the Engineering design process.
   (c) Make your new model.

Unit 17

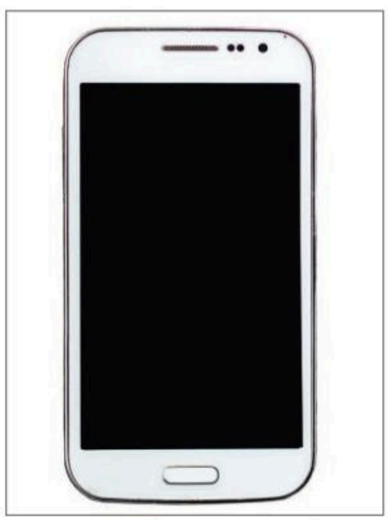
Electricity and magnetism

1 *Hunts Bay Power Station. Electricity is transferred in the wires at a high voltage.*

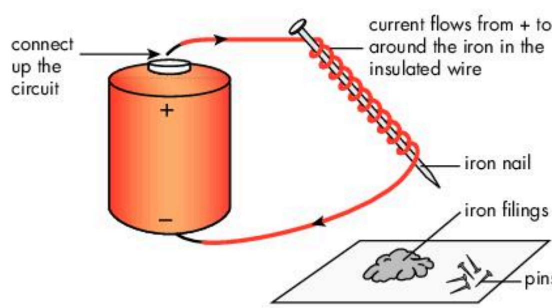
This unit will help you to:

- demonstrate static electricity and describe its uses and hazards
- classify insulators and conductors of electricity
- investigate series and parallel circuits
- investigate the relationship between voltage and current
- describe the uses and costs of electricity in the home
- prepare and practise rules for the safe use of electricity
- investigate magnets and their uses
- make electromagnets and describe their uses.

2 *What energy changes occur as electricity is used to boil the water?*



3 *A smart phone uses radio waves and electronic circuits to receive and respond to information.*



4 *When current passes through the wire wrapped around the nail, the nail becomes a temporary magnet. It can attract the iron filings and pins.*

Static electricity

Electricity is a flow of electric charges. Static electricity is electricity at rest. Static electricity is a build-up of electric charges on the surface of non-metal materials.

You will remember that an atom has three kinds of particle:

- Neutral neutrons and positively charged protons: these are in the nucleus and give it a positive charge.
- Negatively charged electrons surrounding the nucleus.

The atoms and material have an overall neutral charge.

Electrons can move from atoms if they are given some energy. Static electricity can be produced by vigorously rubbing two different dry non-metals together. The rubbing action produces friction. Friction provides energy and causes negatively charged electrons to transfer from one material to the other and build up on the surface. This causes the following:

- The material that gains electrons becomes temporarily negatively charged.
- The material that loses electrons becomes temporarily positively charged.

Note it is only the electrons that can move. The protons are tightly held in the nucleus and cannot move.

17.1 Investigating static electricity

Materials: plastic pen, woollen cloth, small pieces of paper, balloon, thread

Method

Try to do this activity on a dry day.

1 Carry out the activities in small groups.
   (a) Place a plastic pen near your partner's hair. What happens?
   Rub the pen vigorously with a woollen cloth and try again. What happens?
   (b) Tear a piece of tissue paper into very small pieces. Place a plastic pen near the pieces. What happens? Rub the pen with the woollen cloth and try again. Record and explain what happens.
   (c) Blow up a balloon and tie the neck with thread. Place it near a wall and release it. What happens? Rub the balloon with the woollen cloth. Hold the balloon near the wall and release it. Record and explain what happens.

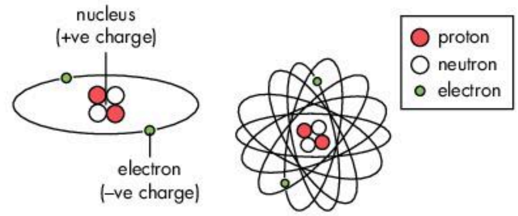
2 Look at all your results. In which cases was there attraction after you had rubbed the materials together?

Explanation: For example, the plastic pen becomes negatively charged. When this is brought close to small pieces of paper the negative charges repel electrons close to the paper's surface, which becomes positively charged. This is called **induction**. Then the negative pen can attract the positive paper.

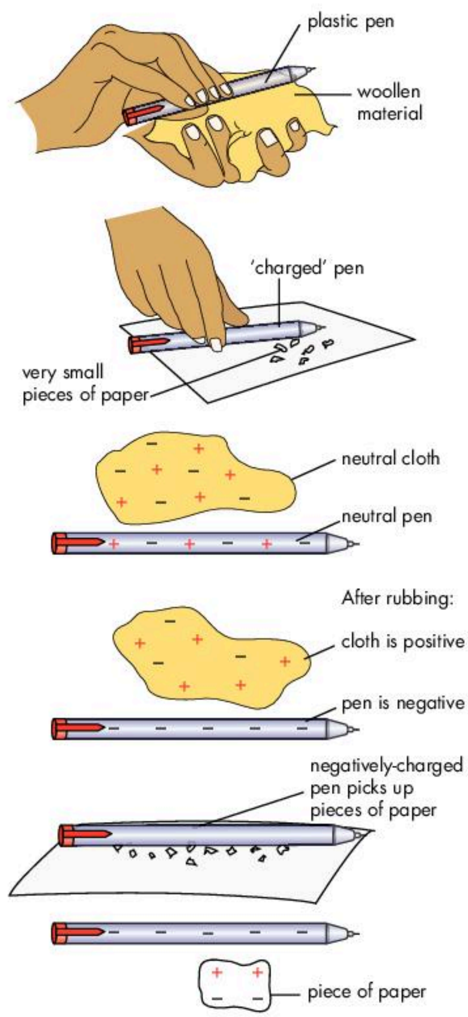
▶ **See Workbook Static electricity.**

Objectives

- Describe and show how static electricity can be produced.
- Outline some uses and hazards of static electricity.



Atom showing +ve and –ve charges



The wool and pen start with equal numbers of (–) and (+) charges: they are both neutral. Rubbing removes some (–) electrons from the wool to the pen. So the wool becomes (+) and the pen becomes (–). The pen then induces charge in the pieces of paper and can pick them up.

17.2 More static electricity

Materials: plastic pen, woollen cloth, plastic spoon, cotton cloth, metal spoon

Method

1 Carry out the activities in small groups on a dry day.
- (a) Turn on a tap so there is gentle flow of water (not droplets). Rub a plastic pen on the woollen cloth. Then slowly move the pen towards the stream of water (without touching it). Suggest reasons for what happens.
- (b) Place a plastic spoon close to some very small pieces of tissue paper. What happens? Rub the spoon vigorously with a cotton cloth and try again. What happens? Why?
- (c) Place a metal spoon close to some very small pieces of tissue paper. What happens? Rub the spoon vigorously with a cotton cloth and try again. What happens? Why?

2 In which cases was there attraction?

Explanation: For (a) and (b) your results are similar to those in the previous activity. Charge is built up on the rubbed object and this induces a charge in the stream of water or pieces of paper, leading to attraction.

In (c), a metal was used. Metals are good conductors of charge and so no charge can be built up on their surface. So a rubbed metal spoon cannot pick up the small pieces of paper.

Some effects of static electricity

Attracting. For example, clothes made of different materials cling together after having been dried in a spin dryer where they received opposite charges.

Repelling. If you charged up two rods with the same charge, you would find they repel (push each other apart).

Producing crackles. For example, when a woollen jumper is pulled over a nylon shirt, they both become charged. There may be crackles and sparks as the static electricity discharges (flows away). This is similar to what happens during a storm with lightning.

Small electric shock. As a car drives along on a hot, dry day, the air drags away some electrons. This leaves the car with a positive charge. When you touch the car, the electricity flows through you and you feel a small tingle. This is like a small electric shock, but it is not dangerous.

Lightning. Ice particles in a cloud become positively charged as they rub against each other. When they fall as rain, they leave the bottom of the cloud with a negative charge. This can build up until a certain point. Then large numbers of electrons jump to the Earth and you get a flash of lightning. If lightning flows through a person it can kill them.

Dealing with static electricity

- Factories using flammable materials. A small spark can cause an explosion. Workers have to wear special shoes and clothes that don't build up charges.
- Large vehicles. Vehicles that transport flammable materials have a chain at the back. This is in contact with the road. If any static electricity builds up on the vehicle, it is discharged safely to the ground.
- Vehicles on the road and planes in the air can build up static electricity on their surfaces. When they refuel, there is a danger of an explosion. To avoid this, special chains or cables are used to let the charge flow away.
- Lightning. If you have to go out in a storm wear rubber shoes to help insulate you against lightning.
- Lightning conductor. This is a metal rod running down the side of a tall building. If lightning strikes, the charge flows down the conductor and does not harm the building. Metal is used because it is a good conductor of charge.

A flash of lightning is an enormous flow of electrons lasting only one millionth of a second

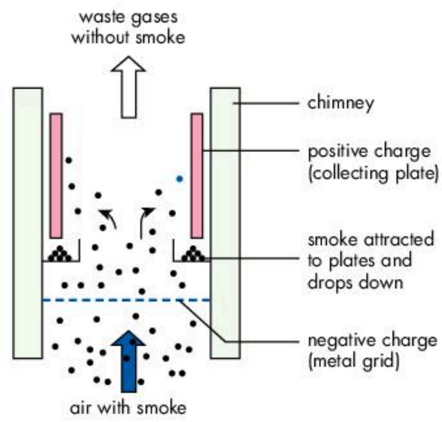
Questions

1 There has been an explosion in an operating theatre. Explain what the cause might be.

2 Ms Lee felt a small tingle when touching the car frame when leaving a taxi. Why might this be?

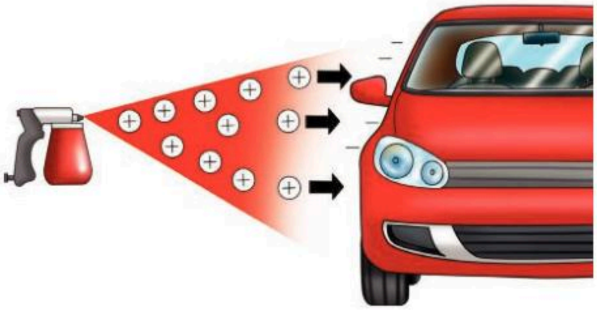
Uses of static electricity

Removing smoke particles. Smoke is produced in factories and power stations. The smoke is led into tall chimneys where it is given a negative charge. As it passes up the chimneys it is then attracted to plates that have been given a positive charge. In this way the smoke particles are removed from the air leaving the factory or power station.



The negatively charged smoke particles are attracted to the positively charged collecting plates and removed from the air

Painting cars. On an assembly line, the car body is given a negative charge and the paint is given a positive charge. As the paint is sprayed, the droplets repel each other (same charge) as they are attracted to the car body (opposite charges). This gives a very evenly painted surface.

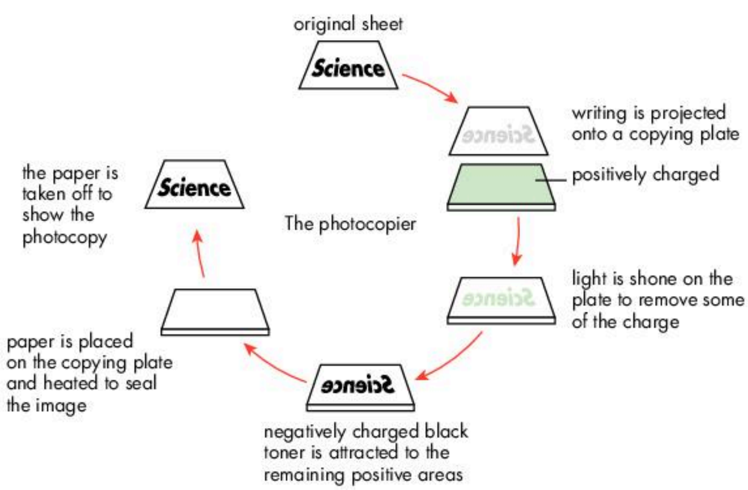


On an assembly line, positively charged paint is sprayed to evenly cover the negatively charged car.

Crop spraying. Insecticides are sprayed from aircraft. But the spray could blow away or fall unevenly. To help prevent this, the spray is given a charge as it leaves the aircraft. So the spray particles repel each other and fall evenly to the earth.

Defibrillator. This is used to give a patient a controlled electric shock to get the heart back into a regular rhythm. There are two well-insulated paddles that are used to pass a high-voltage current through the patient's chest.

Photocopiers. These can use static electricity. The ink is given a charge so that it sticks to the parts of the paper corresponding to the object to be copied. This is then sealed to the paper by a heater (see diagram below). A colour copier builds up the picture using layers of different colours.



Questions

1 Why can non-metals but not metals be given a surface charge? Explain your answer using labelled diagrams.
2 (a) What effect would a charged rod have on small pieces of paper?
(b) Explain your answer.
3 Describe (a) two hazards and (b) three uses of static electricity.
4 How does the electric eel give people a shock? ICT

Quick check ☑

_________ electricity is caused by _________ between two dry, _________ materials. Electrons pass from one material (which becomes _________ charged) to another (which becomes _________ charged). A sudden release of charge can cause sparks, electric shock and _________.

Use these words to fill in the spaces as you write the sentences in your Exercise book.

non-conducting **static** **friction**
negatively **lightning** **positively**

Electrical circuits

In the previous section, you found out what happens when there is flash of lightning. The charge that has built up on the underside of clouds is rapidly discharged to earth. This flow of charge is similar to what happens in an **electrical circuit**.

An **electric current** is the flow of charge around a complete circuit. This charge is often carried by electrons moving in an insulated wire. But it can also be carried by ions, when electricity flows though a solution. To make the current flow, we need an electrical cell (dry cell) to push the electrons and materials to conduct the electricity. In the circuit we also place something like a bulb, which is called a **resistance**, where the electrical energy can be changed to other forms such as heat and light.

17.3 Making a circuit

Materials: D size dry cell (1.5 V), two 12 cm insulated wires, a bulb, scissors, ruler, a flashlight provided by your teacher
Method
Work in small groups:

1 Carefully cut away about 1.5 cm of insulation from the ends of each piece of wire. Cut the insulation, but not the wire.
2 Explore various ways in which you can arrange the items and make the bulb light.
3 If the bulb does not light, check these possible reasons:
   - the connections are not secure (current will not flow if there is not a complete circuit),
   - the dry cell may be flat (its chemicals, which interact to produce electricity, have been exhausted),
   - the bulb is 'blown' (look carefully inside the bulb to see if the metal wire has broken).
4 Identify any faults. Check with your teacher and try other materials to make your circuit.
5 Make a drawing of how you have arranged the items in your circuit.
6 Look at the circuit symbols in the box on the right. Use the symbols to make a circuit diagram.
7 Your teacher has prepared a flashlight for each group to examine. There is something wrong with some parts of the circuit.
   (a) Examine the parts of the flashlight and discuss how it should work.
   (b) Make any adjustments you think are necessary and see if the flashlight can work.
   (c) Repeat step (b) until you get the light to shine. Write a report on what was wrong with the flashlight.

▶ **See Workbook Electrical circuits.**

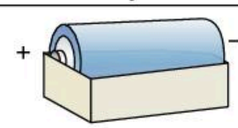
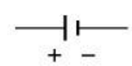
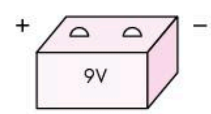
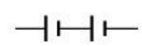
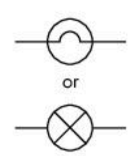
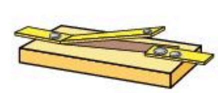
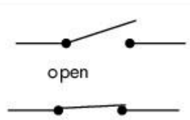
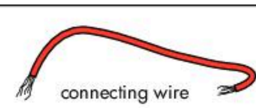
Objectives

- Define electricity as a flow of charge through a circuit.
- Identify insulators and conductors.
- Construct series and parallel circuits and show them using symbols.
- Investigate the relationship between voltage and current.
- Describe and practise rules for the safe use of electricity.
- Describe the uses and cost of electricity in the home.

Fun facts

- Metals and graphite can conduct electricity because they have electrons that are free to move.
- Most non-metals are insulators: they do not allow electricity to pass through them. They are used as insulation on the outside of wires.

Circuit symbols

Component	Symbol
 dry cell	
 battery	
 bulb	
 switch	
 connecting wire	

17.4 Switches

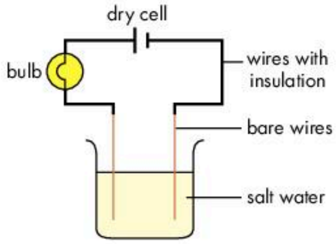
Materials: dry cell, dry cell holder, insulated wires, scissors, bulb, bulb holder, switch

Method

Work in small groups:

1. Carefully use the scissors to remove about 1.5 cm from the ends of all the insulated wires.
2. Screw the bulb into the bulb holder and put the dry cell into its holder. Set up your circuit as in the last activity so that the bulb lights.
3. Your teacher will show you how to connect a switch into the circuit. How does a switch work? How does it control the flow of current in a circuit?
4. ICT Investigate around the home and online to identify electrical devices and places where there are switches to control circuits. Also consider the use of switches in everyday electronic equipment.
5. Discuss in your group how to design your own switch made from simple materials. When it is finished, make it part of your circuit and check that it works.

Students setting up a circuit



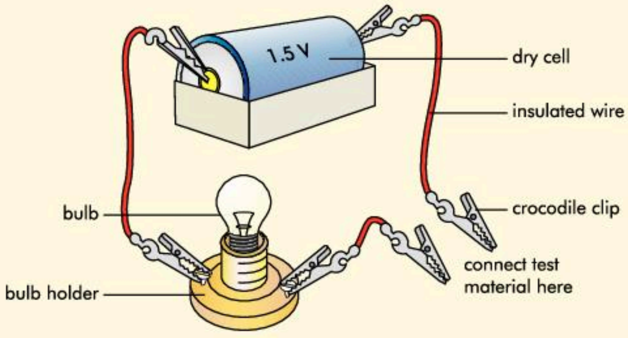
Water containing an ionic substance can conduct electricity

17.5 Conductors and insulators

Materials: dry cell, insulated wire, scissors, bulb, bulb holder, crocodile clips, paper, brass screw, aluminium foil, plastic spoon, cloth, iron nail, glass, copper wire, wooden match, rubber band, carbon rod (graphite) from inside a pencil, distilled water, salt water

Method

1. Use a set-up as shown below. This is a 'tester'.



2. Put each of the materials into the circuit in turn. What will happen if the material is (a) a conductor or (b) an insulator? Why?
3. Collect other solid materials and also test them.
4. For testing the liquids put the bare ends of the wires into the liquids but do not let them touch each other.
5. Collect other liquids and also test them.
6. Make a table of your results and write your report.

▸ **See Workbook Electrical circuits.**

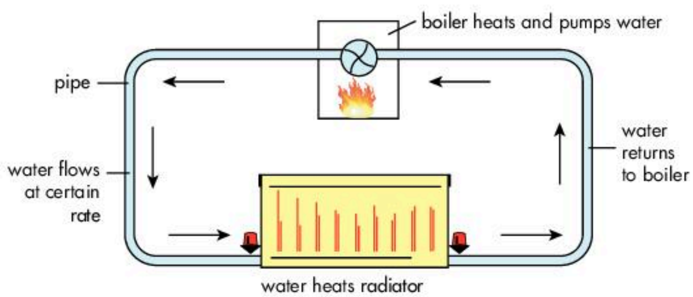
Conductors

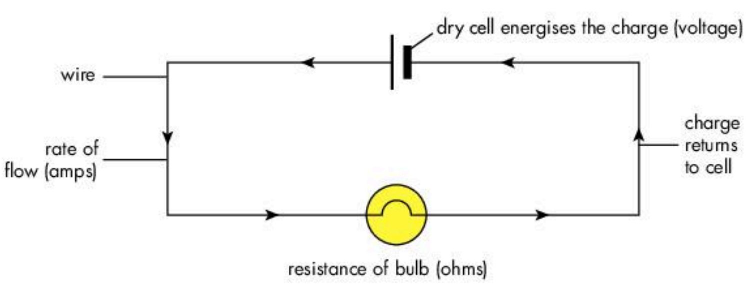
- Electricity can be conducted by electrons and ions.
- Solid metals and graphite are conductors because their electrons can move.
- Non-metals are insulators because their electrons cannot move.
- Solid ionic compounds, e.g. sodium chloride, do not have free-moving electrons or ions and are not conductors.
- Molten (melted) ionic compounds have ions that move and they can conduct electricity.
- Pure (distilled) water is not a conductor.
- When salt is added to water, both the salt and water form ions and the solution conducts electricity: it is called an **electrolyte**.
- The passing of electricity through an electrolyte causes it to breakdown: this is called **electrolysis**.

Describing an electrical circuit

We can compare an electrical circuit to water heated in a boiler and flowing around through pipes and taking heat to a radiator.

- There is a *boiler and pump* that heats up the water and pushes it around the pipes. This is like the *dry cell* that energises the electrons and pushes them around the circuit. The push with which it does this is called the *voltage*.
- The water flows through the pipes. These are like the connecting *wires* through which the electricity flows.
- Depending on how hard the boiler pushes, there will be a certain rate of flow of the water. In a similar way, depending on how hard the dry cell pushes, the electrons will flow at a certain *rate* in the circuit. The rate at which the charge flows is measured in *amperes* or *amps*. One ampere (1 A) is a flow of over 6 million, million, million electrons per second (6.25×10^{18}).
- When the water comes to the radiator it has to push its way through and some of its energy is transferred into heat. When the electric current reaches a bulb, the wire is thinner and *resists* the flow. Energy is transferred into heat and light. The resistance of the bulb is measured in *ohms*.
- The water transfers its heat at the radiator. The cooler water has to return to the boiler to be heated and pumped round again. The electrons lose their 'oomph' as they go round the circuit and return to the dry cell to be re-energised.





Comparison table

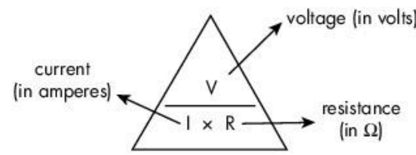
Read again through the account above and set up and fill in a table to compare the water heating system in a house to an electrical circuit. List and explain (a) the similarities between them and (b) the differences.

Fun facts

- The cell used in a flashlight, pushes the electrons around with an electrical pressure (voltage) of 1.5 volts.
- A battery is made up of several cells. We can add together their voltages to find their total 'push'.

Current, voltage and resistance

- Current (I) is the rate of flow of electrons. It is measured in amperes (A) using an appliance called an ammeter.
- Voltage (V) is the difference in electrical pressure between two points. It is measured in volts (V) using an appliance called a voltmeter.
- Resistance (R) is the force opposing the flow of current. It is measured in ohms (Ω).



$V = IR$, $R = V/I$ and $I = V/R$.

17.6 Different circuits

Materials: D size dry cell, dry cell holder, four 12 cm insulated wires, scissors, two bulbs in holders, a switch

Method

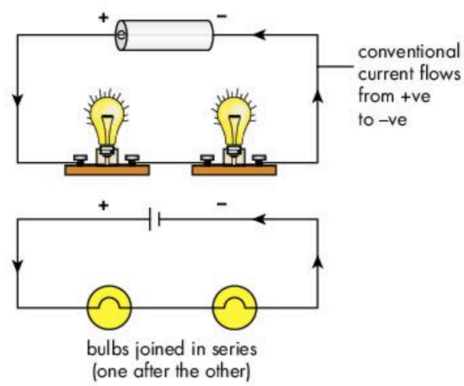
Work in small groups.

1. The challenge is to set up circuits in more than one way so that both the bulbs light up. Discuss what you will do and make some sketches, then, set up your circuits.
2. Draw your two circuits using circuit symbols.
3. Can you place a switch in one of your circuits so that one bulb will be alight while the other goes out?
4. Try out your plan and draw the circuit.
5. What happens when you use a switch in the other circuit?

Series circuits

In a series circuit:

- the bulbs are joined one after another
- the current has only one path it can take
- the current (in amps) is the same all around the circuit. We can measure the flow of current using an ammeter.
- the electrical energy (voltage) has to be shared between the bulbs as the current has only one path to take. We can measure the voltage across a cell, battery or bulb using a voltmeter.



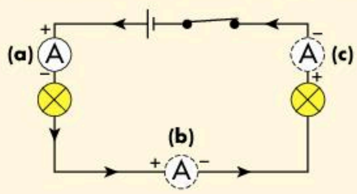
A series circuit

17.7 Using an ammeter

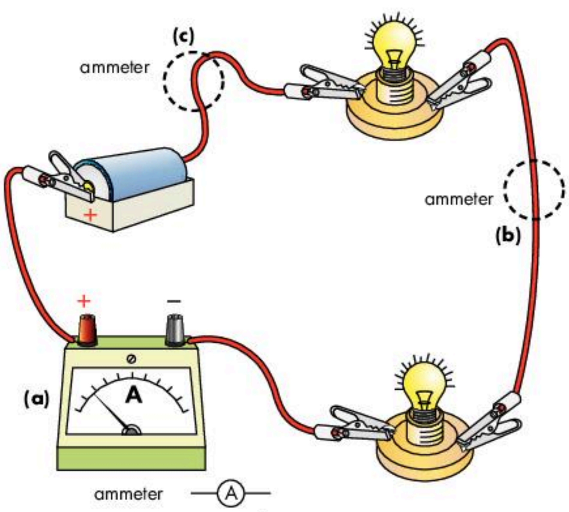
Materials: cell, two bulbs, ammeter, connecting wires, switch

Method

1. Set up a series circuit with a cell and two bulbs.
2. Connect an ammeter into the circuit (its symbol is an A inside a circle). An ammeter is connected in series with its red + terminal connected towards the + terminal of the cell.



3. Use the ammeter to record the reading at position **(a)**.
4. Disconnect the ammeter and put it in at different points **(b)** and **(c)**.
5. From your results what can you say about the amount of current at different places around a series circuit?



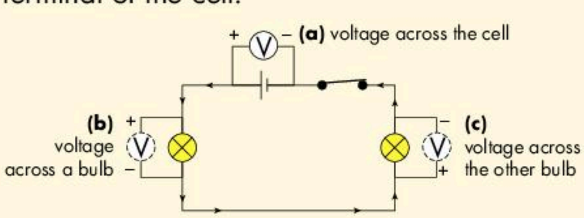
Using an ammeter with a series circuit

17.8 Using a voltmeter

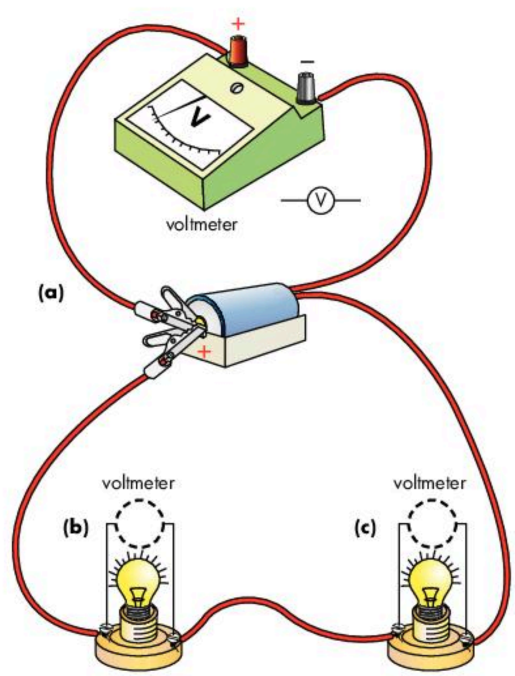
Materials: cell, two bulbs, voltmeter, connecting wires, switch

Method

1. Set up a series circuit with a cell and two bulbs.
2. Connect a voltmeter into the circuit (its symbol is a V inside a circle). A voltmeter is connected across a component with its red + terminal connected towards the + terminal of the cell.



3. Use the voltmeter to record the voltage across the cell **(a)**.
4. Disconnect the voltmeter and record the voltage across each bulb at points **(b)** and **(c)**.
5. From your results what can you say about the voltage across different components in a series circuit?



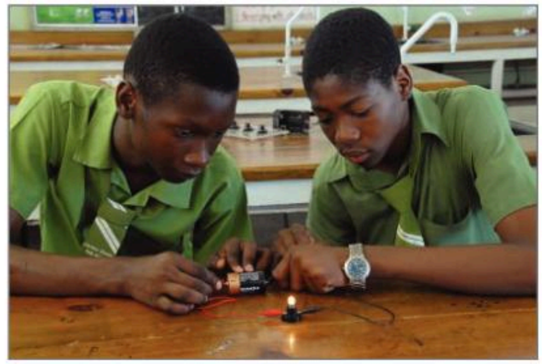
Using a voltmeter with a series circuit

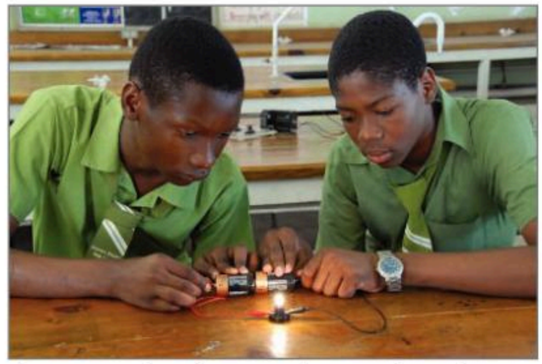
17.9 Adding bulbs or cells to a series circuit

Materials: cells, bulbs, connecting wires
Method
You are first going to add more cells to your circuit.
1 Begin with a circuit with one cell and one bulb (see the top photograph on the right).
2 Now connect two cells in series with the bulb. You can use a bulb holder, or just hold the cells together (as shown in the lower photograph on the right).
3 Record how bright the bulb is with one and with two cells.

Now you are going to add more bulbs in series.
4 Begin again with one cell and one bulb.
5 Now add another bulb into the circuit in series.
6 How does the brightness of the bulbs compare with one bulb and then with two in the series circuit?
7 How can you explain your results?

▶ **See Workbook Series circuits.**


A circuit with one cell with one bulb


A circuit with a battery of two cells, with one bulb. Compare the brightness of the bulb to the one in the photograph above.

Using series circuits

Advantages We use a series circuit when all the bulbs need to be lit at the same time, for example the decorations on a Christmas tree. In this case the bulbs do not need to be very bright and the circuit is not very expensive to run. The bulbs can all be turned off using one switch. The bulbs are either all on (switch closed) or all off (switch open).
Disadvantages If one of the bulbs breaks, then all the bulbs go out, as the current has only one path to follow. We could not use this kind of circuit for house lights, because we need to be able to turn these on and off independently.

Some more characteristics of a series circuit:

- the current has the same value all around the circuit
- if one bulb is removed, no bulbs can light because the circuit has been broken
- all the bulbs can be turned off by a single switch anywhere in the circuit
- the current goes down each time an extra bulb is added
- the bulbs get dimmer each time an extra bulb is added
- the bulbs get brighter each time an extra cell is added.

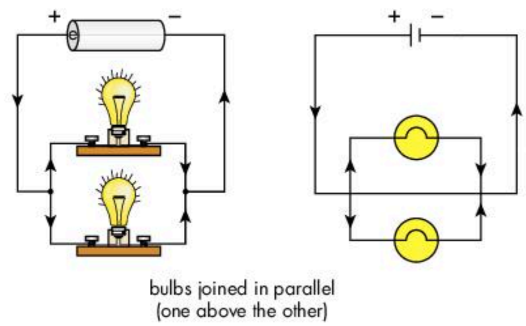
Questions
1 Draw a series circuit with two cells and three bulbs. What would be the effect on the brightness of the bulbs of adding another cell in series? Draw the new circuit diagram.
2 Draw a circuit diagram of a cell and a closed switch connected to two bulbs in series, with a voltmeter connected across one of the bulbs. What does the voltmeter measure?


We use a series circuit to light the bulbs on a Christmas tree

Parallel circuits

In a parallel circuit:

- the bulbs are separated on different paths
- the current has a choice of paths it can take
- the current (in amps) divides to go to the separate paths. It is not the same around the circuit
- the electrical energy (voltage) can be used fully by each of the bulbs as each one has its own connection to the cell.



A parallel circuit

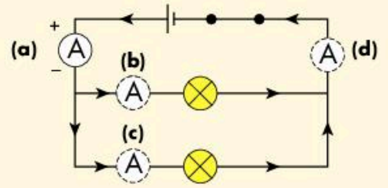
17.10 Using an ammeter

Materials: cell, two bulbs, ammeter, connecting wires, switch

Method

1 Set up a parallel circuit with a cell and two bulbs.

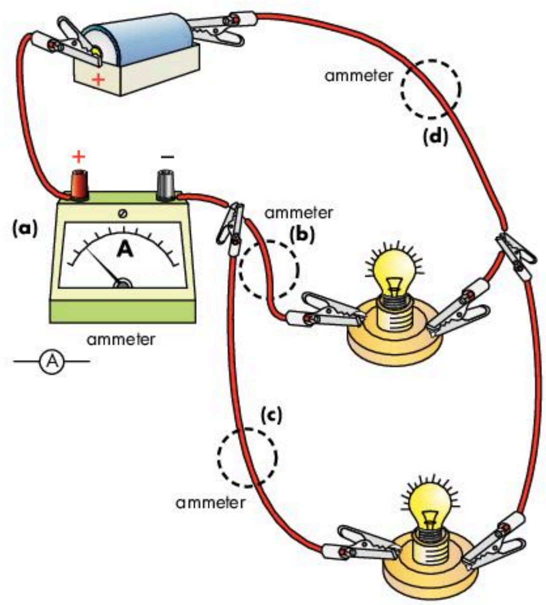
2 Connect an ammeter into the circuit. An ammeter is connected in series with its red + terminal connected towards the + terminal of the cell.



3 Use the ammeter to record the reading at position **(a)**.

4 Disconnect the ammeter and put it in at different points **(b)**, **(c)** and **(d)**.

5 From your results what can you say about the amount of current at different places around a parallel circuit?



Using an ammeter with a parallel circuit

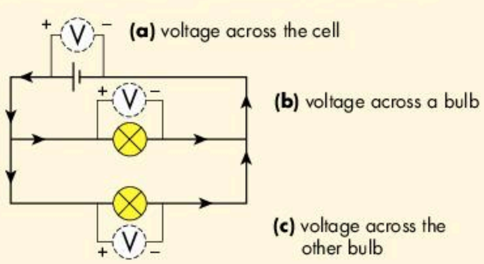
17.11 Using a voltmeter

Materials: cell, two bulbs, voltmeter, connecting wires, switch

Method

1 Set up a parallel circuit with a cell and two bulbs.

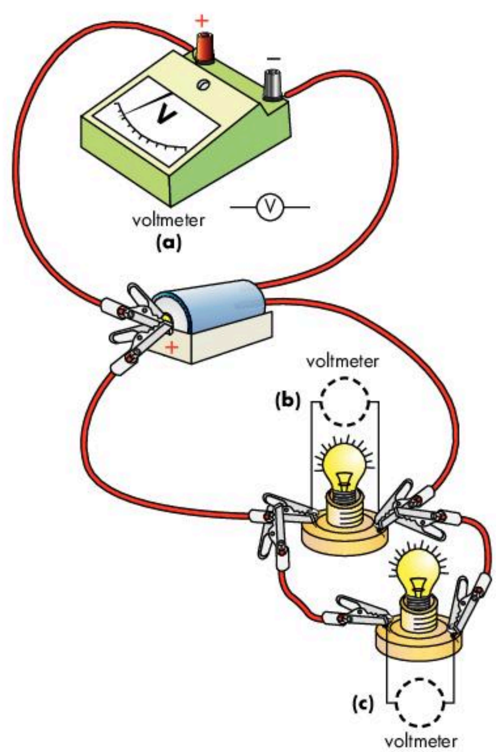
2 Connect a voltmeter into the circuit. A voltmeter is connected across a component with its red + terminal connected towards the + terminal of the cell.



3 Use the voltmeter to record the voltage across the cell **(a)**.

4 Disconnect the voltmeter and record the voltage across each bulb at points **(b)** and **(c)**.

5 From your results what can you say about the voltage across different components in a parallel circuit?



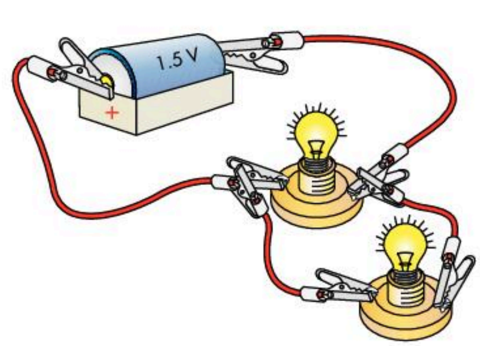
Using a voltmeter with a parallel circuit

17.12 Adding bulbs or cells to a parallel circuit

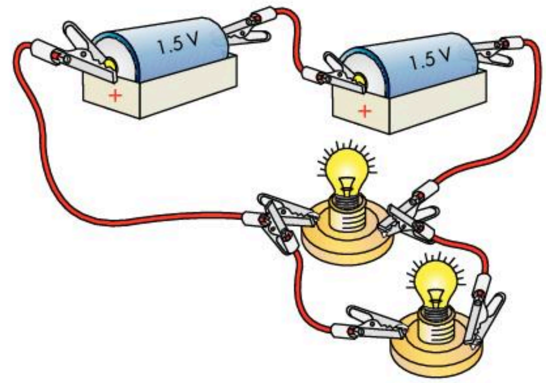
Materials: cells, bulbs, connecting wires
Method
Begin with the parallel circuit shown on the top right.
First add another cell into your circuit.
1 Add another similar cell into your circuit (in series with the first one as shown in the second diagram).
2 Record how bright the bulbs are with one and two cells.

Now add another bulb into your circuit.
3 Begin again with one cell and two bulbs.
4 Now add another bulb into the circuit in parallel (as in the third diagram).
5 How does the brightness of the bulbs compare with two bulbs and then with three in the parallel circuit?
6 Draw circuit diagrams of all the circuits.
7 How can you explain your results?

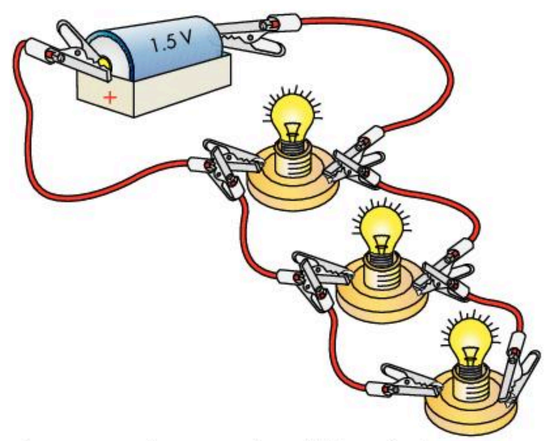
▶ **See Workbook Parallel circuits.**



A circuit with one cell and two bulbs



A circuit with a battery of two cells, with two bulbs



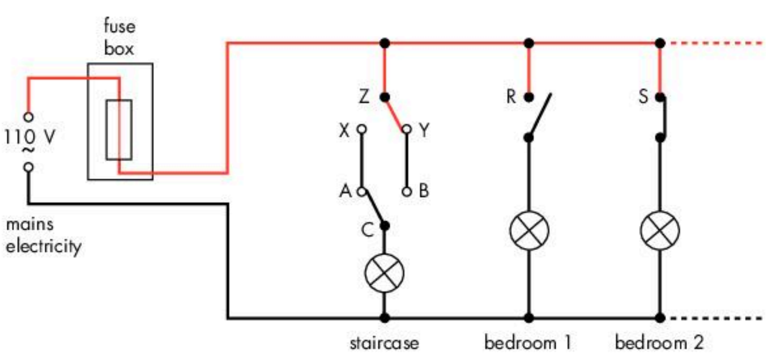
A circuit with one cell and three bulbs

Using parallel circuits

Advantages We use a parallel circuit when we want to be able to switch bulbs on or off independently, for example, the lights in a house (see the diagram below). Each light has its own connection to the source of electricity. If one bulb breaks, the other bulbs are not affected.
Disadvantages The circuit is more expensive to run than a series circuit, but the bulbs are brighter.

Some more characteristics of a parallel circuit:

- the current can have different values in different parts of the circuit
- if one bulb is removed, the other bulbs will still be lit because they have their own connections to the cell
- switches can be put into the circuit to turn on or off only some of the bulbs
- extra current is drawn from the cell each time an extra bulb is added in parallel
- the bulbs stay bright even when extra bulbs are added
- the bulbs get brighter each time an extra cell is added.



Part of the mains circuit for wiring a house

Questions
1 In the mains circuit on the left, which of the bulbs is lit? How do you know?
2 If the bulb in Bedroom 1 was broken, could the other bulbs still work? Explain your answer.
3 On the staircase there is a two-way switch. At the bottom of the stairs **(C)**, the light can be switched on by moving the switch from **(A)** to **(B)**. How can the light be switched off from the top of the stairs?

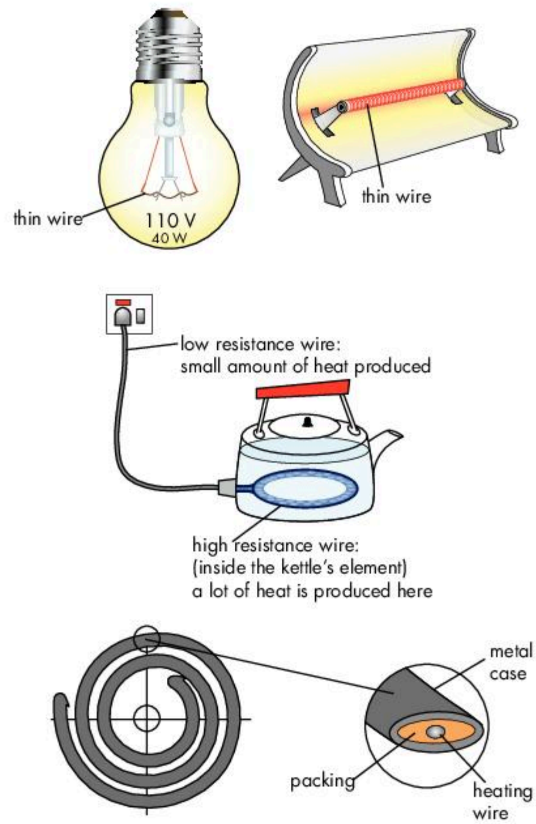
The importance of resistance

Heat is a by-product of electric currents. Several appliances we use depend upon electrical energy being changed to heat. The heat is then used to do work.

As the current goes around the circuit it flows through wires of different kinds and thicknesses. A thin wire, such as that in a light bulb, will have a high **resistance** to the current. As the electrons are forced through this wire they heat it up until it glows white-hot.

Electrical energy is also changed to heat energy in the elements of a radiant heater and in a kettle, and in the heating wires inside the rings on an electric stove.

We can use a variable resistor in a circuit to find out how changing the resistance affects the current. A variable resistor is also called a **rheostat**.



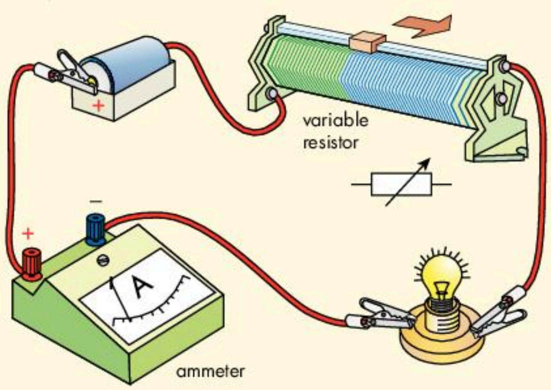
Thin wires change electricity to heat because of their high resistance

17.13 Using a variable resistor

Materials: dry cell, insulated wire, bulb, variable resistor

Method

1 Arrange the components as shown below. (Connect the ammeter so its + terminal is closest to the + of the cell.)
2 Make a circuit diagram of your set up. The symbol for a variable resistor is a rectangle with an arrow across it (see below).



3 The current goes through only one part of the variable resistor. On the diagram, is this: the green or the blue part?
4 What happens when the slider is moved to the right on the diagram? Try it. Then explain why it happens.
5 What happens when the slider is moved to the left on the diagram? Try it. Then explain why it happens.

How does the variable resistor work to make more or less wire part of the circuit? What is the effect of increasing the amount of wire on (a) the brightness of the bulb and (b) the reading on the ammeter? Discuss in your group and research online and then suggest uses for a variable resistor and write an account of your findings. ICT

Using variable resistors

- When the variable resistor has a high resistance, less current can flow through the bulb and it is dimmer.
- When the variable resistor has a lower resistance, more current can flow through the bulb and it is brighter.
- A variable resistor is used in a lighting circuit at home, or e.g. in the theatre, to dim or brighten the lights.
- It is also used in the tuning button on a radio or TV to lower or raise the sound.

Questions

1 How are the three characteristics of an electrical circuit: current, voltage and resistance, related to each other?
2 What are the main differences between series and parallel circuits? Give an example where each would be used.

You will now investigate the relationship between voltage and current, and how the resistance of constantan wire and a torch bulb are different. A variable resistor is used to vary the current through the test material and records are made of the current and the corresponding voltages across it. You will take several readings, plotting the graphs of voltage against current and explain your results.

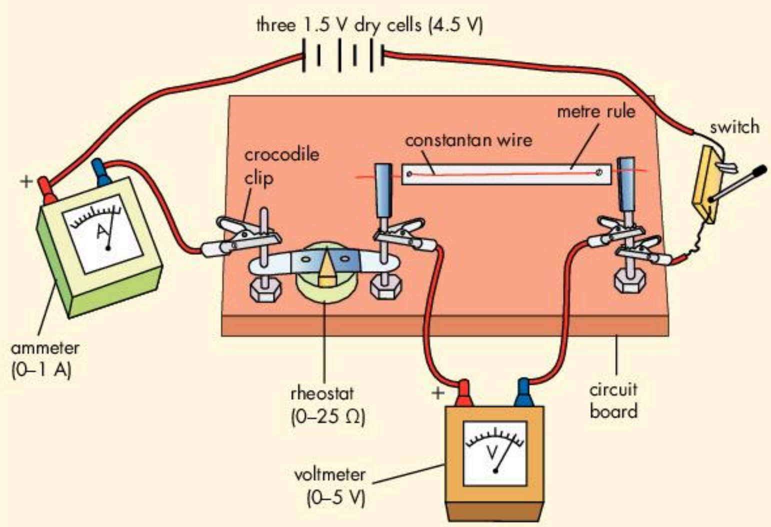
17.14 Relation between voltage and current

Materials: three 1.5 V dry cells in series, a one-metre long resistance wire S.W.G 34 constantan, metre rule, two thumb tacks, variable resistor (rheostat), six connecting wires, four crocodile clips, voltmeter, ammeter, switch, a torch bulb

Method

Work in groups:

1 Attach the resistance wire along the metre rule and secure its ends with the thumb tacks. Leave one centimetre free at each end for making connections.
2 Use the components you have been given to set up the circuit as shown below and draw a circuit diagram using symbols.

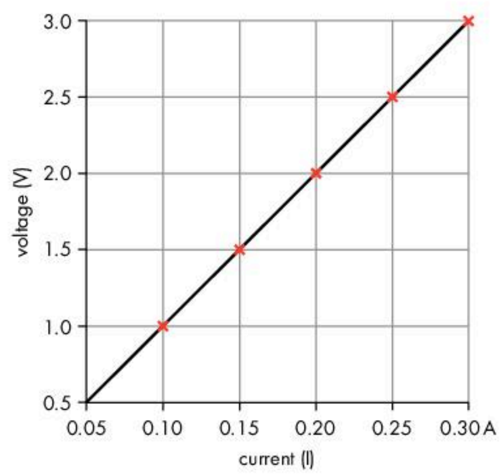


3 Adjust the rheostat to give readings of the current of 0.10, 0.15, 0.20, 0.25 and 0.30 A. For each ammeter reading record the corresponding voltage across the constantan wire.
4 Enter the readings in a table.
5 Set up and complete a graph of your results. Plot the current (I in amps) on the x-axis and the voltage (V) on the y-axis. Use the space available for your scales and mark corresponding points with a small x. Draw a thin line of best fit.
6 Remove the constantan wire and attach the torch bulb (2.5 V, 0.3 A) into the circuit in its place. Draw a circuit diagram.
7 Repeat steps 3–6. Compare your results and the two graphs. How can you explain the differences?

Students found the following readings for constantan wire.

Current (I) in amps	Voltage (V) in volts
0.05	0.5
0.10	1.0
0.15	1.5
0.20	2.0
0.25	2.5
0.30	3.0

They noticed that voltage increased evenly with current. They made a graph, with the current readings on the x-axis and the voltage readings on the y-axis. The gradient (V/I) is the resistance.



The graph shows the voltage across the constantan wire when different currents flow through it. The resistance is V/I.

The students saw the graph showed a straight line, which meant that voltage was directly proportion to the current (V proportional to I).

They checked the resistance (V/I) at several values and found it was constant. This is called **Ohm's Law**.

At 2 volts: R = V/I = 2/0.20 = 10 ohms

At 3 volts: R = V/I = 3/0.30 = 10 ohms

However, when they looked at the graph for the torch bulb, the line showed a curve. This shows that the resistance of the wire increased as the temperature increased. This is because at higher temperatures the particles in the wire move more and resist the flow of electrons along the wire. This produces light and heat.

Electricity in the home

List all the energy sources you use in the home. Here are some examples: wood, charcoal, LPG (cooking gas), kerosene, electricity and solar energy. Which of these is the commonest and most important?

Energy sources become more useful to us when they are converted into other forms of energy we can use, for example, for cooking, cooling, or watching television.

17.15 Energy conversions

Materials: picture of a kitchen, your home or school

Method

1 Look at the pictures and at your surroundings. Make a list of all the appliances and things that are energy changers.

2 Put the names of the appliances in a table and list the energy change for each one. For example, cooker: energy change is from cooking gas (chemical energy) to heat.

Questions

1 Which is the most common energy source? (a) Into how many other kinds of energy can it be changed? (b) Into which kind(s) of energy can it not be changed?
2 Choose two appliances. Explain how the energy changes make the appliances useful to us.
3 Is all the energy that is supplied to an appliance used in a useful way? Explain your answer with reference to two different kinds of appliance.
4 Which form of energy is the one most often not used in a useful way? Name an appliance to illustrate your answer.
5 List the appliances that use dry cells and which have plugs.

▶ **See Workbook Electrical appliances.**

Questions

1 Choose six appliances and divide them into ones that produce heat that is useful, and ones where it is not useful.
2 Which appliances do you think are the most expensive to run? Why?
3 Examine the plugs on electrical appliances. (a) What differences do you find? (b) Make a table of appliances using 2-pin and 3-pin plugs.
4 When we say energy is 'wasted' by an appliance, what do we mean?

washing machine

hairdryer

table lamp

blender

iron

television

Fun facts

- The cooker uses more energy than all the other appliances in a kitchen put together.
- Lights only change 5–20% of their electrical energy into light energy. Most is 'wasted' as heat.

Plugs

The plug is the connection between the appliance and the supply of electricity from the mains. The pins of the plug are pushed into the holes in the socket to make the electrical connection. There are two kinds of plug:

- Two-pin plugs. These are used with a cable that has two wires. These have brown insulation (the live wire), which brings electricity to the appliance and blue insulation (the neutral wire), for the return path of the current. Two-pin plugs can be used with low wattage appliances, such as an electric clock, and those encased in plastic, which are already insulated. If anything goes wrong with the wiring, a person could get an electric shock as electricity flows through them. This can be fatal. Table lamps and food mixers can be fitted with two- or three-pin plugs.
- Three-pin plugs. These have an additional pin, which is connected to an earth wire (with green and yellow insulation). In this case, if anything goes wrong with the wiring, the electricity runs down the earth pin to a metal plate buried in the earth. It is therefore safer to use three-pin plugs. These can also be fitted with a fuse.

17.16 Wiring a three-pin plug

Materials: pliers or wire cutters, screwdriver, three-pin plug, length of three-wire cable

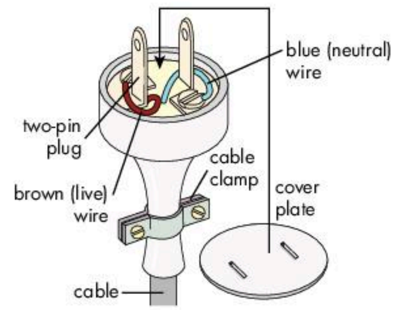
Method

Follow these steps by reference to the drawings.

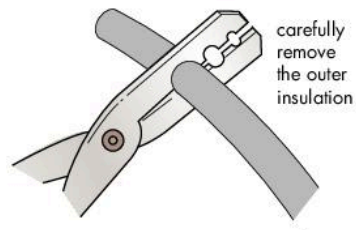
1. Carefully cut away 5 cm from the outer cover of the cable. Do not damage the insulation below.
2. Check the cable in the plug for the lengths of the wires.
3. Cut the three wires so that they would just fit through the holes in the plug pins.
4. Carefully remove the insulation from the last 1 cm of the wires. Twist the small wires together if necessary.
5. In turn, fix the wires into the correct plug pins and screw them down. Check that each connection is tight.
6. Add the correct fuse.
7. Put the cable into the plug under the clamp. Screw the clamp down tightly over the outer insulation.
8. Screw the plug cover on.

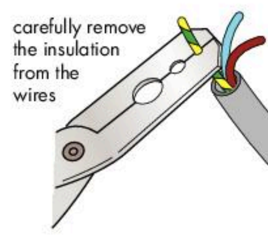
Safety hints against electrical hazards:

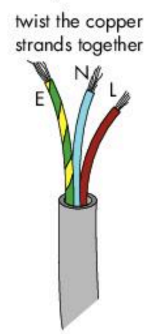
- Use the right cable, with two wires or three.
- Use the right plug, with two pins or three.
- Do not connect too many plugs to one socket (overloading).
- Check the operating voltage. If it is 110 V and you want to plug in a 220 V appliance, use a transformer.

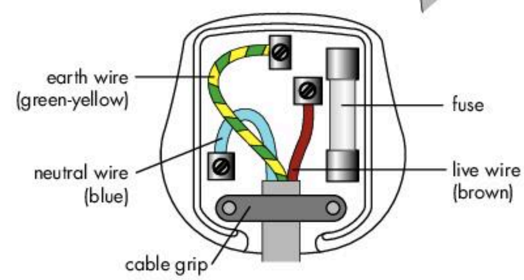


Use the diagram to help you wire a two-pin plug

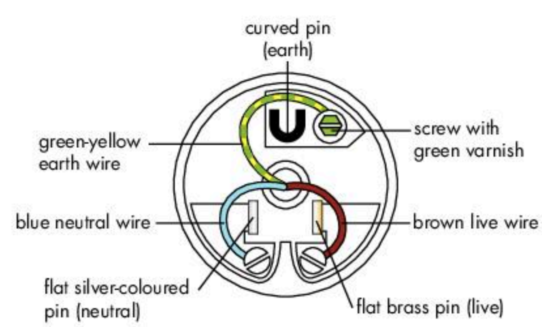








Three-pin plug with a fuse. A fuse is always in the live wire side of the plug.



3-pin plug without a fuse

Use the diagrams to help you wire a three-pin plug

Sources of electricity

Electricity is a flow of charged particles, usually electrons. The force to push the charges around a circuit can come from a cell or battery or from the mains. The electrons are already in the circuit, but they need 'oomph' to push them around.

Cells and batteries	Mains electricity
Mostly small and can be moved.	Need to be plugged in.
Used for portable appliances, e.g. flashlight and for a car.	Used for appliances in the home, e.g. cooker, fridge.
Electricity is more expensive.	Electricity is less expensive.
The chemicals are 'used up', though some cells and batteries can be re-charged.	Mains electricity is usually available, except during power cuts and disasters.

Cells and batteries

They contain chemicals, with stored chemical energy. When they are connected in a circuit, the chemical energy is changed into electrical energy. Two or more cells working together form a battery. Most cells and batteries contain dry chemicals. An exception is the car battery, which contains sulphuric acid. Some batteries are re-chargeable. This means they can be re-charged with electricity so that they work again.

Common dry cells and batteries e.g. used in flashlights, electric clocks, smoke alarms. Cheap. Not very powerful and go flat when chemicals are used up.

A 12 volt lead-acid car battery, e.g. used in cars, tractors. Produce large currents and can be recharged when flat. Expensive and contain acid.

Button cells, for hearing aids watches. Very small and light. Expensive.

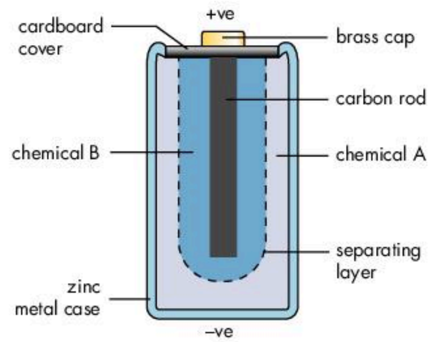
Rechargeable cell, e.g. for power tools and cell phones. Convenient but expensive.

▶ **See Workbook Electrical appliances.**

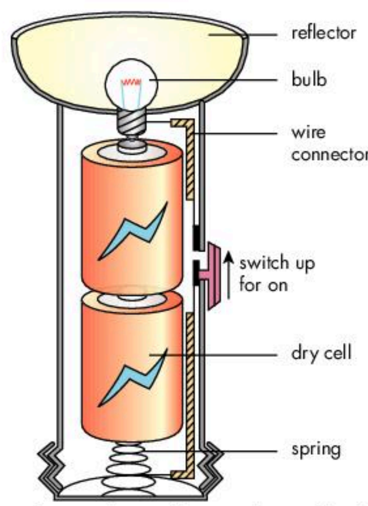
How a dry cell works

The diagram shows an LS of a dry cell.

- The +ve end is the brass cap in contact with the carbon rod.
- The –ve end is the zinc metal case around the outside.



- When connected into a circuit, electricity is generated as charged particles move through chemicals A and B between the carbon and zinc.
- The flow of charged particles is pushed around the circuit.



Battery of two dry cells used in a flashlight

Questions

1 (a) Use the diagram of the flashlight to write an account of how it works.
(b) Draw the circuit diagram.

2 Which electrical power source(s) would you use in a (a) digital camera, (b) toy car, (c) laptop, (d) portable printer, (e) lorry. Give reasons in each case.

Mains electricity

Electricity is produced in cells and batteries from the chemicals inside them. Mains electricity is produced from kinetic (movement) energy in a machine called a **generator**.

In a similar way the kinetic energy of a moving bicycle can be converted to electricity using a dynamo (see box).

What happens at the power station?

The kinetic energy to turn the giant magnet inside the coils of wire in the generator comes from the **turbine**. The turbine is made of blades that are turned either by moving air (in windmills), by water (in hydroelectric power stations) or by steam (in most power stations).

The energy needed to heat water to make the high-pressure steam can be supplied by:

- heating fossil fuels such as coal, natural gas or oil, or
- from nuclear energy.

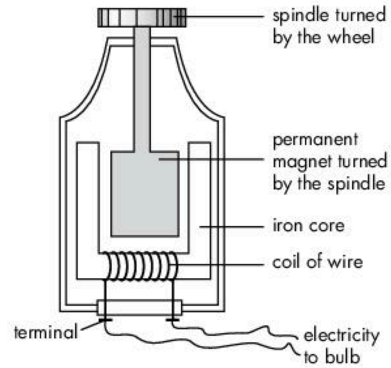
The diagram below shows the

- boiler: where water is heated to make steam
- turbine: where the steam turns the blades
- generator: where the turning effect from the turbine is used to generate electricity.

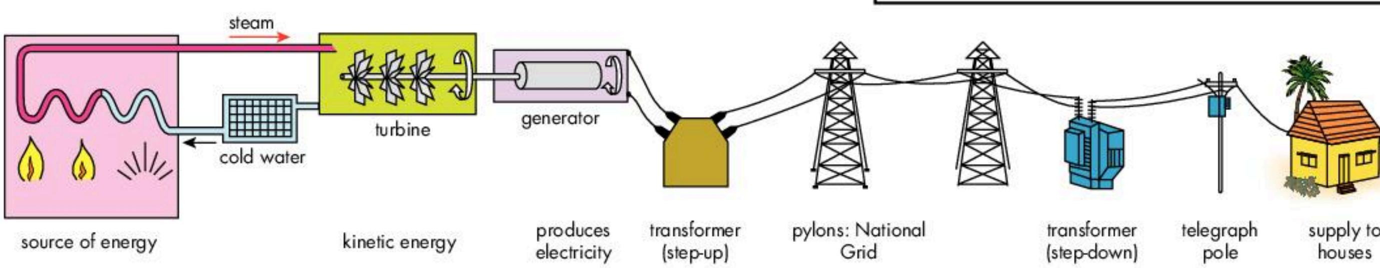
How a bicycle dynamo works

The diagram shows an LS of a dynamo.

- The spindle is held close to the wheel. As the wheel turns the spindle turns.
- The spindle turns the magnet inside an iron core, which has a coil of wire wrapped around it.



- As the magnet spins, electricity is produced in the wire, which can be used to light the bicycle lamps.



How does the electricity get to our homes?

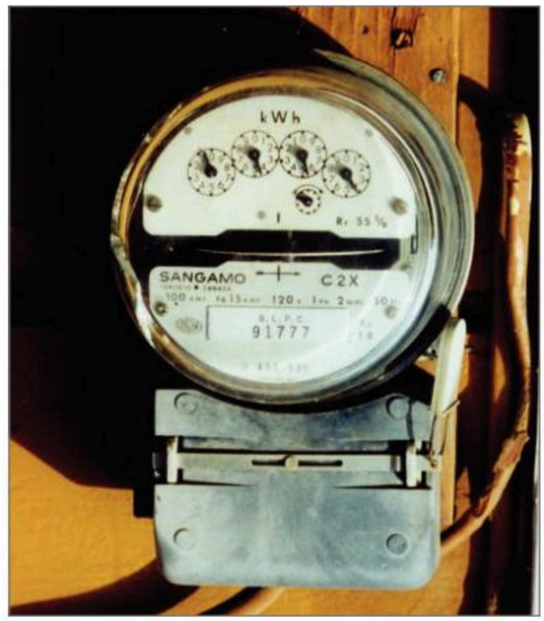
- At the power station the voltage of the electricity is increased (using a step-up transformer). Increasing the voltage reduces the current. The electrons are pushed harder, so fewer are needed to carry the energy. This means that thinner (and cheaper) wires can be used with little loss of heat. This is also the reason why power lines are so dangerous and can cause accidents or even death.
- The electricity is distributed by pylons in the National Grid and taken to sub-stations.
- Here the voltage is reduced (using a step-down transformer) to levels that can be used in factories or homes.
- The electricity is then carried through wires supported on telegraph poles, which may also have their own step-down transformers. For homes in Jamaica and Barbados, the voltage is reduced to 110 V, and to 120 V in Trinidad.
- When we plug an appliance into a socket and switch it on, we complete the circuit that connects us to the power station. Electricity flows and our appliances start to work.

A telegraph pole with a transformer, bringing the electricity supply to a home

How are we charged for electricity?

When electricity comes to our homes, the cables go first to an electricity meter. There are two kinds, as shown on the right. The meters record how many units of electricity have been used. The energy units are measured in kWh (kilowatt-hour).

A digital electricity meter

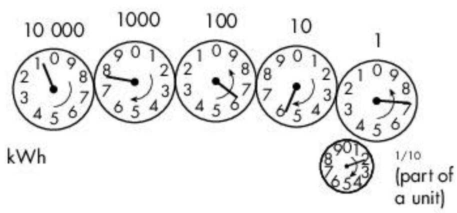


An analogue or dial electricity meter

How do we read electricity meters?

A digital meter (top photograph) has a series of numbers. We usually ignore the fractions of a unit, so the reading is 91404 kWh. If the reading on the same day next month is 91929 kWh, how many energy units have been used?

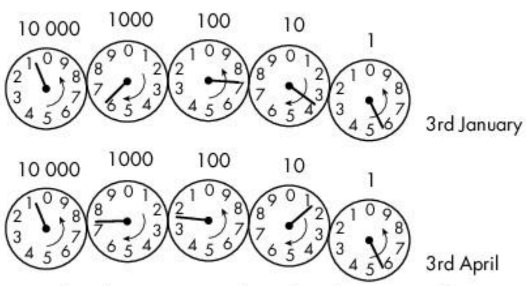
An analogue or dial meter (lower photograph) has a series of dials marked alternately from 0 to 10 and from 10 to 0. The value of each dial is shown below.



We read the lower number from each dial and ignore the parts of a unit on the last dial. The reading is therefore 07657 kWh.

Look at the dial meter on the right. What is the reading? If the reading the next month is 0643 kWh, how many energy units have been used?

Here is another example.



How many units (kWh) were used in the three months January to April?

Watts, kilowatts and kilowatt-hours

- Power, measured in watts, describes the rate at which electrical energy is changed into another form within our appliances. One joule/second (J/s) = 1 watt (W). Many appliances are marked with their power rating.
- One watt (W) is also equal to the voltage across the appliance times the current flowing through it.
  1 watt (W) = 1 volt (V) × 1 amp (A).
  Some appliances have their voltage and current markings. These are multiplied to give the wattage.
- One kilowatt (kW) is equal to 1000 W.
- One kilowatt-hour (kWh) is the amount of energy we use if we run an appliance of 1 kW for 1 hour, or one of 500 W for 2 hours, etc.

Questions

1. What is an energy unit?
2. An electric oven is marked 4 kW and a microwave oven 650 W. Which would be cheaper to run? How would you make it a fair test?
3. A toaster is marked 1000 W and an iron is marked 110 V and 7 A. Which would be more expensive to run for the same amount of time?

Fun facts

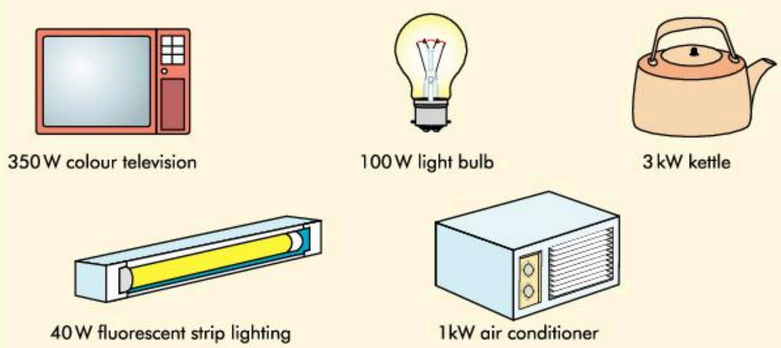
- An Olympic runner in the 100 m has been calculated to generate 3000 W for each of his strides.

17.17 Making a model

1 The assignment is to make a model of a dial electricity meter that uses moving discs to show the number of energy units (kWh). You can use any materials you need.
2 Use the Engineering Design Process steps of Engage (Ask questions), Explore (Imagine), Elaborate (Plan), Execute (Create), Explain (Assess, improve and report) and Evaluate (Has the problem been solved)?
3 Demonstrate the use of your model.

17.18 Calculating energy usage

Materials: electrical appliances, pictures of appliances
Method
1 Look carefully at each appliance. Many of them are marked with their power rating in W or kW. Record the names and the power ratings, in kW, in a table.
2 For appliances marked in volts and amps, multiply these first to get W. Then divide by 1000 for kW and put it in the table.
3 What do you notice about the appliances that produce a lot of heat, such as an electric kettle? Do they have higher power ratings than, for example, a fan or television set?



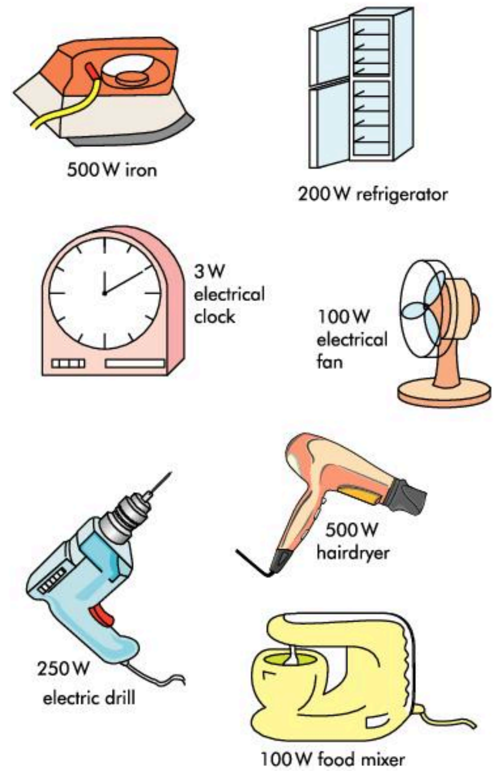
4 For each appliance decide how long (in hours) you would use it each day. Enter the values in the table.
5 Calculate the kWh used by each appliance in a day.

▸ **See Workbook Electrical appliances.**

17.19 Reading electricity meters

Materials: electricity meters in different locations
Method
1 Try to record the readings on electricity meters in three different places, such as school, home and church.
2 Record the readings again after a month.
3 Calculate the energy usage in each place. Try to account for any differences. Share your findings with the class.

▸ **See Workbook Electrical appliances.**



Electrical appliances

17.20 Paying the bill

Ask at home it you can look at the electricity bill that relates to the month you took the readings.
1 Find the meter readings listed on the bill. Are these the same as the ones you recorded?
2 Find the total units used. Is this the same figure that you calculated?
3 Find and record the cost of each unit. (This may vary: sometimes the first lot of units may be cheaper or more expensive than the rest.)
4 Identify any other standing charges.
5 Try to calculate your bill and see if it comes to the same as the actual one.

Questions
1 What are the steps that occur from you plugging in the electric jug to you drinking a cup of coffee?
2 Which appliance is (a) the most and (b) the least expensive to run?
3 How does the amount of time we run an appliance affect the amount of money we have to pay? Explain your answer.

Safe use of heat and electricity

The electricity supplied to an appliance is converted into different forms for it to work. Most electrical conversions also produce heat. The materials we use, the rules we follow and the safety devices found in appliances make sure that electricity and heat go mainly to where they are required.

- Conductors are the route for electricity and the transfer of heat in wires and cooking utensils.
- Insulators cover the wires and isolate us from electricity. They are also used when handling hot objects.

PS 17.21 Using a bimetallic strip

1 Identify the two metals that are joined together in the bimetallic strip: the goldish brass and the greyish steel.
2 Hold the end of the bar in a Bunsen flame. What happens to the bar?
3 Lay the bar on a heatproof pad as it cools. Do not touch it. What happens when the bar cools?

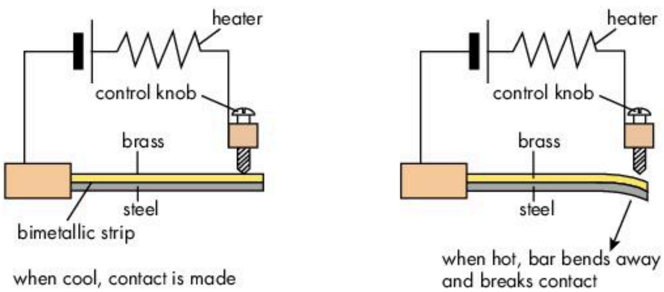
Uses of thermostats

A thermostat uses a bimetallic strip to keep an oven or iron to a fairly constant temperature, so, for example, food is cooked properly.

A thermostat is a safety device:

- It does not allow the temperature to rise too high and perhaps cause a fire.
- Control knobs can be adjusted on an oven or iron so that food or clothes are not burned. Different temperatures can be chosen for different kinds of food or material.

An electric oven



As the oven warms up, the bimetallic strip is also warmed and it bends away from the contact. This breaks the circuit and electricity stops flowing. So the oven starts to cool down. But as this occurs, the bimetallic strip also cools down. It therefore straightens out and makes contact. This completes the circuit and electricity flows again.

Questions

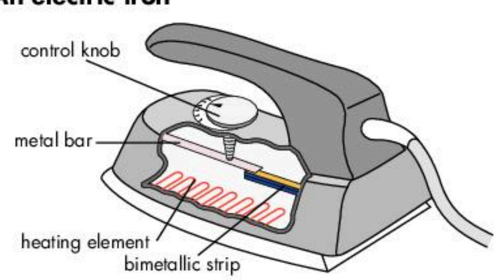
1 (a) How does a bimetallic strip work?
(b) Explain its use in one appliance.
2 Describe the use of safety devices, e.g. thermostats, fuses, 3-pin plugs.

Safety rules

Explain the reason for each rule.

- Assume that any appliance that is in use, or has just been used, will be hot – for example, a light bulb.
- Do not touch working appliances or hot pans with bare hands – use a padded glove.
- Never put anything except the plug into an electric socket.
- Do not use an appliance if the insulation on the cable is damaged.
- Never use a cable near water or if your hands are wet.
- Always switch off an appliance before you gently pull out the plug.
- Choose the correct two- or three-pin plug and wire it correctly.
- Choose the correct fuse for an appliance.
- Do not replace a fuse until the fault in the circuit has been corrected.

An electric iron



An electric current passes through the wire of the heating element. The hot base of the iron is used to press the clothes. The circuit is connected to a bimetallic strip. When the temperature rises the strip curves down away from its contact and breaks the circuit. On cooling, the strip straightens again and the current flows to heat the iron.

Fuses

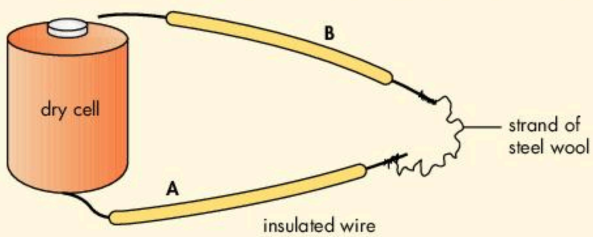
A fuse is another safety device. It prevents a circuit from carrying too much current. Excess current can make a cable become very hot, which can cause a fire. A fuse also protects appliances in the circuit, which operate with a certain current, from being damaged. The fuse melts and breaks the circuit.

PS 17.22 How do fuses work?

Materials: dry cell, paper tape, scissors, pieces of wire, piece of steel wool

Method

1. Use the scissors to cut off some of the insulation from both ends of two pieces of copper wire.
2. Tape one end of piece **(A)** to the base of the cell. Wind a single strand of steel wire round the other end of the wire.
3. Wind the other end of the steel wool to the other wire **(B)**.



4. Lightly touch the exposed end of wire **B** to the top of the dry cell to complete the circuit. What happens to the steel wool? You should find it breaks, as a fuse would.

Circuit breakers

The main circuit of the house may be protected by fuses. If a fuse blows, a new fuse or fuse wire needs to be inserted, after the cause of the problem has been corrected.

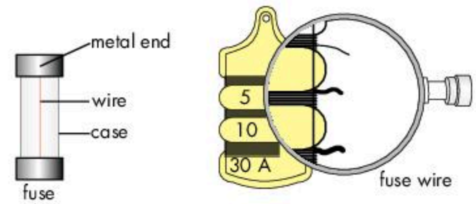
But in new houses, a circuit breaker may be used instead. This works with an electromagnet. If the current exceeds a certain value, the electromagnet attracts an iron bar. This breaks the circuit and also pushes up a button. After checking for the cause of the fault and correcting it, the button can be pushed down to reset the circuit breaker. These are easier to use than changing fuses, but they are expensive to buy.

▸ **See Workbook Electrical appliances.**

Which fuse should you use?

The wires in different fuses are of different thickness.

- A thicker wire allows more current to flow before it melts and breaks.
- A thinner wire allows a smaller current to flow before it melts and breaks. For example, a 3 A fuse can carry 3 A but will melt with a bigger current.



- The fuse rating (in amps) of the fuse should be only a little higher than the current the appliance usually uses.
- These fuses are fitted into the live wire side of the three-pin plug, which is attached to the appliance.

Appliances	Fuse to use
Electric kettle	13 A
Hairdryer Electric iron Vacuum cleaner Toaster Food mixer Computer	5 A
TV Fridge or freezer Sewing machine Table lamp Radio Video	3 A

- There are also fuses in the main fuse box. The main circuit for the house usually has a 30 A fuse and the one for the kitchen is 60 A.
- If a fuse 'blows', it is very important to fix the fault before replacing the fuse wire. Never use thicker wire to replace a broken fuse.

Quick check ☑

An electric current is usually a flow of ________. Cells arranged in several pathways are called a ________ circuit. In a ________ circuit the current has the same value all round the ________. Resistance is ________ divided by current. A ________ -pin plug can contain a ________, which melts and breaks if excess current flows.

Use these words to fill in the spaces as you write the sentences in your Exercise book.

voltage **series** **circuit** **3** **parallel** **fuse** **electrons**

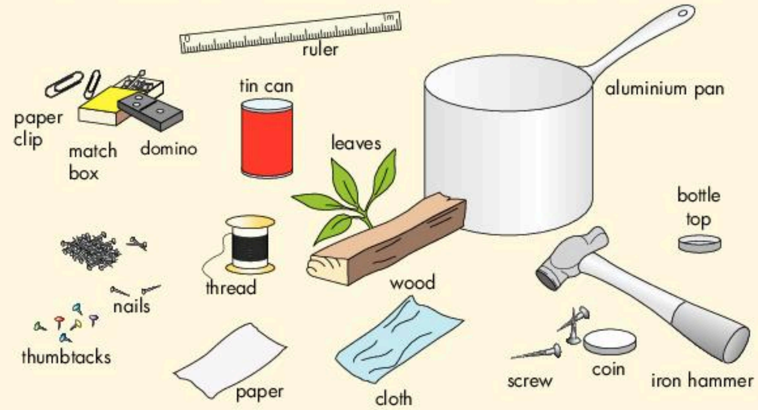
Magnetism

17.23 What materials do magnets attract?

Materials: magnet, objects such as nails, wood, leaves, tin can, aluminium pan, paperclip, coins, key, iron hammer

Method

1 Bring the magnet close to each object in turn. Make a table to record which objects are attracted and which are not. Record the materials of which the objects are made.



2 What do the objects attracted by the magnet have in common? Do they all contain iron or steel? We call them magnetic. Objects that are not attracted are called non-magnetic. Note that a 'tin can' is made of iron that has been covered by another metal.

17.24 How do magnets behave?

Materials: iron or steel pins, two bar magnets, pencil, pile of books, paper, cotton thread, paper tape

Method

1 Run a magnet over the pins. Where are the pins mostly attracted? You will find they are attracted to the ends of the magnet, which we call the North and South poles.
2 Make a paper holder for a magnet. Stick a piece of thread to the holder and suspend it from a pencil supported by books. The magnet should swing freely.
3 Bring the North (N-pole) of another magnet towards each end of the suspended magnet in turn. Record what happens.
4 Bring the South (S-pole) of the magnet towards each end of the suspended magnet in turn. Record what happens.
5 Complete a table of your results.
6 What happens between like poles? (N – N and S – S)
7 What happens between unlike poles? (N – S)
8 Record your findings about how magnets behave.

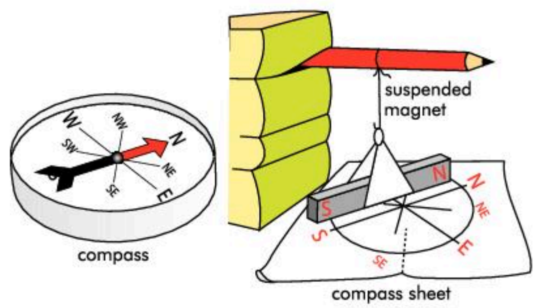
▶ **See Workbook Magnetism.**

Objectives

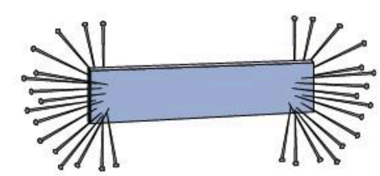
- Investigate the properties and uses of magnets.
- Investigate the properties and uses of electromagnets.
- Investigate the relationship between magnetism and electricity.

Fun facts

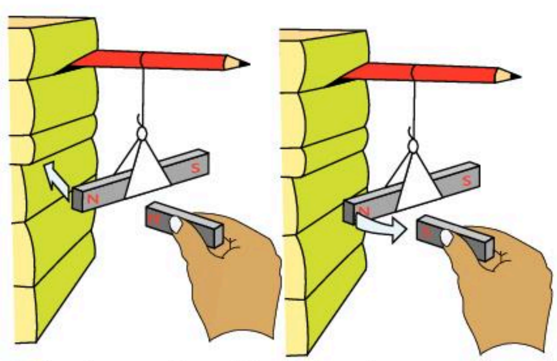
- Permanent magnets are mainly made from compounds of iron with cobalt or nickel.
- Magnets attract materials containing iron. Steel is a compound of iron with other elements.
- The Earth acts like a giant magnet, with magnetic north and south poles.



In which direction does a suspended magnet point?



The magnetic force is concentrated at the poles



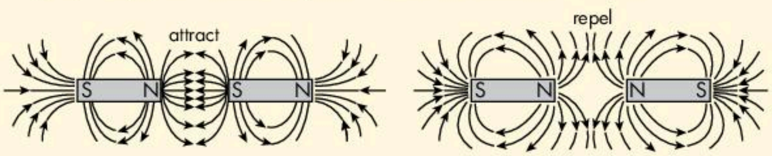
What is true about like poles of magnets?
What is true about unlike poles of magnets?

The area around a magnet where its magnetic force works is called its **magnetic field**. For example, a paper clip is pulled towards a magnet when it is placed within its magnetic field. We can use iron filings or small plotting compasses to show the **lines of force** within the magnetic field.

17.25 Investigating magnetic fields

Materials: two bar magnets, iron filings, paper
Method

1 Arrange the magnets so a N pole faces a S pole. Place the paper on top. Shake some iron filings on the paper **(a)**. Sketch the pattern of the lines of force.
2 Now arrange the magnets so N poles face each other. Place the paper on top. Shake some iron filings on the paper **(b)**. Sketch the pattern of the lines of force.



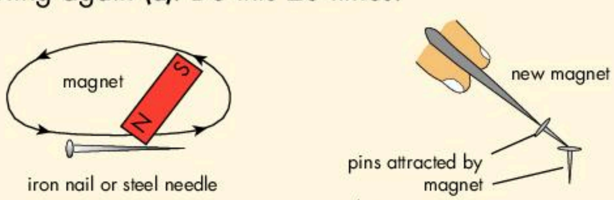
(a) lines of force in the magnetic field (b)

3 How do your results compare to what you found out when you had the magnet suspended?

17.26 Making magnets

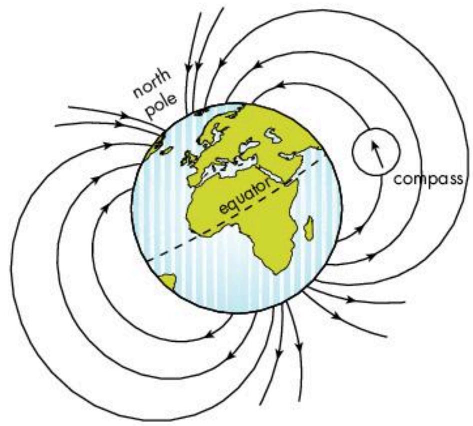
Materials: bar magnet, pencil, iron nail, pins, steel sewing needle
Method

1 Stroke the iron nail with one end of the magnet, each time in the same direction and lifting it away before starting again **(a)**. Do this 20 times.

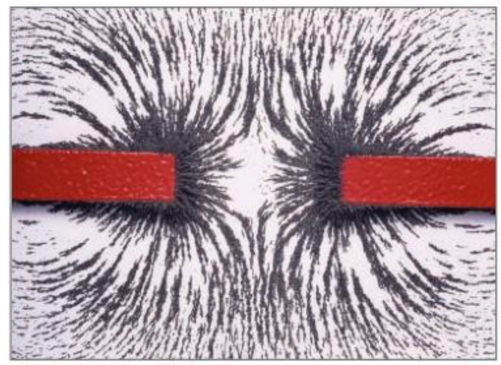


(a) (b)

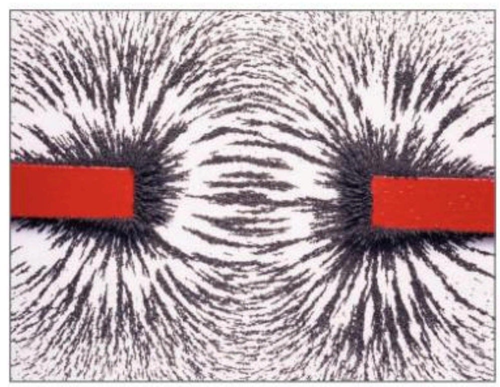
2 Stroke the steel sewing needle in a similar way, 20 times.
3 See how many pins you can pick up with each new magnet **(b)**. Which material, iron or steel was easier to magnetise?
4 Leave your magnets for two minutes and then see how many pins they pick up. Which material, iron or steel keeps its magnetism for the longer time?
5 You are given an iron nail. How can you determine if (a) it is a magnet and (b) if it is, then which end is the N pole?
6 Design a test to compare the strength of two magnets.
7 Why is repulsion the only true test of a magnet?



A compass or other magnet lies along a line of force in the magnetic field of the Earth



(a) Unlike poles



(b) Like poles

Showing the lines of force inside the magnetic fields

Uses of permanent magnets

A permanent magnet does not depend upon electricity. Magnets have different shapes, e.g. bar, horseshoe, 'doughnut' and button.

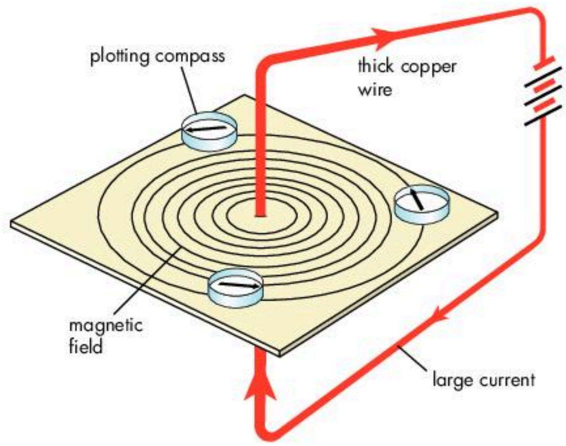
- They are used to hold onto iron or steel surfaces such as the fridge or a board.
- Two magnets to hold doors closed.
- The magnet in a bicycle dynamo.

Electromagnets

When electricity flows through a wire it creates a weak magnetic field. To make it stronger, the wire is made into a coil. As long as the electricity is flowing, the coil behaves like a magnet. The magnetic strength can be increased by:

- increasing the number of turns on the coil
- increasing the current flowing in the coil
- putting an iron core inside the coil.

The coil and the core together are called an **electromagnet**. Any metal wire can be used to make the coil. Iron is the best metal to use to make the core, which becomes magnetised. It quickly loses its magnetism when the current is switched off.



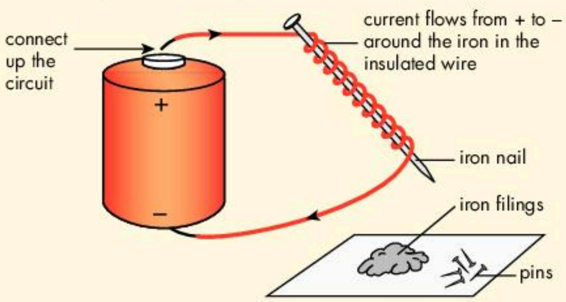
An electric current can produce a magnetic effect: the compass needles show the lines of force of the magnetic field

17.27 Making an electromagnet

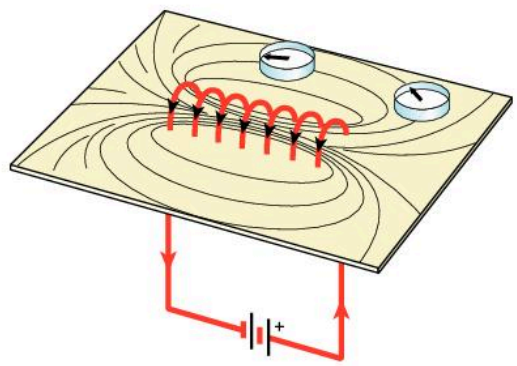
Materials: iron nail, dry cells, pins, scissors, iron filings, pieces of insulated wire, paper tape, steel sewing needle

Method

1. Remove about 2 cm of insulation from the ends of the copper wire.
2. Wind the central part of the wire many times around the iron nail, keeping the same direction all the time.
3. Then connect one end of the wire to the base of the dry cell using paper tape. Now hold the other end of the wire to the top of the dry cell to complete the circuit.



4. While the current is flowing, see if the nail can pick up iron filings or pins.
5. After counting to five, break the circuit. Test again to see if the nail is behaving like a magnet.
6. Choose one way in which the electromagnet could be made stronger. Decide how you will carry out a fair test and then do the investigation. Discuss your results.
7. Make the steel sewing needle into an electromagnet. What do you notice when the current is switched off?



Magnetic field around a coiled wire in which an electric current is flowing

Questions

1. Electromagnets are used where a temporary magnet is needed, which will lose its magnetism when the current is switched off. Which metal is best for the core and why?
2. How are magnets and electromagnets different?


Student making an electromagnet

Magnetism and electricity

You have seen how the magnetic field around a coiled wire in which an electric current is flowing can induce magnetism into an iron nail. This makes the iron into an electromagnet and the effect lasts as long as the current is flowing.

Now you will explore how moving a conductor through a magnetic field can be used to induce an electric current. Alternatively, the magnet can be moved into a solenoid (a coil of conducting wire) connected to a sensitive ammeter. Moving a magnet in a coil is the way in which an electric current can be produced in a dynamo attached to a bicycle wheel. The process is called **electromagnetic induction**.

PS 17.28 Electromagnetic induction

Materials: two strong bar magnets, scissors, 50 cm and 80 cm connecting wires, a 2.5 cm PVC pipe, sensitive ammeter

Method

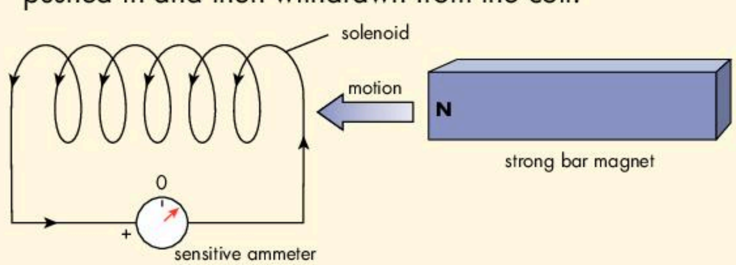
Work in groups:

Moving the wire

1 Use the 50 cm length of wire. Cut off the insulation from the ends and connect the wire to a sensitive ammeter in the microampere range.
2 Set up the two magnets so they are held to create a magnetic field between them (see diagram on the right).
3 Now move the wire rapidly through the magnetic field. The current induced will be very small. This is why a sensitive ammeter is used. The effect only occurs when the wire is bring moved.

Moving the magnet

4 First make a coil of wire. Use the longer connecting wire and close wrap it around the PVC pipe. Then slide out the pipe to leave the coiled wire (this is called a solenoid).
5 Connect the ends of the wire to the sensitive ammeter.
6 Insert one end of a strong bar magnet into the middle of the wire coil and rapidly withdraw it. Note what happens to the reading on the ammeter.
7 Repeat Step 6 with the other end of the magnet being inserted and withdrawn.
8 Was there any reading on the scale when (a) the magnet was stationary inside the coil and (b) when it was being pushed in and then withdrawn from the coil?

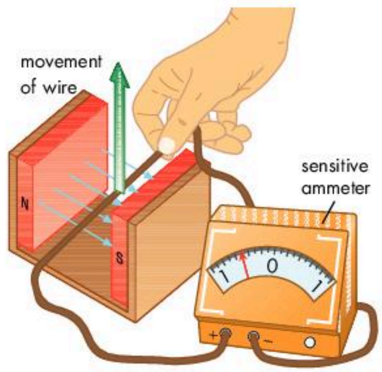


▶ **See Workbook Magnetism.**

How it works

Moving the wire

When a conducting wire is moved through a magnetic field the electrons in the conductor experience a force which tends to make them move.
If the conductor is connected in a circuit, this induced current can be measured with a sensitive ammeter.



As the wire is moved in the magnetic field, a current is generated

UK 17.29 Investigating changes

Discuss in your group and then set up fair tests to find the effects of the following on the induced current:

- moving the magnet more quickly
- using a stronger magnet
- having more loops in the solenoid.

How it works

Moving the magnet

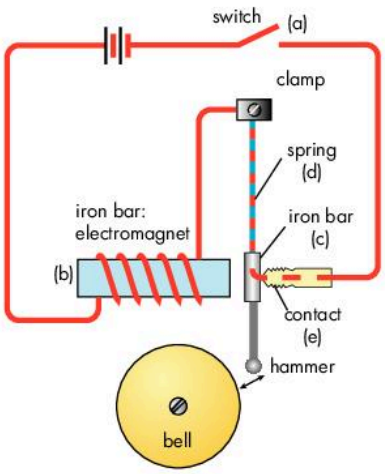
It is usually easier to move the magnet into a solenoid (a coil of connecting wire). Pushing in the magnet makes its magnetic field pass through the loops of wire and this induces a small current. The direction of this current is reversed as the magnet is pulled out. While the magnet is stationary, there is no induced current.

Reversing the direction in which the magnet is pushed in reverses the direction of the current.

There is a larger current with a stronger magnet, faster movement of the magnet or having more loops in the solenoid.

Uses of electromagnets

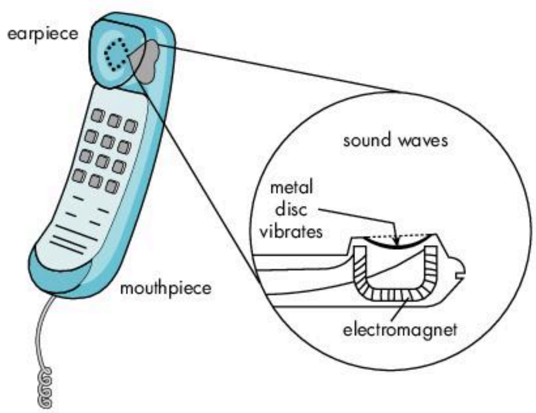
An electric bell



When the doorbell is pushed, switch **(a)** is closed and the circuit is completed. As the current flows the iron bar **(b)** becomes an electromagnet. This pulls the iron bar **(c)** towards it, which causes the hammer to strike the bell. The hammer returns to its rest position because of the springy metal **(d)** and reconnects the contact **(e)**. As long as the switch is closed, the hammer goes backwards and forwards hitting the gong.

When the switch is opened again, no current flows and **(b)** stops being an electromagnet. So the iron bar **(c)** is not attracted and the bell does not ring.

A telephone



In the mouthpiece of a telephone sound waves are changed into electrical currents. These are distributed to the earpiece of another telephone. The current passes around an iron horseshoe, which becomes an electromagnet. When the current is on, the metal disc is attracted to the magnet, and when it is off, it springs back. So the disc vibrates and makes sound waves.

▶ **See Workbook Magnetism.**

A crane

Electromagnets can be made stronger than permanent magnets and their strength can be varied by adjusting the current passing around them. They can also be easily switched on and off. So they are used at a scrap-yard to attract scrap iron and steel from other metals. They are also used in a steel-works to shift iron and steel bars from one place to another.

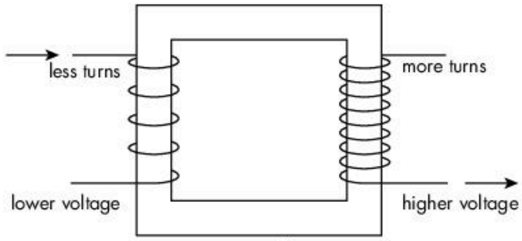
A Maglev train

'Maglev' is short for magnetic levitation. Electromagnets on the track repel electromagnets on the underside of the train as it passes by. The train floats above the rails. This reduces the friction and so the train can move very fast.

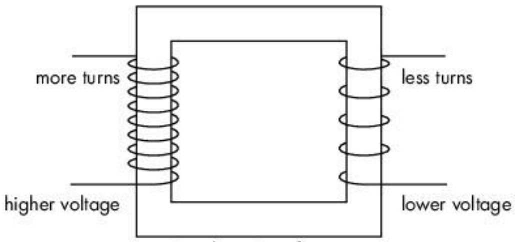
Questions

1 Why could a permanent magnet not be used in any of the ways described above?
2 Research and write a report on the importance of magnets in everyday life. **ICT**
3 Comment on this statement: Electricity can be used to make a magnet and a magnet can be used to make electricity.

Transformers



step-up transformer



step-down transformer

Transformers are able to change the voltage from one value to another. A transformer is made of a soft iron core that has two separate coils of wire. The electricity is led into one coil and this sets up a flow of electricity in the other coil. If the number of turns of wire in the coils are different then the voltage can be increased (stepped-up), or decreased (stepped-down).

Transformers make use of two principles:

- Electromagnetism: an electric current can produce a magnetic field.
- Electromagnetic induction: a changing magnetic field within a coil of wire induces a voltage across the end of the coil so a current flows.

For transmission along grid wires it is important that the voltage be high and the current low. This produces the least heating effect in the wires and allows thinner (and cheaper) wires to be used. A step-up transformer is used at the power station.

But for home use, the voltage must be stepped-down so that it is not so dangerous. This may be done by a series of step-down transformers in electricity sub-stations and also attached to electricity poles.

Other uses of electromagnets

- Tape recorder. The recording head is an electromagnet. The sounds are converted to patterns of magnetised particles on the tape. These can be 'read' by the playback head.
- Loudspeaker. A paper cone vibrates to make sounds, depending on the direction and power of a current flowing around an electromagnet.
- Eye hospital. A doctor can use a strong electromagnet to remove small pieces of iron or steel that may be in a patient's eye.

TS 17.30 Making models

Work in a group:

1. Carry out research into the uses of magnets and electromagnets. ICT
2. Brainstorm how to make a device using a magnet or electromagnet. Research your plan and find or ask for the materials you need.
3. Use the Engineering Design Process to develop your device: Engage (Ask questions), Explore (Imagine), Elaborate (Plan), Execute (Create), Explain (Assess, improve and report) and Evaluate (Has the problem been solved?)
4. Here are some ideas:
   - A working compass
   - A quiz board with a bulb that lights up when you choose the correct answer
   - A dexterity game where you move a metal ring over a wire without touching the wire (otherwise a bulb lights up)
   - A rubbish sorter that separates non iron from iron objects
   - An electric bell
   - A model electromagnet you use for moving iron and steel objects from place to place
   - A levitating train
   - A levitating train that moves

Quick check ☑

Unlike poles __________ and like poles __________.
There is a __________ field around a magnet and around an __________ current in a __________.
An __________ is made as an __________ current flows in the coil around an iron core.

Use these words to fill in the spaces as you write the sentences in your Exercise book.

magnetic **electromagnet** **repel**
electric **attract** **wire**

Questions

Answer these questions in your notebook

For questions **1–32** answer **A**, **B**, **C** or **D**.

1 When an object is rubbed and it becomes negatively charged, what has happened?
A it has gained protons
B it has lost protons
C it has gained electrons
D it has lost electrons

2 Why can a plastic pen with a negative charge pick up small pieces of paper?
A all paper is negatively charged
B all paper is positively charged
C the pen induces a negative charge on the paper
D the pen induces a positive charge on the paper

3 Which of these make use of static electricity?
A spray painting a car
B using a photocopier
C removing smoke particles in a factory
D all of the above

4 Which of these is a dangerous effect of static electricity?
A crackling of clothes from a dryer
B lightning
C spraying of crops
D small electric shock when touching metal

5 Which of these are good conductors of electricity?
A glass **B** copper
C wood **D** plastics

6 You could confirm your answer to Question **5** by using a
A tester **B** ammeter
C voltmeter **D** rheostat

7 Which statement is true?
A only metals can conduct electricity
B only metals that are magnetic can conduct electricity
C metals and graphite can conduct electricity
D metals and non-metals can conduct electricity if they are made into wires

8 Which of these would best be used as an insulator around metal wires?
A the same kind of metal
B a different, less reactive, metal
C plastic or rubber
D padded cloth

9 Why can a metal conduct electricity? Because
A its electrons are free to move
B its protons are free to move
C its ions are free to move
D all of the above

10 Current (measured in amps) is the
A electrical pressure between two points
B rate of flow of electricity
C force opposing the flow of current
D transfer of electricity to a bulb

11 Voltage (measured in volts) is the
A electrical pressure between two points
B rate of flow of electricity
C force opposing the flow of current
D rate at which work is done

12 Which of these is varied using a rheostat?
A voltage **B** current
C resistance **D** magnetic field

13 The role of a dry cell in a circuit is to
A produce electrons
B use up electrons
C change electrons into heat
D energise electrons

14 In which kind of circuit can bulbs be turned on and off independently?
A series circuits **B** parallel circuits
C circuits with cells **D** any kind of circuit

15 In a series circuit, when the number of bulbs is increased
A they all become brighter
B some of them become less bright
C they all become less bright
D they stay the same brightness

16 In a parallel circuit, when the number of bulbs is increased
A they all become brighter
B some of them become less bright
C they all become less bright
D they stay the same brightness

17 Which characteristic of the wire in a bulb is MOST important in causing the bulb to light?
A resistance **B** colour
C voltage **D** insulation

18 How would you find resistance?
A I/V **B** V/I
C $I \times V$ **D** $I + V$

19 In which units is resistance measured?
A amps **B** ohms
C volts **D** watts

20 Energy is doing work when
A a bulb is lit
B a kettle heats water
C a television is switched on
D all of the above

21 The earth wire in a plug is
A brown **B** blue
C green-blue **D** green-yellow

22 Which of these is NOT a source of electricity?
A coal **B** dry cell
C transformer **D** wind

23 What units are recorded on an electrical meter?
A kWh **B** kW **C** Wh **D** J/s

24 A 250 W electric drill and a 500 W hair dryer are used for the same length of time.
A the hair dryer uses more energy
B the electric drill uses more energy
C they both use the same amount of energy
D it depends on the brands that are used

25 Another name for a dial electrical meter is
A digital **B** analogue
C wheel **D** round

26 Which of these is NOT a safety device?
A overloading **B** fuse
C thermostat **D** earth wire

27 Which of these statements is NOT correct?
A magnets can be made inside an electric coil
B magnets have a force field around them
C magnets attract all metals
D magnets have north and south poles

28 What happens between the north pole of a compass needle and the S-pole of a magnet?
A repulsion **B** attraction
C nothing **D** electrostatics

29 Which of these does NOT have lines of force?
A compass **B** the Earth
C an electromagnet **D** bimetallic strip

30 Electromagnets are NOT used in
A telephones **B** electric bells
C compasses **D** circuit breakers

31 Why does a thermostat work? Because
A it has two metals
B the two metals expand at the same rate
C one metal expands more than the other
D metals are conductors of electricity

32 Electromagnetic induction can be use to produce
A an electromagnet **B** a current
C a permanent magnet **D** a compass

For questions **33–51** write full answers.

33 (a) What is static electricity? (b) How can it be demonstrated? (c) Give one example of its use.

34 (a) Why do non-metals not conduct electricity? (b) Why are they used as a layer around wires?

35 (a) Why is it dangerous to handle electrical equipment with wet hands? (b) Why is it not safe to have electrical appliances in a bathroom?

36 Write out these sentences correctly:
(a) Conventional current flows from ________ to ________.
(b) The rate of flow of electricity is measured in ________ using an ________ placed in ________.
(c) The electrical pressure is measured in ________ using an ________ placed in ________.

37 Draw circuit diagrams of (a) a dry cell with two bulbs in series (b) a dry cell with two bulbs in parallel. In which case will the bulbs be brighter?

38 Draw a circuit to show a battery of two cells and a series circuit with two bulbs. On the diagram add an ammeter and voltmeter. Mark all +ve and –ve terminals and the direction of conventional current.

39 List three differences between series and parallel circuits. Explain a use for each circuit.

40 What is resistance? Explain one use in a named appliance used in the home.

41 Give three examples of electricity being changed into other forms. Name an appliance for each one.

42 List two appliances that use dry cells or batteries. What are the advantages and disadvantages of this method?

43 Trace the energy chain from the chemicals in a battery, to the sound of a transistor radio.

44 Describe how a fuse works. Why is it important to use the correct fuse wire?

45 List three differences between two- and three-pin plugs. Which is it safer to use, and why?

46 Which of these appliances would use more energy units? A 100 W bulb for 60 minutes, or a 60 W bulb for 2 hours? Explain your answer.

47 Describe how you would make a magnet from a piece of (a) steel and (b) iron. How is each useful?

48 I have two magnets marked **A – B** and **C – D**. I find that pole **B** repels pole **C**. When I suspend the first magnet, pole **A** points towards the north pole. What are the poles **A**, **B**, **C** and **D**?

49 Which of these metals expands the most when heated: brass or steel? How do you know?

50 How are transformers used?

51 Look back through this unit and identify precautions that should be taken when using (a) static electricity (b) current electricity (c) magnets and (d) electromagnets.

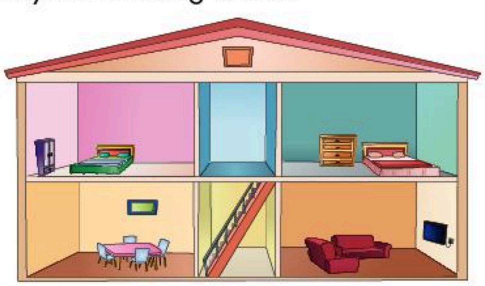
Key ideas

- Non-conductors can build up surface charges by friction that causes movement of negative electrons. This is called static electricity.
- Static electricity has several uses; the major hazard is lightning (when charges discharge).
- Metals and graphite are good conductors and non-metals are poor conductors of electricity.
- Conventional current flows from +ve to –ve.
- Current (I) is rate of flow of electrons, measured in amps (A) using an ammeter connected in series.
- Voltage (V) is electrical pressure, measured in volts (V) using a voltmeter connected in parallel (across the component).
- Resistance (R) opposes the flow of electricity. It is measured in ohms (Ω). It is found by dividing the voltage by the current: $R = V/I$.
- Bulbs arranged in series are one behind each other in one circuit. The current is shared between the bulbs, which are not very bright.
- Bulbs arranged in parallel each have their own circuit with the dry cell, so each one is bright.
- Wood, charcoal, LPG, kerosene, food, solar energy and electricity provide energy in the home.
- Electrical energy can be changed to heat, light, sound and motion in different appliances.
- A dry cell contains chemicals that generate electricity when it is placed in a circuit.
- Energy for turning a turbine is produced from a variety of sources and used in generators to produce electricity.
- Transformers are used to step-up (increase) voltage at power stations or to step-down (decrease) voltage in sub-stations for factory and house use.
- Rate of energy transfer, power (P), is measured in joules/second (J/s) or watts (W).
- The unit of energy usage is the kilowatt-hour (kWh). This is 1 kW used for 1 hour, or equivalent.
- Electricity meters record the number of energy units (kWh) that we use and are charged for.
- Magnets attract objects of iron and steel.
- Magnets have two poles, where magnetic force is strongest. Like poles repel and unlike poles attract.
- A thermostat contains a bimetallic strip.
- The earth pin and a fuse are safety devices.
- Iron can be made into an electromagnet if a current is passed through a wire coiled around it.
- Electromagnets have several uses, e.g. electric bell and Maglev train.

▶ **See Workbook Electricity and magnetism.**

Problems

1 Your project is to build a simple doll's house and then supply it with ceiling lights. You should have two rooms downstairs and two rooms upstairs. The picture below will give you some ideas. Different groups could build a room each and then put them together by building a stairway and making a roof.



(a) Decide how you will divide the class into groups and what will be their assignments. Also decide if you will be trying to make any furniture or model appliances for your house.

(b) Research the different ways in which you could set up the lighting circuit for your house. Decide if you want each room to have an independent switch, or whether the bulbs will be arranged in a single pathway. ICT

(c) Decide on the best time for wiring the house and the materials you will need.

(d) Use the engineering design process to plan and carry out your project: Engage (ask questions), Explore (imagine), Elaborate (plan) Execute (create), Explain (assess, improve and report) and Evaluate.

(e) You may need a Project Controller who is in charge of making sure that everything is done at the right time, as with a real building project.

(f) When your house is complete with its lighting system you could invite in another class of students to see what you have done. They may have some other suggestions for you as to how you could improve your model.

Unit 18

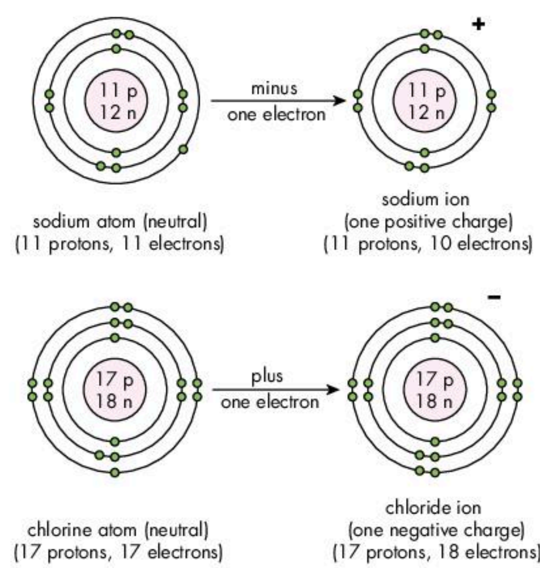
Chemical bonding, reactions and equations

1 Students using balls and bonds to build up models of molecules

This unit will help you to:

- recall the names and symbols of the first 20 elements
- identify important groups in the periodic table
- describe atoms and ions
- identify the use of combining power in forming ionic and covalent compounds
- write chemical formulae
- investigate the law of conservation of mass
- identify a range of chemical reactions
- write word equations and construct balanced chemical and ionic equations.

2 Sodium reacting with water. Write the word equation and a balanced chemical equation.



3 How sodium and chlorine atoms lose or gain electrons to become ions.

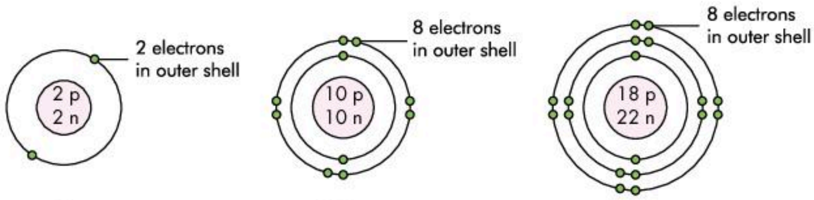
Chemical bonding

The periodic table

Elements are arranged by increasing atomic number. We can identify similar arrangements of electrons by looking at the columns: these form **groups** with similar reactions.

Group 0: Noble gases

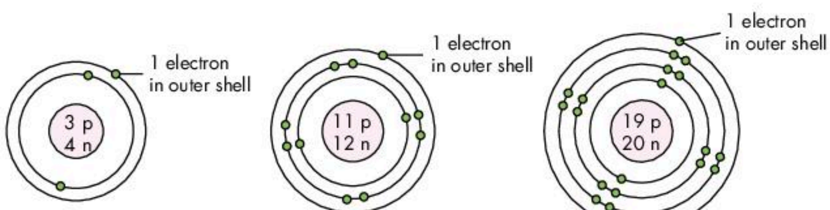
These include helium, neon and argon. These gases have a full outside shell of two or eight electrons. They are all very unreactive. They very rarely react with other elements. They do not need to lose or gain electrons to fill their outside shell.



2 *helium* | 2,8 *neon* | 2,8,8 *argon*

Group 1: The alkali metals

These include lithium, sodium and potassium. They have one electron in their outside shell. They are very reactive metals. They easily lose their outer electron in chemical reactions: they become ions with one positive charge. They are called **cations**.

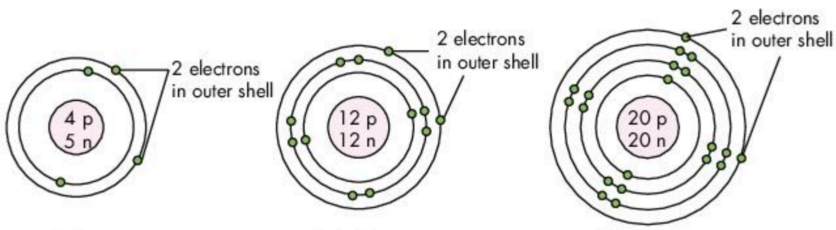


2,1 *lithium* | 2,8,1 *sodium* | 2,8,8,1 *potassium*

Group 2: Alkaline earth metals

These include beryllium, magnesium and calcium. They have two electrons in their outside shell. They are reactive metals.

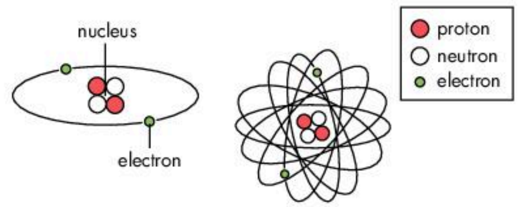
They lose their two outer electrons in chemical reactions: they become ions with two positive charges. They are cations.



2,2 *beryllium* | 2,8,2 *magnesium* | 2,8,8,2 *calcium*

Objectives

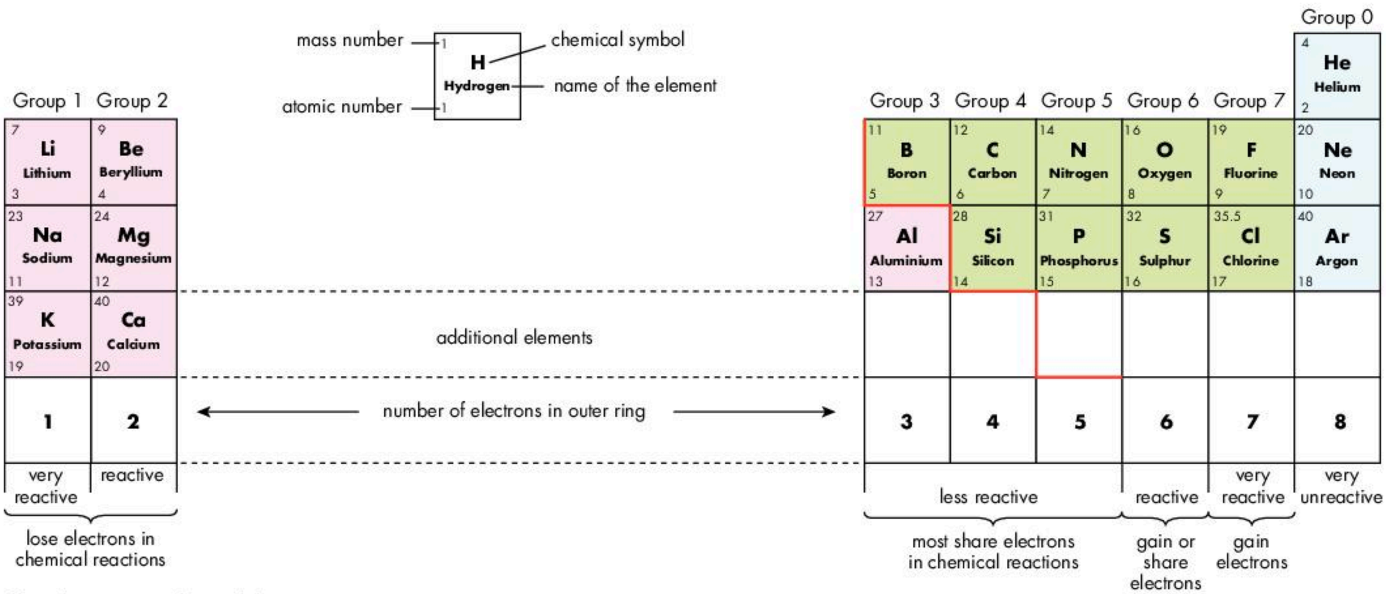
- Revise the periodic table.
- Name and give symbols and structures for the first 20 elements.
- Describe the link between arrangements of electrons and activity.
- Describe ionic and covalent bonding and write chemical formulae.



A model of atomic structure: Nucleus with neutrons (neutral) and protons (+ve), surrounded by electrons (-ve)

Symbol	Atomic number	Electrons in shells			
		1st	2nd	3rd	4th
H	1	1			
He	2	2			
Li	3	2	1		
Be	4	2	2		
B	5	2	3		
C	6	2	4		
N	7	2	5		
O	8	2	6		
F	9	2	7		
Ne	10	2	8		
Na	11	2	8	1	
Mg	12	2	8	2	
Al	13	2	8	3	
Si	14	2	8	4	
P	15	2	8	5	
S	16	2	8	6	
Cl	17	2	8	7	
Ar	18	2	8	8	
K	19	2	8	8	1
Ca	20	2	8	8	2

The arrangement of electrons in shells: for example, the electrons in sodium are 2,8,1 in three shells

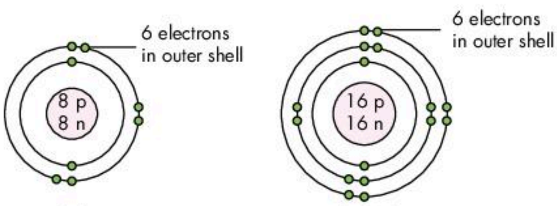


On the periodic table:

- Identify and name the metals (shown in pink), the non-metals (green) and the noble gases (blue).
- Identify the members of Group 0 (noble gases), Group 1 (the alkali metals), Group 2 (alkaline earth metals), Group 6 (the oxygen group) and Group 7 (the halogens).

Group 6: The oxygen group

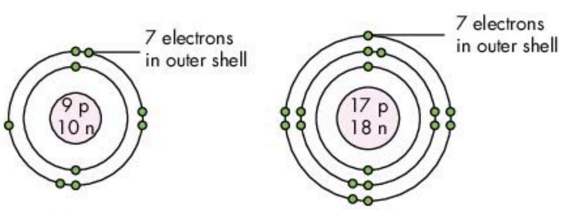
These include oxygen and sulphur. They have six electrons in their outer shell. They are reactive non-metals. In chemical reactions they either gain two outer electrons to become ions with two negative charges (**anions**) or they share electrons.



2,6 *oxygen* 2,8,6 *sulphur*

Group 7: The halogens

These include fluorine and chlorine. They have seven electrons in their outer shell. They are very reactive non-metals. They easily gain one outer electron, to become ions with one negative charge (anions), or they share electrons.



2,7 *fluorine* 2,8,7 *chlorine*

▶ **See Workbook Chemical bonding.**

18.1 Names and symbols

Materials: sheets of pink, green and blue card, ruler, pencil, scissors, marker pen

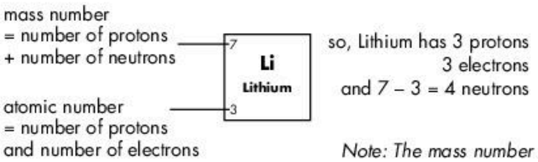
Method

1. Use your instruments to measure, mark and cut each sheet of card into 24 small pieces.
2. On one set of seven pink pieces (to show metals), write the names of the elements. On another set, write their symbols and, on a third set, name their group and arrangement of electrons.
3. On one set of nine green pieces (to show non-metals), write the names of the elements. On another set, write their symbols and, on a third set, name their group and arrangement of electrons.
4. On one set of three blue pieces (to show noble gases), write the names of the elements. On another set, write their symbols and, on the third set, name their group and arrangement of electrons.
5. Mix up your card pieces and then sort them into cards belonging together.
6. Design a game to play with the cards.

Atoms

When comparing the mass of atoms, the mass of a proton and the mass of a neutron are each taken as 1. The mass of an electron is very much smaller and is ignored (see table).

Each atom has a **mass number** and an **atomic number**:



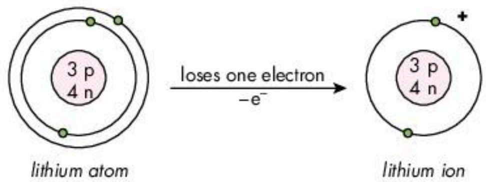
Note: The mass number is also the nucleon number.

Forming ions

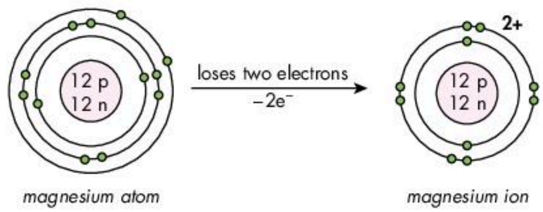
Atoms are neutral: they have the same number of electrons as protons (look at the previous pages). In reactions, atoms lose or gain electrons to become positive or negative ions.

- Metals lose electrons: as electrons have a negative charge, the ions will be positive cations (check the numbers).

Group 1 loses one electron: the ion is charged (+)

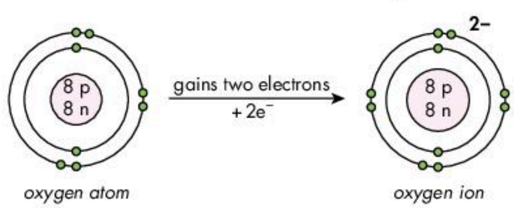


Group 2 loses two electrons: the ion is charged (2+)

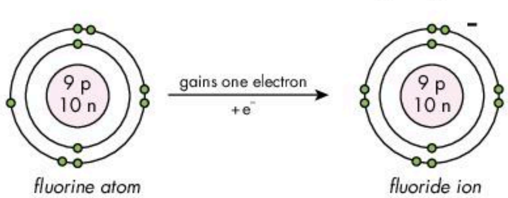


- Non-metals gain electrons: as electrons have a negative charge, the ions will be negative anions (check the numbers).

Group 6 gains two electrons: the ion is charged (2-)



Group 7 gains one electron: the ion is charged (-)



Parts of an atom			
	Position	**Charge**	**Relative mass**
Proton	nucleus	positive	1
Neutron	nucleus	neutral	1
Electron	orbit	negative	1/1860

Note: Protons and neutrons together are called nucleons

18.2 Protons and neutrons

Materials: periodic table

1 Prepare a table (as below) in your Exercise book. One is done for you.

Element	**Number of** Protons	Neutrons	**Mass number**
H	1	0	1

2 Work out and record the numbers for atoms of the first 20 elements.

Fun facts

- It would take a hundred million atoms side-by side to cover 1 centimetre.
- Most of an atom is empty space; the nucleus is 10 000 times smaller than the atom.

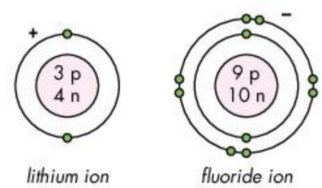
Formation of ions		
Atoms	**Symbol**	**Charge on ions**
Metals		
Lithium	Li	+
Sodium	Na	+
Potassium	K	+
Beryllium	Be	2+
Magnesium	Mg	2+
Calcium	Ca	2+
Non-metals		
Oxygen	O	2-
Sulphur	S	2-
Fluorine	F	-
Chlorine	Cl	-

In forming ions, the outer shells become complete with 2 or 8 electrons (the duplet or octet rule).

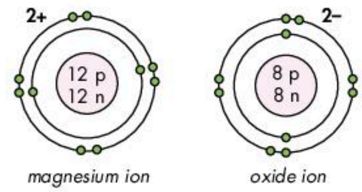
Ionic bonding

When metals and non-metals interact, they form positive and negative ions that attract. This is called **ionic bonding**. The ions combine so that the overall result is neutral. So, for example, if the non-metal ion has two +ve charges it will combine with two metal ions each with one charge, so the chemical formula for lithium oxide is Li_2O.

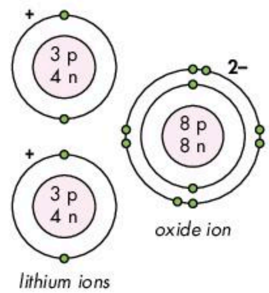
lithium + fluorine = lithium fluoride (LiF)



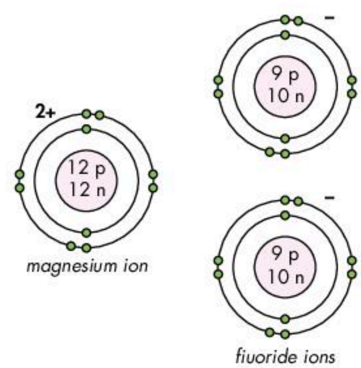
magnesium + oxygen = magnesium oxide (MgO)



lithium + oxygen = lithium oxide (Li_2O)



magnesium + fluorine = magnesium fluoride (MgF_2)

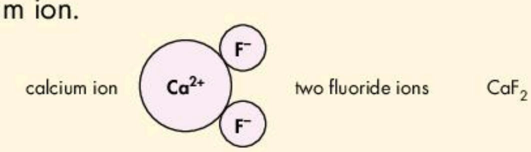


18.3 Making ionic compounds

Materials: cards with symbols of elements 1–20 and those with group numbers and arrangements of electrons

Method

1 Choose one metal (pink card) and one non-metal (green).
2 Sketch structures of the ions the atoms will make (with the number of charges and whether they are negative or positive). How can you work it out?
3 Form a molecule so that the overall charge is zero. For example, when combining calcium (2+) with fluoride ions (-), you will need two fluoride ions to interact with one calcium ion.



4 Name your compound (its formula is CaF_2).
5 Repeat the above twice more, choosing each time a card with a metal and one with a non-metal.
6 Now make sodium chloride, beryllium oxide, or potassium sulphide. Write the chemical formula.

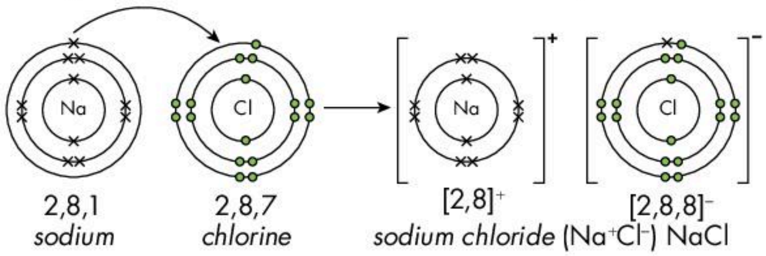
Chemical names and formulae

- The names and symbols of the elements are used.
- The metal part is listed first, e.g. sodium + chlorine = sodium chloride
- If there are just two elements, the name of the second part ends in –ide, e.g. magnesium + oxygen = magnesium oxide
  iron + sulphur = iron sulphide
- The number of atoms is sometimes shown in the name, e.g. carbon dioxide has two oxygen atoms per molecule.
- We write small numbers to follow a symbol to show how many of each atom is present in the molecule, e.g. Na_2O = sodium oxide, with two atoms of sodium and one oxygen, $BeCl_2$ = beryllium chloride, with one atom of beryllium and two chlorine.

▶ **See Workbook Chemical bonding.**

Ionic bonding (cont.)

- Ionic bonding occurs between metals and non-metals, for example, between sodium and chlorine.
- Electrons are **transferred** from the metal to the non-metal atom so that each ion has 8 electrons in the outer shell.
- The number of electrons that are transferred depends upon the combining power (determined by the number of electrons in the outer shells of the atoms).
- The metal becomes a positive ion and the non-metal a negative ion. These attract to form the compound.



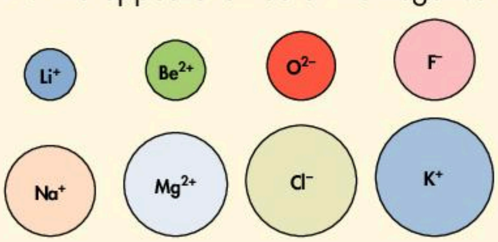
18.4 More ionic compounds

Materials: paper, crayons, scissors

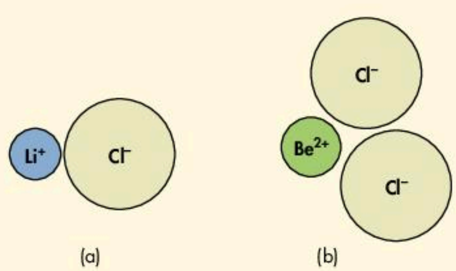
Method

1 Make some circles to represent the ions of lithium, beryllium, oxygen, fluorine, sodium, magnesium, chlorine and potassium. Make several copies of each ion.

Note: Where the ion has been made by loss of an electron it has a positive (+) charge. If two electrons have been lost it is marked 2+. The opposite is true of the negative ions.



2 Now make lithium chloride with the model circles. As each has a single charge, you need one of each (**a**) below.



3 But for beryllium chloride, you need two chloride ions (**b**) above for each beryllium one.

4 Make other ionic compounds and write their names and chemical formulae.

Ionic or covalent bonding

- Ionic bonds form when a metal reacts with a non-metal, for example, a group 1 or 2 metal with a group 6 or 7 non-metal.
- Compounds are likely to be covalent when two non-metals react. This is because the power of the atoms to attract electrons is similar: neither can pull the electron to make an ion.
- Non-metal gases, e.g. oxygen, chlorine and hydrogen also have covalent bonds in their molecules.
- Therefore, non-metals can form both ionic and covalent bonds depending on what they react with.

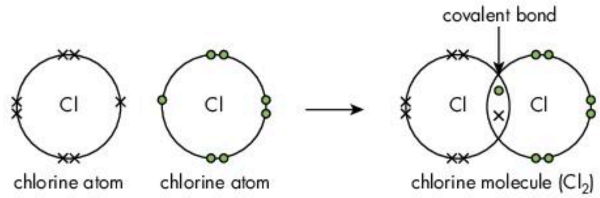
Combining power

- The **combining power** of an atom is the number of electrons it loses, gains or shares during a chemical reaction.
- It depends on the number of electrons in the outer shell of the atom:
  - metals: combining power = number of electrons,
  - non-metals: combining power = 8 minus the number of electrons.
- The combining power tells us the number of charges (ionic) or bonds (covalent) an atom makes as it forms compounds.
- Some atoms stay together in groups called radicals. They each have a certain combining power.

Combining power		
Atoms	**Electrons in outside shell**	**Combining power**
H	1	1
Na, K Mg, Ca, Cu, Zn Al	1 2 3	1 2 3
C, Si N, P O, S F, Cl	4 5 6 7	4 3 2 1
Radicals Carbonate (CO_3) Sulphate (SO_4) Nitrate (NO_3) Hydroxide (OH)		 2 1

Covalent bonding

- Covalent bonding occurs between non-metals, for example, carbon and oxygen, and in gases, e.g. chlorine.
- Electrons are **shared** between the non-metal atoms so that each one has 2 or 8 electrons in the outer shell.
- The number of electrons that are shared depends upon the combining power (determined by the number of electrons in the outer shells of the atoms).
- The non-metals stay together because of their shared electrons. This forms the covalent compound.

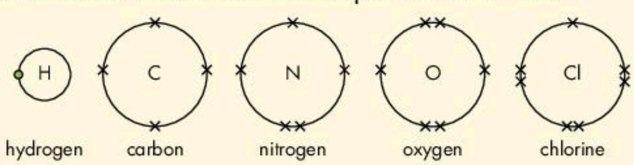


We show only the electrons in the outer shells

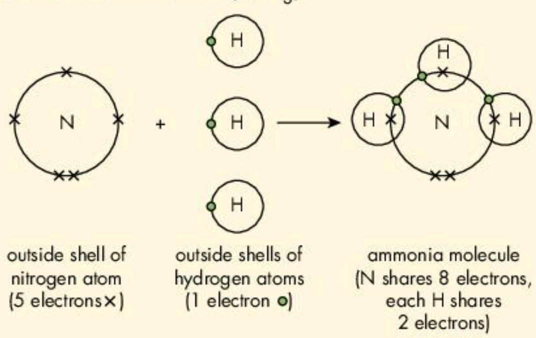
18.5 Sharing electrons: covalent compounds

Materials: wax paper, pen, scissors
Method

1 Make models to show the outer shell of electrons for the non-metal elements: hydrogen, carbon, nitrogen, oxygen and chlorine. Make several copies of each one.



2 Make a model of an ammonia molecule, with nitrogen and hydrogen. Check the table of combining powers: you need three hydrogen atoms to interact with one nitrogen atom to make ammonia (NH_3).



3 Use other shells to make models of molecules: hydrogen chloride (HCl), water (H_2O) and carbon dioxide (CO_2).
4 Hydrogen, oxygen, chlorine and nitrogen gas each have molecules made of two atoms sharing electrons. Make the models.
5 Write chemical formulae for all your molecule models.

Combining power and valency

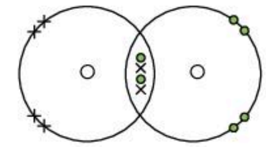
- Valency is a measure of the combining power of an element when it forms chemical compounds or molecules.
- Valency is related to the number of electrons in the outer shells.

Group	1	2	3	4	5	6	7	0
Valency	1	2	3	4	3	2	1	0

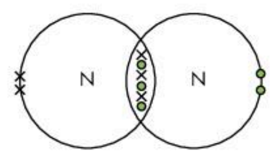
- The noble gases (group 0) have a valency of 0 as they do not usually combine with other elements.

Some covalent compounds

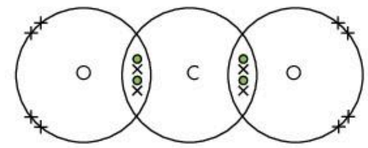
Check the structures and see how the chemical formulae are written.



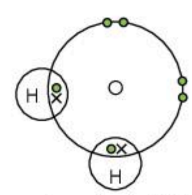
oxygen molecule O_2



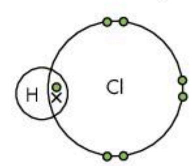
nitrogen molecule N_2



carbon dioxide molecule CO_2



water molecule H_2O



hydrogen chloride molecule HCl

▸ **See Workbook Chemical bonding.**

18.6 Ionic and covalent compounds

Materials: pink and green cards with group numbers and arrangements of electrons

Method

1 Choose a pink and a green card, e.g. potassium (Group 1: electrons 2, 8, 8, 1) and sulphur (Group 6: electrons 2, 8, 6). Decide how they will form ions (to make their outer shells into 8 electrons) and the name and formula of the ionic compound. Repeat with other pairs of metals and non-metals and fill in a table.

+ ve ion	electrons lost	– ve ion	electrons gained	formula of compound	name of compound
K^+	1	S^{2-}	2	K_2S	potassium sulphide

2 (a) Choose a non-metal (green card) of an element that is a gas at room temperature. It has molecules of two atoms held together by shared electrons. Fill in the table below.

(b) Choose two green cards (two different non-metals). Check their arrangements of electrons and fill in the table below.

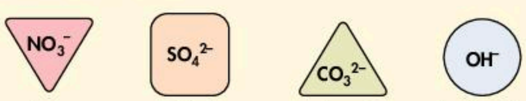
non-metal	electrons shared	non-metal	electrons shared	formula and name of compound
chlorine carbon	1 4	chlorine oxygen	1 2	Cl_2 (chlorine gas) CO_2 (carbon dioxide)

3 Construct models of all your molecules.

18.7 Compounds with radicals

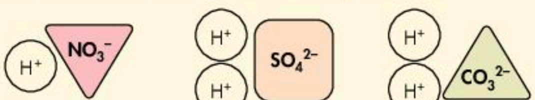
Materials: wax paper, pen, scissors

1 Trace over the pictures representing the radicals shown in the box on the right. Or you can trace over the simpler models shown below.



nitrate sulphate carbonate hydroxide

2 Now, choose a metal ion and make some compounds containing radicals. As an example, here is the hydrogen ion used to make some acid compounds.



HNO_3 nitric acid; H_2SO_4 sulphuric acid; H_2CO_3 carbonic acid

3 Make other compounds with radicals. Write the formulae.

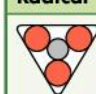
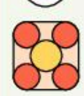
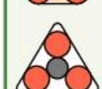
Making models: Models are a simple way to try to understand the structure of something, for example:

- *Atomic structure*: make an atom with a central nucleus (with two colours of small, similar size balls for protons and neutrons) and 'electrons' as very small balls on wire shells held outside it.
- *Atoms*: use balls of different coloured modelling clay (make the sizes represent the relative size of the atoms of the element).
- *Ions*: add bumps of modelling clay to show where atoms gained electrons (– ve) charge; and small pits where they lost electrons (+ ve) charge. Use your ions to combine to make molecules with an overall neutral charge.
- *Covalent molecules*: use different coloured clay balls for non-metal atoms. Push small pieces of matchstick into the balls to represent the number of shared electrons. Match up your molecules with the same numbers of shared electrons.

Radicals

Radicals are groups of atoms that stay together. They have an overall combining power of a negative charge. They make ionic compounds with metal ions.

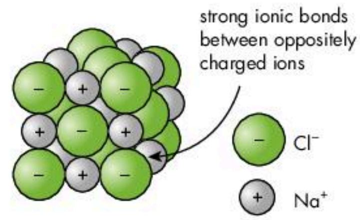
In chemical formulae they may or may not be enclosed in brackets, e.g.: $Mg(OH)_2$, $ZnSO_4$, K_2SO_4 $Ca(NO_3)_2$, $LiNO_3$, Na_2CO_3

Radical	Name	Combining power
	nitrate (NO_3)	– (single negative)
	hydroxide (HO)	– (single negative)
	sulphate (SO_4)	2^- (two negative)
	carbonate (CO_3)	2^- (two negative)

Key: = oxygen, = nitrogen, = sulphur, = carbon, = hydrogen,

Structure and properties

When studying Chemistry you will find many times when you can use the structure of an atom, ion or molecule to predict the properties (how the element or compound will behave). You will also find what seem to be exceptions to your 'rules'. But if you look a little closer, you will find a reason for the difference and will have found a new rule.



Tightly packed ions of sodium chloride

Ionic compounds

Calcium chloride and magnesium sulphate are examples. Ionic compounds have strong bonds between the ions (see the model of sodium chloride).

- Because the attraction is high between the ions, it is more difficult for an ionic compound to become a liquid, so ionic compounds have high melting points.
- Because the ions are held tightly together, the solid does not conduct electricity.
- However, when melted or dissolved in water the ions can separate and then the compound can conduct electricity.

Covalent compounds

For simple compounds, e.g. carbon dioxide and chlorine, the covalent bonds are strong between the atoms but weak between the molecules.

- So, the melting points are low and many simple covalent compounds are gases at room temperature.
- The electrons are shared within the molecules so there are no free ones to conduct electricity.

Many covalent compounds form giant structures with strong bonds between molecules as well as within molecules, for example most forms of carbon.

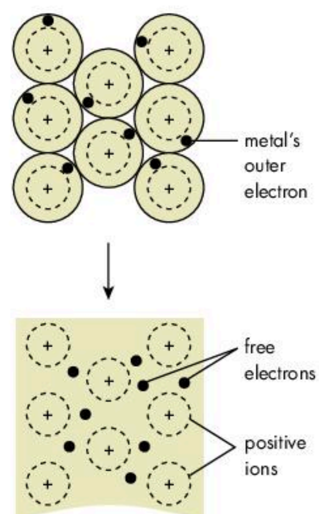
- The molecules are held together, so the melting point is therefore high.
- As there are no ions or free electrons, they do not conduct electricity.

The exception to the rule

Graphite is a form of carbon and therefore a non-metal. You would think it could not conduct electricity – but it does! Why? In graphite the carbon atoms are arranged in layers and there are free electrons that can move around – and therefore conduct electricity.

Here is another rule

Metals conduct electricity – why? The atoms in a metal are packed closely together in layers. The outer electrons become separated from the rest of the atom (which becomes a positive ion). The metal is held together by the attraction between the electrons and the positive ions. This attraction means that the melting points of most metals are high.



The electrons are free to move, and so metals can conduct electricity both when they are solid and when they are melted to liquids.

▶ **See Workbook Chemical bonding.**

Quick check ☑

________ atoms lose ________ to become ________ charged ________. Non-metals can form ________ and ________ compounds. The valency of an atom depends on the number of ________ in the outer shell.

Use these words to fill in the spaces as you write the sentences in your Exercise book

positively	**ionic**	**metal**
ions	**electrons**	**covalent**

Chemical reactions

Reactants and products

In a chemical reaction, substances react to form new ones. We can write a word equation for the reaction.

- **Reactants:** these are the substances we start with. We write their names on the left in a word equation.
- **Products:** these are the new substances produced. We write their names on the right in a word equation.

For example: when magnesium is burnt in oxygen, the reactants are magnesium and oxygen, and the product is magnesium oxide. We write the word equation as:

magnesium + oxygen → magnesium oxide

When we dissolve magnesium oxide in water, it makes magnesium hydroxide. The reactants are magnesium oxide and water, and the product is magnesium hydroxide:

magnesium oxide + water → magnesium hydroxide

The law of conservation of mass

In a chemical reaction atoms in the reactants are rearranged to form the products. The numbers of different atoms on the left side will be equal to the numbers of the atoms of the same element on the right side. No atoms are lost or gained; matter is conserved. This is the law of conservation of mass.

The total mass of the reactants = the total mass of the products. How can we show this in an experiment? We choose:

- a reaction that does not produce a gas (a gas could escape into the air and not be measured, or explode if we were using a sealed container)
- a reaction where one of the products is an insoluble solid (a precipitate): this shows us when the reaction is complete.

18.8 The law of conservation of mass

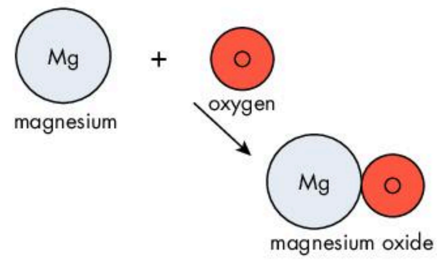
Materials: top-loading balance, measuring cylinders, lead nitrate solution, potassium iodide solution

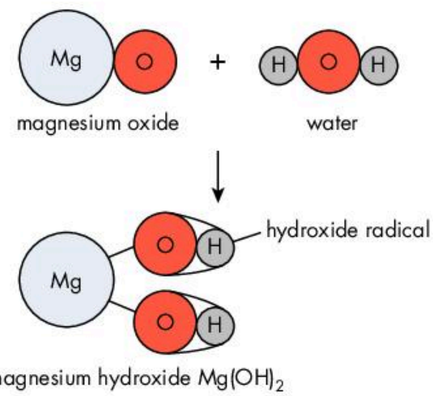
Method

1. Find the mass of one empty measuring cylinder.
2. Add 10 cm^3 of lead nitrate solution and record the mass.
3. Find the mass of another empty measuring cylinder.
4. Add 10 cm^3 of potassium iodide solution and record the mass.
5. Pour one solution into the other. Observe and then record the new mass.
6. Calculate the mass of the reactants and products. What do you notice?
7. Write a word equation for the reaction.

Objectives

- Explain and give examples of the terms reactants and products.
- Investigate the law of conservation of mass and say why it is important.
- Name examples of endothermic and exothermic reactions.
- Identify a range of chemical reactions and write word equations.





In the two reactions, count the numbers of atoms in the reactants, and the products: they are equal

Exothermic and endothermic reactions

Bond breaking needs energy; bond making releases energy. Whether a reaction, overall, needs or releases energy depends on the particular reactants and products.

An **exothermic** reaction releases energy. As the atoms in the reactants are broken and rearranged and new bonds formed in the products, there is an overall release of energy. We can sometimes feel the container become warmer.

Some examples are:

- reactions of acids with metals
- neutralisation of acids with bases
- burning or combustion of fuels (including the combustion of foods in the process of respiration).

An **endothermic** reaction takes in energy. Overall, more energy is needed to break bonds than to make new ones. We can sometimes feel the container become cooler.

Some examples are:

- dissolving potassium or ammonium nitrate in water
- decomposition of carbonates
- combination of carbon dioxide and water in photosynthesis (requires energy input from solar energy via chloroplasts).

PS 18.9 Exothermic and endothermic reactions

Materials: glass trough with water, forceps, knife, sodium kept under oil, beaker of water, few grams of potassium or ammonium nitrate or ammonium chloride

Your teacher may demonstrate these reactions.

1 A small piece of sodium is carefully cut off from the metal and transferred by forceps. (Sodium is kept under oil away from the air, as it is very reactive with oxygen.)
2 The small pellet of sodium is put into the water in the glass trough. Observe and record what happens. Feel the trough before and after the reaction. Has energy been released or absorbed? What kind of reaction has occurred?
3 A few grams of potassium or ammonium nitrate or ammonium chloride are measured and put into the beaker of water.
4 Observe and record what happens. Feel the beaker before and after the reaction. Has energy been released or absorbed? What kind of reaction has occurred?

Different types of chemical reactions

In the following pages you will investigate different types of chemical reactions:

- Oxidation and Combustion
- Decomposition
- Synthesis
- Displacement

Fun facts

- A cold pack contains separate packets of ammonium chloride and water. When the packets are broken, the chemical reaction makes the pack cold.

What does it mean?

Chemical reaction: The rearrangement of reactants to make new substances, the products.

Exothermic: Heat is given out in a chemical reaction.

Endothermic: Heat is taken in during a chemical reaction.

Physical reaction: No new substances are formed and there is no change in energy; the original substances can be separated by physical means.

PS 18.10 Two reactions

Materials: small amounts of salt (sodium chloride) and quicklime (calcium oxide); two beakers of water, two stirrers

Method

1 Carefully put some salt into a beaker with water. Stir it. Observe and record your observations.
2 Carefully put some quicklime into a beaker with water. Stir it. Observe and record your observations.

Questions

1 For salt: Has there been a change in temperature? Do you think a chemical or a physical reaction has taken place? Would you be able to separate the salt from the water? How?
2 For quicklime: Has there been a change in temperature? Do you think a chemical or a physical reaction has taken place? Would you be able to separate the quicklime from the water? How?
3 Write any word equations to show chemical reactions.

Types of chemical reactions

A. Oxidation reactions

(a) Metals combining with oxygen

PS 18.11 The reactions of magnesium, a metal

Materials: magnesium ribbon, gas jar with lid, deflagrating spoon, matches, distilled water, test tubes, litmus paper, dilute hydrochloric acid, wooden splint

Method

Record your results in the Workbook.

Heat magnesium with the oxygen in the air.

1. Put a small piece of magnesium ribbon into a deflagrating spoon (**a**). Light a match and hold it near to the ribbon to make it burn. (Do not look at the flame, as it is very bright.) (**b**). Quickly plunge the burning magnesium into the gas jar (**c**).
2. When the burning has stopped, remove the spoon. Add a little distilled water to the gas jar and then add a lid. Shake the jar around (**d**). Add a piece of neutral (purple) litmus paper (**e**). Record what happens. What has been made? Was the reaction exothermic or endothermic?

Find how magnesium reacts with water.

3. Put a small piece of magnesium ribbon into distilled water in a test tube. Observe if there is any reaction.

Find how magnesium reacts with dilute hydrochloric acid.

4. Put a small piece of magnesium ribbon into a test tube. Add 2 cm depth of dilute hydrochloric acid. Observe and record.
5. Put your thumb over the top of the test tube to stop the gas escaping (**f**)
6. Plunge a lighted splint into the neck of the test tube (**g**). If hydrogen is produced, a 'pop' will be heard.

▶ **See Workbook Chemical reactions.**

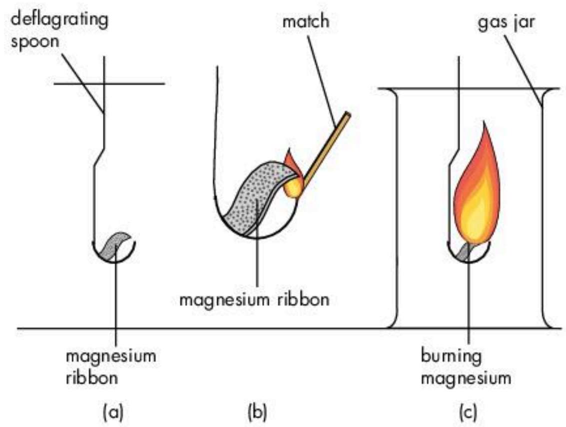
What does it mean?

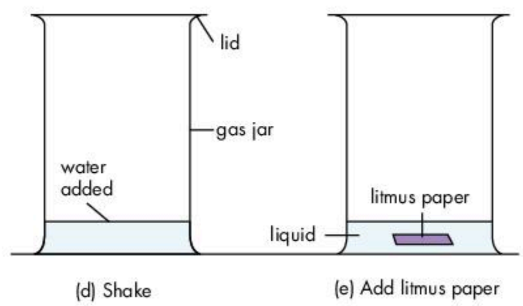
Oxidation: having oxygen added, or hydrogen removed, in a reaction.

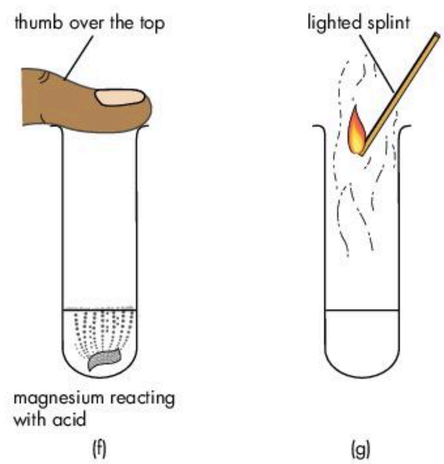
Reduction: having oxygen removed, or hydrogen added, in a reaction.

Basic oxide: formed when metals combine with oxygen. They turn damp litmus paper blue.

Acidic oxide: formed when non-metals combine with oxygen. They turn damp litmus paper red.







The reactivity of metals

Various metals react differently with air. See how their reactivity compares.

Reactivity series of metals	
Metal	**With air**
Potassium	Reacts very rapidly } stored
Sodium	Reacts rapidly } under oil
Calcium	Reacts quickly
Magnesium	{ Become coated with
Aluminium	{ a protective layer
Zinc	{ of the metal oxide
Iron	Rusts slowly with moist air
Copper	Reacts slowly to form the oxide

(b) Non-metals combining with oxygen

18.12 The reactions of sulphur, a non-metal

Materials: sulphur, gas jar with lid, deflagrating spoon, matches, distilled water, test tubes, litmus paper, dilute hydrochloric acid, wooden splint

Method

Record your results in the Workbook.

Heat sulphur with the oxygen in the air.

1. Put a little sulphur powder into a deflagrating spoon. Start it burning by using a lit match. Quickly plunge the burning sulphur into the gas jar.
2. When the burning has stopped, remove the spoon. Add a little distilled water to the gas jar and then add a lid. Shake the jar around. Add a piece of neutral (purple) litmus paper. Record what happens. What has been made? Is this what you expected? Was the reaction exothermic or endothermic?

Find how sulphur reacts with water.

3. Put a small amount of sulphur into distilled water in a test tube. Observe if there is any reaction.

Find how sulphur reacts with dilute hydrochloric acid.

4. Put a small amount of sulphur into a test tube. Add 2 cm depth of dilute hydrochloric acid. Observe and record.
5. If there is a reaction, then carry out the test for hydrogen.

▸ **See Workbook Chemical reactions.**

Sulphur being heated with oxygen in the air

(c) Combustion

Combustion is also a reaction with oxygen. Oxygen combines with organic compounds (ones containing carbon) to give carbon dioxide and water molecules with the release of energy. There are two main examples of combustion:

- Burning of **fossil fuels**, which are largely made up of compounds of hydrogen and carbon. Sulphur is also present in some fuels. When fossil fuels are burned, the hydrogen, carbon and sulphur all combine with oxygen to make oxides and energy is released (flames are produced). The main products are hydrogen oxide (water), carbon dioxide and sulphur dioxide. Carbon and sulphur dioxide (examples of non-metal oxides) dissolve in rainwater and contribute towards acid rain.
- Respiration of **food**, such as glucose. Glucose is made up of carbon, hydrogen and oxygen. During respiration, the carbon and hydrogen combine with oxygen to form the oxides, water and carbon dioxide. You can test exhaled air with limewater to show the presence of carbon dioxide. Enzymes control the respiration process: energy is released slowly and transferred to other molecules to be used in the cell.

Incomplete combustion

- When fossil fuels are burnt, there is sometimes not enough oxygen to change all the carbon into carbon dioxide. In this case the combustion is **incomplete**.
- This means that carbon monoxide and carbon may be formed as products.
- The carbon monoxide is a poisonous gas produced from some car exhausts. It combines with the haemoglobin in the blood. This stops the haemoglobin from doing its job of transporting oxygen.
- The carbon is seen as soot, which makes things dirty and can harm the lungs.

The burning of fossil fuels can be dangerous for many reasons

B. Synthesis reactions

(a) Metal plus non-metal

Synthesis is the combination of simpler substances to make larger ones. The reaction between iron and sulphur is an example. In Grade 8 you did an activity with these elements and the mixture and the compound made from them. You will now repeat part of that activity and examine the chemical reaction that occurs.

PS 18.13 Joining of iron and sulphur

Materials: iron filings, sulphur, test tubes, test tube rack, magnet, teaspoons, dilute hydrochloric acid, Bunsen burner, tin lid or bottle top, tongs, pestle and mortar

Method

Properties of the reactants

Do these tests on the mixture. Record your results.

1 Test the mixture with a magnet.
2 Shake some with half a test tube of water. Let it stand.
3 Add some to half a test tube of dilute hydrochloric acid.

Properties of the product

Your teacher will combine 10 g of iron filings with 7 g of sulphur and give you some of the mixture. Heat this on a metal lid until it is red hot. This will make the compound iron sulphide. Let it cool and break it up in a pestle and mortar to make a powder. Carry out the same tests as above and record your results.

Questions

1 Write the word equation.
2 How do the elements in the mixture react differently to the compound that is formed from them?
3 Do you think that the making of iron sulphide is a physical or chemical change? Give reasons for your answer.
4 Was the reaction exothermic or endothermic?

▸ **See Workbook Chemical reactions.**

(b) Photosynthesis

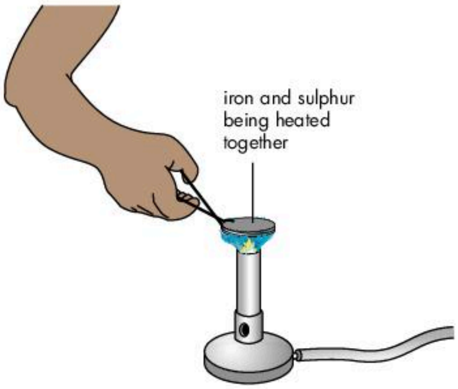
In photosynthesis, carbon dioxide is combined with water to form carbohydrates, such as glucose and oxygen. This chemical reaction can only take place in the presence of light (which provides energy), chlorophyll (which traps energy and makes it available for the reaction) and special enzymes. This reaction takes in energy: it is endothermic. The energy is used to make the high-energy bonds in the glucose.

$$\text{carbon dioxide} + \text{water} \rightarrow \text{glucose} + \text{oxygen}$$

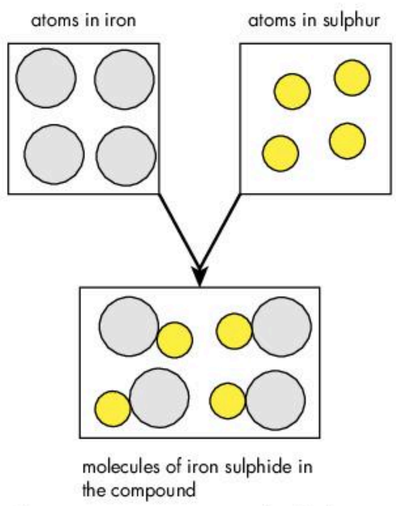
This is the reaction on which all life depends; it produces the food and oxygen for all animals and plants.

Synthesis reactions

- The combination of iron and sulphur, hydrogen and oxygen, and carbon and oxygen are all examples of synthesis reactions.
- These reactions release energy and so are exothermic.



Making the compound: iron sulphide



The reactants iron and sulphur combine to make the product: iron sulphide

Photosynthesis

- This means 'using light for building'. Light energy is trapped by chlorophyll and used in the production of glucose and oxygen.
- Because photosynthesis absorbs energy to make the reaction happen, it is endothermic.
- The product of photosynthesis is carbohydrate, such as glucose. Glucose can later be respired to release the trapped energy during respiration.

C. Decomposition reactions

Thermal decomposition

In a **decomposition** reaction a single compound breaks down into two or more elements or new compounds. These reactions usually need an energy source, such as heat or electricity that breaks apart the bonds of the compound.

You will carry out a thermal decomposition, where the energy source is heat. You will observe the changes that occur and test for any gas that is produced.

18.14 Thermal decomposition

Materials: copper carbonate, calcium carbonate, spoons, test tubes, Bunsen burner, glass rod, limewater (calcium hydroxide)

Method

Copper carbonate

1 Put a small amount of copper carbonate into a test tube. Note its colour.
2 Heat the copper carbonate strongly with the Bunsen flame. What do you observe?
3 You can test the gas given off. Hold a drop of limewater at the neck of the test tube to see if carbon dioxide has been produced.
4 Write a word equation for the reaction.

Calcium carbonate

5 Put a small amount of calcium carbonate into a test tube, Note its colour.
6 Heat the calcium carbonate strongly with the Bunsen flame. What do you observe?
7 Test for any gas given off. Hold a drop of limewater at the neck of the test tube to see of carbon dioxide has been produced.
8 Write a word equation for the reaction.

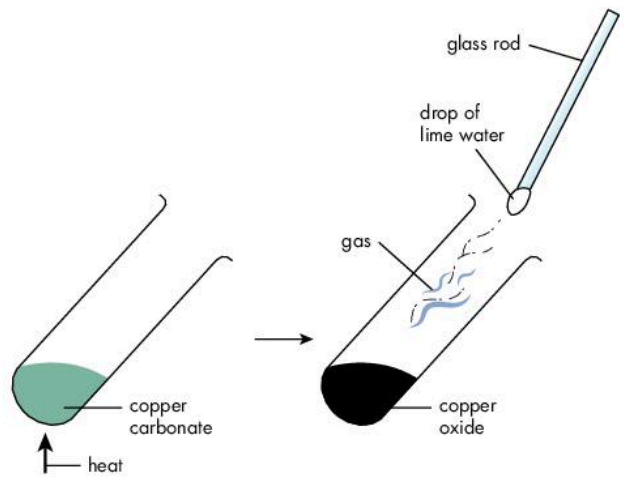
Questions

1 Which carbonate was easier to decompose?
2 In which reaction was it easier to see when the decomposition was complete?
3 What do you predict will be the products when
(a) iron carbonate
(b) zinc carbonate
are heated strongly? Write the word equations.
4 Your friend has heard of sodium bicarbonate (also called sodium hydrogencarbonate or baking soda) and wonders if it decomposes when heated. Explain to her how she could set up an activity to find out. Advise her on how she could test for any gas produced. With your teacher's permission you could also try out the activity.

Types of decomposition

Decomposition needs energy: it is an endothermic reaction.

- Thermal decomposition: the energy needed is supplied as heat, e.g. the thermal decomposition of carbonates.
- Decomposition using an electric current: e.g. the electrolysis of water to produce oxygen and hydrogen.



Copper carbonate decomposes to make copper oxide and carbon dioxide

Test for carbon dioxide

A drop of limewater (calcium hydroxide) is held on a glass rod at the neck of the test tube to test any gas produced.

If the limewater goes milky, it means calcium carbonate is now suspended in the limewater. This shows carbon dioxide was released. Write the word equation.

Fun facts

- Not all the carbonates of Group 1 metals decompose at the temperatures reached by a Bunsen burner.
- Light can be used as the source of energy for the decomposition of some compounds, e.g. oxygen molecules can be broken down by ultraviolet light and this leads to the production of ozone.

▸ See Workbook Chemical reactions.

D. Displacement reactions

(a) Metal with another metal solution

In a displacement reaction, an element (often a metal) will displace a less reactive one from its compound. To observe this we can use:

- a reactive metal, such as magnesium
- a solution containing a salt of a less reactive metal, preferably coloured so we can watch the reaction.

Reactivity series of metals	
Potassium (K)	(most reactive)
Sodium (Na)	
Calcium (Ca)	
Magnesium (Mg)	
Aluminium (Al)	
Zinc (Zn)	
Iron (Fe)	
Copper (Cu)	(least reactive)

18.15 Displacement reaction

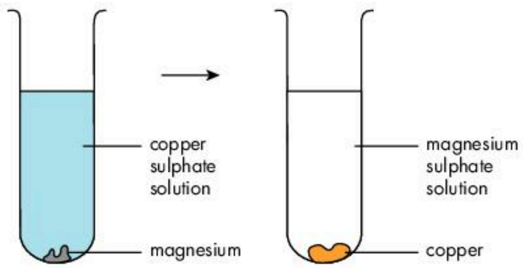
Materials: magnesium powder, copper sulphate solution, test tube rack, glass rod

Method

1 Record the colours of the magnesium powder and the copper sulphate solution.
2 Add a small amount of magnesium to the copper sulphate solution and stir with the rod.
3 Record any colour changes you see.
4 What do you think happened? Write a word equation.

Questions

1 Why is this called a displacement reaction?
2 What do you think would happen the other way around – if you put copper powder into magnesium sulphate solution?



magnesium + copper sulphate → magnesium sulphate + copper

What does it mean?

Displacement reaction: A more reactive element, e.g. a metal displaces a less reactive one from its compound.

Double displacement reaction: One ion, usually of a metal, in one compound displaces a less reactive ion from another compound and the two remaining parts join up.

(b) Double displacement: swapping partners

When we mix solutions of two compounds, the more reactive ion in one compound displaces the less reactive ion from the other compound. The other two parts can then join together.

18.16 Double displacement reaction

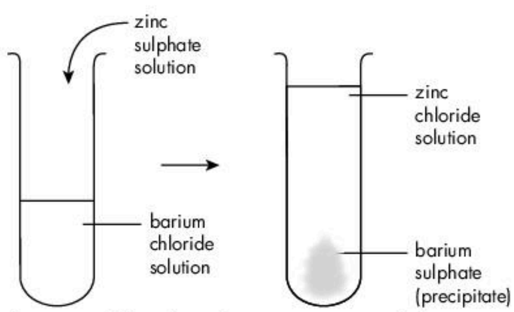
Materials: barium chloride solution, zinc sulphate solution, test tube rack, glass rod

Method

1 Record the appearance of the barium chloride and zinc sulphate solutions.
2 Pour the zinc sulphate solution into the barium chloride solution and stir with the rod.
3 Record any changes you see.
4 What do you think happened? Write a word equation.

Questions

1 Why is this called a double displacement reaction?
2 What do you think would be formed if you mixed silver nitrate and sodium chloride solutions?



barium chloride solution + zinc sulphate solution → barium sulphate (precipitate) + zinc chloride solution

▶ **See Workbook Chemical reactions.**

Reactions of metals

When metals are part of a reaction, we find that some react more readily than others. A table of the metals in order of their reactivity has been made (box on the left).

You have just seen how the position in the table is important in predicting which metal will replace another. We can also use the table to predict how different metals will react with water and dilute acids (see below).

Reactivity series of metals			
Metal	**With water**	**With dilute acid**	
K	Violent with cold water	Explosive	hydrogen gas is produced
Na	Vigorous with cold water	Violent	
Ca	Rapid with cold water	Vigorous	
Mg	Reacts with steam	Rapid	
Al	Red hot reacts with steam	Less rapid	
Zn	Red hot reacts with stem	Less rapid	
Fe	Red hot reacts with steam	Less rapid	
Cu	No reaction	No hydrogen	

PS 18.17 Metals with water

Materials: calcium, iron filings, water in two test tubes, Bunsen burner, test tube holder, test tube rack

Method

1 Put a small amount of calcium into some water. Record what happens.
2 Put a small amount of iron filings into some water. Record what happens.
3 If there is no reaction, gently warm the test tube.
4 Write word equations for any reactions.

Questions

1 Which of the two metals is more reactive?
2 How could you test for what is produced?
3 Why do you think your teacher did not give you potassium or sodium to test?

▸ **See Workbook Chemical reactions.**

PS 18.18 Metals with dilute acids

Materials: magnesium, iron filings, dilute hydrochloric acid, test tubes, test tube rack, wooden splint, matches

Method

1 Put a small amount of dilute hydrochloric acid into two test tubes.
2 Add magnesium to one test tube of acid. Observe and record what happens. Test for hydrogen gas (see below).
3 Add iron filings to the other test tube of acid. Observe and record what happens. Test for hydrogen gas.

Questions

1 Which metal was more reactive?
2 Was hydrogen gas produced in one or both cases?
3 Write word equations for both of the reactions.
4 How would you predict that (a) calcium and (b) aluminium would react with dilute hydrochloric acid?
5 Do you think that reacting the metals with dilute sulphuric and nitric acids would produce similar results? Discuss your answer with your teacher.

Test for hydrogen

Use a match to light the end of a wooden splint. Then hold the burning splint in the neck of the test tube.

If hydrogen has been produced in the reaction, you will hear a 'pop'. The hydrogen combines with a small explosion with oxygen in the air.

Quick check ☑

Substances made in a chemical reaction are ________. If energy is released in a reaction it is an ________ reaction. Metals form ________ oxides with oxygen. Heating of copper carbonate is a ________ reaction. Magnesium is ________ reactive than copper.

Use these words to fill in the spaces as you write the sentences in your Exercise book.

more **basic** **products** **exothermic** **decomposition**

Balancing chemical equations

1 Write the word equation

What you start with (the reactants) are on the left and what is produced (the products) are on the right. For example:

sodium + chlorine → sodium chloride

magnesium + oxygen → magnesium oxide

hydrogen + oxygen → hydrogen oxide (called water)

sodium + water → sodium hydroxide + hydrogen

copper oxide + sulphuric acid → copper sulphate + water

sodium carbonate + calcium chloride → sodium chloride + calcium carbonate

calcium hydroxide + nitric acid → calcium nitrate + water

2 Write the chemical formulae

These are made from the symbols of the elements. Use the table of combining power: a compound should be neutral.

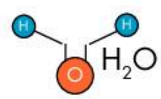
Metals with non-metals

- If they have the same combining power, there will be equal numbers of each atom in the formula:

  e.g. sodium chloride is made from sodium plus chlorine both with a combining power of 1, so the compound is NaCl

  e.g. magnesium oxide is magnesium plus oxygen: MgO.
- If they have different combining powers, the numbers of the atoms are different. We use small numbers (subscripts) in the formula to show the numbers of atoms.

  e.g. water is hydrogen plus oxygen:
  hydrogen: a combining power of 1, and
  oxygen: a combining power of 2.



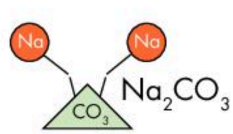
Metals with radicals

- If they have the same combining power, there will be equal numbers of each.

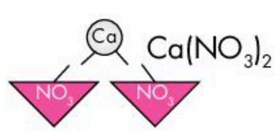
  e.g. sodium hydroxide is sodium plus hydroxide radical both with a combining power of 1, so the compound is NaOH.

  e.g. copper sulphate is copper plus sulphate radical both with a combining power of 2, so the compound is $CuSO_4$.
- If they have different combining powers, the numbers are different. We use brackets and subscripts to show this.

  e.g. sodium carbonate:
  sodium: a combining power of 1, and
  carbonate: a combining power of 2.



  e.g. calcium nitrate:
  calcium: a combining power of 2, and
  nitrate: a combining power of 1.



Objectives

- Write word equations.
- Revise the writing of chemical formulae.
- Apply the law of conservation of mass to the writing and balancing of chemical and ionic equations.

Combining power and charges

Atoms	Electrons in outside shell	Combining power
H	1	1+
Na, K Mg, Ca, Cu, Zn Al	1 2 3	1+ 2+ 3+
C, Si N, P O, S F, Cl	4 5 6 7	4– 3– 2– 1–
Radicals Carbonate (CO_3) Sulphate (SO_4)		2–
Nitrate (NO_3) Hydroxide (OH)		1–

What does it mean?

Chemical formula: The numbers of different atoms in a molecule based on the combining power of the atoms and radicals.

Subscript: A small number below the line in a chemical formula to show the number of atoms on its immediate left.

Radical: A group of atoms that stay together.

Brackets: Used to enclose a radical. A subscript after a bracket multiplies all the atoms in the radical.

Coefficient: A large number at the front of a molecule to show how many molecules are present. It multiplies all of the atoms in the molecule.

Balanced chemical equation: Chemical formulae written so all the atoms in the reactants are shown in the products.

▸ **See Workbook Chemical equations.**

3 Balance the equation

The law of conservation of mass says that the mass of reactants equals the mass of products. When we 'balance an equation' we check there are the same number of each kind of atom in reactants and products. (No atoms are lost or made.)

Remember:

- You must use all the correct chemical formulae (and not change these to try and 'balance' an equation).
- Gases interact as molecules. For example, in a chemical reaction we need to write O_2 for oxygen and not O.
- A subscript multiplies the number of atoms to its immediate left; it also multiplies all the atoms inside a radical that is inside brackets.
- A number in front of a molecule (coefficient) multiplies all the atoms in the molecule.

Steps to balance an equation

1 Write the word equation and add the chemical formulae.

magnesium + oxygen → magnesium oxide

$$Mg + O_2 \rightarrow MgO$$

2 Count the numbers of atoms in turn in the reactants and products and make them the same (balance them) by adding numbers in front of the molecules (coefficients).

(a) There are 2 oxygen atoms in the reactants, so there must be 2 in the product, so $Mg + O_2 \rightarrow 2MgO$ (the '2' in front of MgO means 2 of Mg and 2 of O).

(b) But now there are 2 magnesium atoms on the product, so there must be 2 in the reactants, so $2Mg + O_2 \rightarrow 2MgO$

3 This is now a balanced equation and we can put an 'equals' sign. $2Mg + O_2 = 2MgO$

Here is another example. Follow the three steps:

1 Write the word equation and add the chemical formulae.

magnesium oxide + water → magnesium hydroxide

$$MgO + H_2O \rightarrow Mg(OH)_2$$

(The subscript '2' after the bracket means there are two hydroxide ions and so 2 oxygen and 2 hydrogen atoms.)

2 Count the numbers of atoms in turn.

(a) Magnesium: 1 in reactions and 1 in products.

(b) Oxygen: 2 in reactions and 2 in products.

(c) Hydrogen: 2 in reactions and 2 in products.

3 The equation is balanced: $MgO + H_2O = Mg(OH)_2$

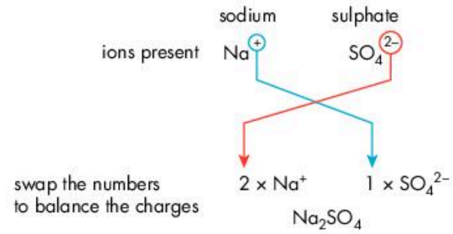
Balancing equations

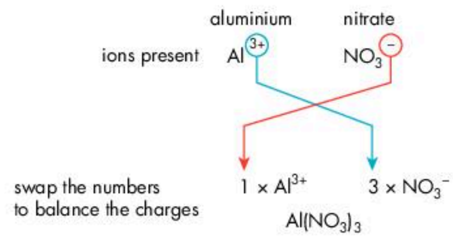
Try these examples. Follow the steps.

1 barium chloride + sodium sulphate → barium sulphate + sodium chloride
2 calcium hydroxide + nitric acid → calcium nitrate + water
3 hydrogen + oxygen → water
4 sodium + water → sodium hyroxide + hydrogen

Swap method for writing chemical formulae

This is a quick way for writing chemical formulae. You use the charges on the ions to predict the formulae of the compounds:





18.19 Balancing equations

Materials: sets of cards from your teacher

Method

Each set contains: names and chemical formulae of reactants and products, cards with the coefficient '2' and an arrow and an equals sign.

1 Set up the word equation using the names of the reactants and products and the arrow card.
2 Add the correct chemical formula under each reactant and product.
3 Make a table and record the elements in:
   - the reactants and number of atoms of each one
   - the products and number of atoms of each one.
4 For each atom, check if the numbers are the same. If not add coefficient cards in front of some of the chemicals.
5 Check again with another element.
6 Continue until your equation balances.
7 Change the arrow to an equals card.
8 Check with your teacher and then get another set of cards.

Balancing equations

Let us look at the examples you were given:

	barium chloride	+	sodium sulphate	→	barium sulphate	+	sodium chloride
Chemical formulae:	$BaCl_2$	+	Na_2SO_4	→	$BaSO_4$	+	$NaCl$
Correct sodium:	$BaCl_2$	+	Na_2SO_4	→	$BaSO_4$	+	$2NaCl$
Cl_2, Ba, SO_4: correct							
Balanced equation:	$BaCl_2$	+	Na_2SO_4	=	$BaSO_4$	+	$2NaCl$
	calcium hydroxide	+	nitric acid	→	calcium nitrate	+	water
Chemical formulae:	$Ca(OH)_2$	+	HNO_3	→	$Ca(NO_3)_2$	+	H_2O
Correct hydrogen:	$Ca(OH)_2$	+	$2HNO_3$	→	$Ca(NO_3)_2$	+	$2H_2O$
O, Ca, NO_3: correct:							
Balanced equation:	$Ca(OH)_2$	+	$2HNO_3$	=	$Ca(NO_3)_2$	+	$2H_2O$

	hydrogen	+	oxygen	→	water
Chemical formulae:	H_2	+	O_2	→	H_2O
Correct oxygen:	H_2	+	O_2	→	$2H_2O$
Correct hydrogen:	$2H_2$	+	O_2	→	H_2O
Balanced equation:	$2H_2$	+	O_2	=	$2H_2O$

	sodium	+	water	→	sodium hyroxide	+	hydrogen
Formulae:	Na	+	H_2O	→	NaOH	+	H_2
Hydrogen:	Na	+	$2H_2O$	→	2NaOH	+	H_2
Sodium:	2Na	+	$2H_2O$	→	2NaOH	+	H_2
Oxygen: correct							
Balanced:	2Na	+	$2H_2O$	=	2NaOH	+	H_2

Ionic equations

The first of the reactions above we can also show by writing the ions and how they interact. This is called an **ionic equation** (see next page). When reactions occur in solution in water, the water separates ionic compounds into their ions.

- We write the word equation.
- We write the ions and their charges.
- For example, we can write barium chloride as $Ba^{2+} + 2Cl^-$ (one barium ion plus two chloride ions). Check that the number of positive charges equals that of the negative charges.
- We write 'aq' after the ions to mean 'aqueous' or 'in water'.
- We write all the ions in the reactions in a similar way.
- If a precipitate is formed in the products, we write 's' after it to show it is a solid. This is shown as a compound, as it is no longer in the form of ions.
- To balance the ionic equation the charges must balance. We now have a full ionic equation.
- We look for ions that are in both the reactants and products. These are called **spectator** ions and can be ignored.
- We can write a simplified ionic equation that just shows the ions that interact to make the solid precipitate.

What the numbers mean

- Small numbers as superscripts show the numbers of positive or negative charges on metal and non-metal ions.
- In formulae, a subscript multiplies the number of atoms immediately to its left:
  H_2O means two hydrogen atoms and one oxygen atom
  CO_2 means one carbon atom and two oxygen atoms
  Na_2CO_3 means two sodium atoms, one carbon atom and three oxygen atoms.
- We often use brackets in formulae if there are radicals:
  $Ca(NO_3)_2$ means one calcium atom. Each nitrate radical has one nitrogen atom and three oxygen atoms, so two nitrate radicals will have two nitrogen and six oxygen atoms.
- A large number in front of a formula (called a coefficient) multiplies all the atoms that come after it:
  $2H_2SO_4$ Do one molecule first: two hydrogen atoms, one sulphur and four oxygen atoms. So in two molecules: four hydrogen, two sulphur and eight oxygen atoms.
  $2Zn(NO_3)_2$ Do one molecule first: one zinc atom, two nitrogen atoms and six oxygen atoms. So in two molecules there will be two zinc atoms, four nitrogen atoms and twelve oxygen atoms.

Balancing an ionic equation

Word equation:	barium chloride	+	sodium sulphate	→	barium sulphate	+	sodium chloride
Balanced equation:	$BaCl_2$	+	Na_2SO_4	→	$BaSO_4$	+	$2NaCl$
Ions:	$Ba^{2+}(aq) + 2Cl^-(aq)$	+	$2Na^+(aq) + SO_4^{2-}(aq)$	→	$BaSO_4(s)$	+	$2Na^+(aq) + 2Cl^-(aq)$

Identify spectator ions: They are $2Cl^-(aq) + 2Na^+(aq)$ that occur in both reactants and products. Omit these.

Write the ionic equation: $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ (precipitate)

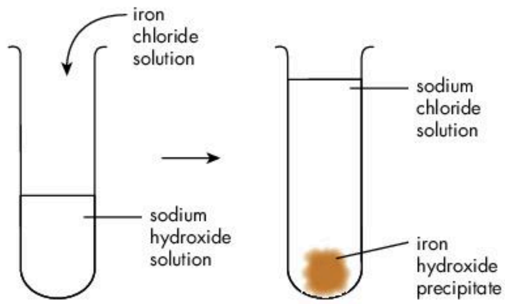
Check that the charges balance: Yes, there are 2 positive and 2 negative charges which cancel out.

Balanced ionic equation: $Ba^{2+}(aq) + SO_4^{2-}(aq) = BaSO_4(s)$

If two solutions are mixed and a solid (precipitate) is formed you can write the ionic equation like this:

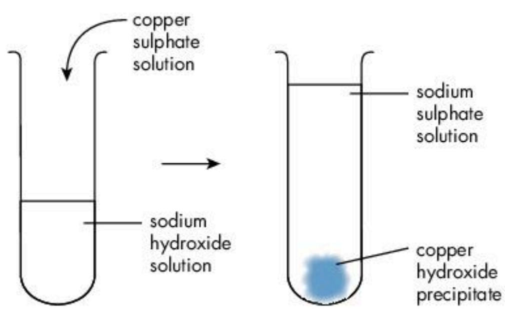
For example, when a solution of iron chloride (brown) is added to sodium hydroxide (transparent), we observe a precipitate of iron hydroxide (brown solid) in a transparent solution. We can follow these steps:

- Word equation: iron chloride + sodium hydroxide
  → iron hydroxide + sodium chloride
- Chemical formulae: $FeCl_3 + NaOH \rightarrow Fe(OH)_3 + NaCl$
- Add (aq) and (s) (these are called state symbols):
  $FeCl_3(aq) + NaOH(aq) \rightarrow Fe(OH)_3(s) + NaCl(aq)$
- Balanced chemical equation: $FeCl_3(aq) + 3NaOH(aq)$
  $= Fe(OH)_3(s) + 3NaCl(aq)$
- The precipitate is iron hydroxide: $Fe(OH)_3(s)$
- Identify the ions that combine to make the precipitate: these are $Fe^{3+}(aq)$ and $3OH^-(aq)$
- Check that the charges balance: 3^+ and $3^- = 0$
- Write the ionic equation: $Fe^{3+}(aq) + 3OH^-(aq) = Fe(OH)_3(s)$



Here is another example:
Solutions of sodium hydroxide and copper sulphate are mixed to form a precipitate of copper hydroxide.

- Word equation and state symbols:
  sodium hydroxide(aq) + copper sulphate(aq)
  → copper hydroxide(s) + sodium sulphate (aq)
- Copper hydroxide: $Cu(OH)_2(s)$ is the precipitate.
- The ions needed to make this are: $Cu^{2+}(aq)$ and $2(OH)^-$
- Check that the charges balance: 2^+ and $2^- = 0$
- So the ionic equation is: $Cu^{2+}(aq) + 2(OH)^-(aq) = Cu(OH)_2(s)$



Fun facts

- The reaction of metal salt solutions with sodium hydroxide solution can be used to identify the metal, based on the colour of the precipitate.

▶ **See Workbook Chemical equations.**

Quick check ☑

A superscript shows the ________. ________ are small numbers showing numbers of atoms. In equations, large numbers in front of molecules are ________. In equations (aq) means ________ and (s) means ________.

Use these words to fill in the spaces as you write the sentences in your Exercise book.

aqueous **charge** **products**
subscripts **solid** **coefficients**

Questions

Answer these questions in your notebook

For questions **1–23** answer **A, B, C** or **D**.

1 Which of these is a group 1 element?
A potassium **B** argon
C fluorine **D** calcium

2 How many electrons are in the outside shell of a group 1 element?
A 0 **B** 1 **C** 2 **D** 7

3 When are the shells full of electrons for the elements with atomic numbers 1–18?
A 2, 8, 8 **B** 2, 2, 8
C 8, 2, 8 **D** 8, 8, 8

4 Which particle in an atom does not contribute to the mass number?
A neutron **B** proton
C electron **D** nucleus

5 The exact number of neutrons
A equals atomic number
B equals mass number
C equals atomic number plus mass number
D cannot be predicted

6 If an ion has four protons, how many electrons will it have?
A always 4 **B** more or less than 4
C usually 4 **D** it is not possible to say

7 What does the –ide usually mean in a chemical formula? The molecules contain
A oxygen **B** only two similar atoms
C chloride ions **D** only two different atoms

8 Which of these does not contain oxygen?
A sodium chloride **B** water
C iron oxide **D** sulphuric acid

9 Ionic compounds form between
A metals and non-metals
B metals and metals
C non-metals and non-metals
D any two elements than are reactive

10 Covalent compounds form between
A metals and non-metals
B metals and metals
C non-metals and non-metals
D any two elements that are reactive

11 What is formed when sulphur is burned in air?
A oxygen **B** a basic oxide
C a salt **D** an acidic oxide

12 When the answer to Question **11** is tested with damp purple litmus paper what will happen?
A it changes to red **B** it changes to blue
C it stays the same **D** it becomes bleached

13 In an exothermic reaction
A energy is released to the environment
B energy is taken in from the environment
C there is no overall energy change
D the container feels cooler than the air

14 Which of these reactions would produce carbon dioxide?
A burning **B** acid with carbonate
C respiration **D** all of the above

15 What is the test for carbon dioxide? It
A re-lights a glowing splint
B it gives a pop with a lighted splint
C it turns limewater milky
D none of the above

16 In a displacement reaction using a metal
A a less reactive metal replaces another metal from its compound
B a more reactive metal replaces another metal from its compound
C nothing happens unless the reactants are heated
D it is impossible to predict what will happen

17 Hydrogen is made when acids react with some
A non-metals **B** metals
C carbonates **D** bases

18 A subscript in a chemical formula
A tells us about how many atoms are in a molecule
B tells us the combining power
C tells us about the charge on the ions
D is the same as the coefficient

19 If the combining power of zinc is 2, what is the combining power of a nitrate radical in $Zn(NO_3)_2$?
A 0 **B** 1 **C** 2 **D** 3

20 How many atoms of nitrogen are in $Zn(NO_3)_2$?
A 0 **B** 1 **C** 2 **D** 3

21 In the formula, K_2SO_4, the combining power of potassium is 1, what is that of the sulphate radical?
A 0 **B** 1 **C** 2 **D** 3

22 How many atoms of carbon in $2Al_2(CO_3)_3$?
A 3 **B** 6 **C** 8 **D** 18

23 In balancing a chemical reaction
A the numbers of atoms of the reactants are more than the similar atoms in the products
B the numbers of atoms of the products are more than the similar atoms in the reactants
C we just need to write the correct chemical formulae
D the numbers of atoms in the reactants should equal the numbers of similar atoms in the products

For questions **24–41** write the answers in your notebook.

24 What is one interesting thing you have learned in this unit? Why is it interesting?

25 Write five sentences about atomic structure.

26 Write five sentences about how elements are arranged in groups in the periodic table.

27 Choose a type of chemical reaction and describe its characteristics.

28 All atoms contain protons, neutrons and electrons. How is it possible that there are so many different kinds of atoms?

29 (a) What is the atomic number?

(b) The atomic numbers of some elements are given below. Use this information to draw the arrangements of their electrons in their shells.

Element	Atomic number	Element	Atomic number
Lithium	3	Neon	10
Nitrogen	7	Sodium	11
Oxygen	8	Chlorine	17

30 (a) What is the mass number?

(b) The atomic number and number of neutrons for some elements are given below. Work out the mass number for each element.

Element	Atomic number	Number of neutrons
Helium	2	2
Boron	5	6
Potassium	19	20

31 (a) What is combining power?

(b) The combining power of some atoms and radicals are given below.

Atoms or radicals	Symbol	Combining power
Sodium	Na	1
Fluoride	F	1
Calcium	Ca	2
Sulphate	SO_4	2

(c) Write the chemical formulae for calcium sulphate, sodium fluoride, calcium fluoride and sodium sulphate.

32 What are the chemical formulae for these common substances? Oxygen gas, water, carbon dioxide, hydrochloric acid, sodium hydroxide?

33 Write the word equation and balanced chemical equation for the reaction between hydrochloric acid and sodium hydroxide.

34 How are magnesium and sulphur (a) similar and (b) different in their reaction of burning in air?

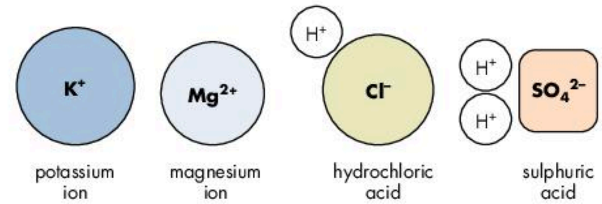
35 Describe one important result of non-metals burning in air and the product then dissolving in water.

36 Is the reaction of carbon dioxide with limewater a physical or chemical change? How could you show that you were right?

37 Aluminium sulphate reacts with sodium hydroxide in solution to form a precipitate of aluminium hydroxide. Write the ionic equation.

38 Choose a reaction to illustrate how chlorine reacts to produce (a) an ionic compound and (b) a covalent compound. Write balanced equations.

39 The diagrams to represent potassium and magnesium ions, and hydrochloric and sulphuric acid are shown below. What salts can be made from these chemicals? Show by diagrams and chemical formulae.



40 Balancing equations. Write chemical equations for the following word equations and then balance them if necessary.

(a) iron + sulphur → iron sulphide

(b) sodium hydroxide + hydrochloric acid → sodium chloride + water

(c) magnesium oxide + water → magnesium hydroxide

(d) sulphur + oxygen → sulphur dioxide

(e) magnesium oxide + sulphuric acid → magnesium sulphate + water

(f) calcium sulphate + sodium carbonate → calcium carbonate + sodium sulphate

(g) magnesium + zinc chloride → magnesium chloride + zinc

(h) iron + copper sulphate → iron sulphate + copper

(i) sodium + water → sodium hydroxide + hydrogen

41 The correct chemical formulae of all the reactants and products are shown for some reactions. Balance each of the equations.

(a) $Ca(OH)_2 + HCl \rightarrow CaCl_2 + H_2O$

(b) $CaCO_3 + HCl \rightarrow CaCl_2 + H_2O + CO_2$

(c) $CuO + HNO_3 \rightarrow Cu(NO_3)_2 + H_2O$

(d) $MgO + HCl \rightarrow MgCl_2 + H_2O$

(e) $KHCO_3 + H_2SO_4 \rightarrow K_2SO_4 + CO_2 + H_2O$

(f) $ZnCO_3 + HNO_3 \rightarrow Zn(NO_3)_2 + CO_2 + H_2O$

Key ideas

- The periodic table arranges elements in groups that have similar structures and properties, e.g. noble gases, alkali metals and halogens.
- Each group has similarities in the arrangement of their electrons in shells.
- An atom has protons (+ve) and neutrons (neutral) in its nucleus. The electrons (–ve) orbit in shells.
- The atomic number equals the number of protons; the mass number equals protons plus neutrons.
- Atoms are neutral: they have the same numbers of protons as electrons.
- Metals lose electrons to become +vely charged ions; non-metals gain electrons to become –vely charged ions. Different groups of elements gain or lose different numbers of electrons.
- The combining power (or valency) of an atom depends on the number of electrons in the outside shell. This in turn determines how it will react to form compounds.
- Ionic compounds form between metals and non-metals by the losing and gaining of electrons and the attraction between their ions.
- Covalent compounds share electrons; they are formed between non-metals, e.g. carbon dioxide and in non-metal gases, e.g. chlorine gas.
- Radicals are groups of atoms that stay together; they have a -ve charge. They react with metal ions.
- Reactants are the chemicals that interact in a chemical reaction; they produce the products.
- The mass of reactants and numbers of atoms are equal to the mass and numbers of similar atoms in the products (law of conservation of mass).
- An exothermic reaction, overall, releases energy while an endothermic reaction, overall, takes in energy from the environment.
- Different types of chemical reaction can be identified, e.g. synthesis and decomposition.
- Metals burn in oxygen to make basic oxides; non-metals burn in oxygen to make acidic oxides.
- Decomposition of carbonates by heating produces carbon dioxide; many metals react with dilute hydrochloric acid to release hydrogen.
- A more reactive metal can displace a less reactive metal from its compound.
- Word equations and balanced chemical equations show what happens when substances react.
- In solution, ionic equations show the ions that are involved, for example, in forming a precipitate.

▶ **See Workbook Introduction.**

Problems

1 Work in a group: Choose a metal that you have studied in this unit. Research its structure and properties online.
Prepare an illustrated account that can include, for example: ICT
(a) a model to show the structure of its atoms.
(b) an account of the characteristics of the group to which it belongs in the periodic table.
(c) a description of how it forms ions and how this relates to its combining power.
(d) an account of two reactions in which it takes part. In each case write the word equation and chemical formulae of the reactants and products. Then prepare balanced chemical equations.
(e) Name a metal that is more reactive than the one you have chosen. Identify reactions to support your choice.
(f) Name a metal that is less reactive than the one you have chosen. Identify reactions to support your choice.

2 Work in a group:
(a) Make a list of the information you need to write a chemical formula from the name of a substance.
(b) Research the steps for preparing the chemical formula. ICT
(c) Prepare a chart that lists each step.
(d) Illustrate your chart with three worked examples of different substances.
(e) Challenge another group to follow your instructions to write a chemical formula.

3 Work in a group:
(a) Make a list of the information you need to write a balanced chemical equation. ICT
(b) Research the steps online.
(c) Prepare a chart that lists each step, starting from the word equation.
(d) Illustrate your chart with three worked examples of different reactions.
(e) Challenge another group to follow your instructions to write a balanced equation.

Unit 19

Sensitivity and co-ordination

1 *Part of the network of 100 billion neurones in the brain. Computer systems are modelled on the connections in the neural network.*

This unit will help you to:

- realise how sense organs help us to sense and respond to our environment
- explore how we use touch, taste, smell, sight and hearing
- understand the role of the central nervous system in coordinating the body's response to the environment
- investigate reflex actions
- appreciate the role of hormones from the endocrine system, in helping to respond to internal body changes.

2 *This is a model of a human eye. Identify the lens and the muscles that hold the eye protected in the socket in the skull.*

3 *Bob Marley in action. Sound waves are made as objects vibrate. The sound waves travel through the air to our ears.*

Sense organs

For organisms to survive they need to find out (**sense**) any changes (**stimuli**) in their environment. They can then react (**respond**) in the correct way to the changes. This can help the animal find food and protect it from danger.

Mammals, such as humans, have five special **sense organs**. Each sense organ contains sensory (receptor) cells. These are able to sense different stimuli. For example, the skin is sensitive to temperature and pressure, the tongue and nose are sensitive to chemicals. The eye is sensitive to light and the ear to sound. When the sensitive cells have been stimulated they send messages along nerves to the spinal cord or the brain. Suitable return messages are sent out along different nerves to the muscles or glands. Then the correct response is carried out.

Sense	Touch	Taste	Smell	Sight	Hearing
Sense organ	Skin	Tongue	Nose	Eye	Ear

Touch

The sense organ for touch is our skin. It is not limited to one place – such as our hands or feet – but is found all over our body. The skin holds the body parts together and protects the tissues underneath. The skin is sensitive to temperature (hot and cold) and to touch (light touch, pain and pressure). It also gets rid of sweat and helps to control the body temperature.

19.1 Our sense of temperature

Materials: three similar containers: one with warm water, one with tap water and one with water with ice added

Method

1 Put one hand in the warm water and the other in the cold water. Leave them there for one minute.
2 Take out both hands and put them in the tap water.
3 How does each hand feel? How can you explain your results?

Explanation: The hand that was in the hot water will feel that the tap water is cold. This is because it is colder than the water that hand was used to.

The hand that was in the iced water will feel that the tap water is warm. This is because it is warmer than the water that hand was used to.

We are not good at judging an actual temperature, only a comparison, warmer or colder than before. The heat and cold sensors in our skin only measure differences in temperature. Our skin can make automatic changes to keep our temperature steady – for example, we sweat more to cool the body.

Objectives

- Deduce the importance of responding to changes in the environment.
- Appreciate why we need sense organs.
- Identify the sensory (receptor) cells in each sense organ and the stimuli they detect.
- Relate structure to function for the skin, tongue, nose, eye and ear.

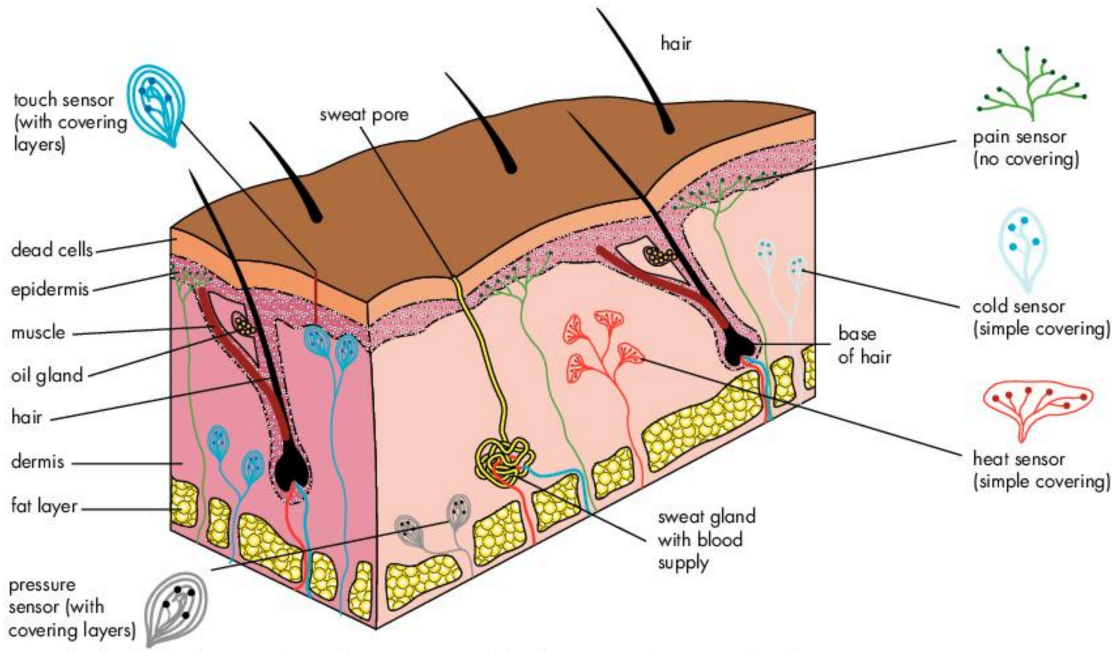
Fun facts

- The skin of an adult has a mass of 4.5–5 kg and measures 2 m^2.
- Each year the body loses about 4 kg of rubbed-off dead skin.
- The skin has a layer of dividing cells, which continually replaces the skin that is rubbed away.

How do we sense temperature?

Questions

1 Why should mothers not use their hands to test a baby's bath water, milk or body temperature?
2 How could you find the position of hot and cold sensors? Design and carry out a test. Report on your results.
3 Explain how the following sensory cells in the skin are important: (a) heat, (b) pain, (c) light touch.
4 Do we feel with our skin or with our brain? Explain your answer.



Section through the human skin to show the sensory cells, hairs and sweat gland

▶ **See Workbook Sense organs: Skin.**

19.2 Our sense of touch

Materials: forceps, hairpin or bread tie, a blindfold

Method

1 Bend a hairpin or bread tie until the points are 5 mm apart.
2 Blindfold your partner.
3 Gently touch the back of their hand with either 1 or 2 points of the forceps, hairpin or bread tie. Your partner has to say whether they can feel 1 or 2 points. Record the number of correct choices out of ten in a table.
4 Repeat and, this time, touch forehead and then fingertips. Record all your findings in a table.

Questions

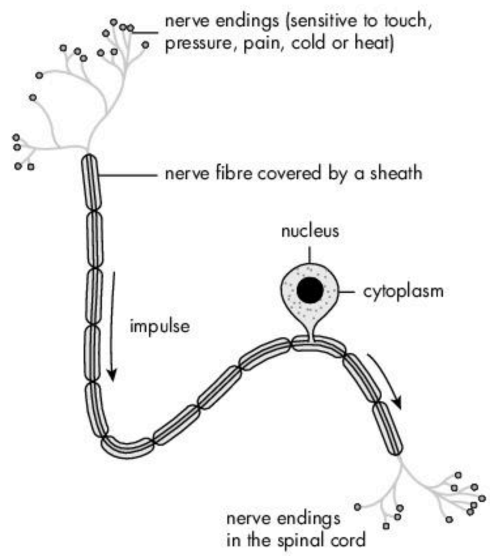
Which part of your skin was most sensitive, and which was least sensitive? What does this tell you about the number of touch sensors in different parts? Why is this important?

Which part is most sensitive to touch?

How the skin works

The sensors in the skin are the endings of sensory nerve cells. When a sensor receives its particular stimulus, an electrical message or impulse is set up. This is sent along the sensory nerve fibre to the spinal cord or to the brain. The diagram on the right shows a sensory nerve cell or neurone.

A response is then sent back along a motor nerve fibre. This will make muscles move in order to remove the person from danger. The response may be quick and automatic. But if we are aware of the heat, cold, or in pain, etc., it means that the messages have gone to the brain. So, our skin receives the stimuli, but it is our brain that understands or interprets them.



A sensory nerve cell or neurone

Tasting

The sense organ for tasting is our tongue. It has sensory cells that are sensitive to different chemicals in our food. The cells are inside taste buds and have hairs sensitive to the flavours in our food. The taste buds are on the sides of bumps on the tongue's surface. We have different taste buds sensitive to salt, sweet, sour and bitter. We also have taste buds sensitive to 'savoury', such as the taste of meat broth, cheese and chemicals used in Chinese cooking.

It had been thought that different areas of the tongue had taste buds sensitive to different tastes. But scientists now believe that we can appreciate all the tastes on all parts of the tongue, but that the sides of the tongue are the most sensitive. There is also a very sensitive area for 'bitter' at the back of the tongue. This may have helped our ancestors to sense and spit out bitter plants or food that might have been poisonous. There is also research being done on whether we have special taste buds sensitive to 'fats'.

In addition, the tongue also contains all the sensors present in the skin. So, for example, it can also sense heat, cold, pain and pressure. The appreciation we have for 'hot and spicy' is not really a taste, but is caused by signals sent from our touch and temperature sensors on our tongue to our brain. For example, food seasoned with chilli cause a sensation of pain and heat and we call them 'spicy'.

▶ **See Workbook Sense organs: Tongue.**

PS 19.3 Our sense of taste

Work in small groups:

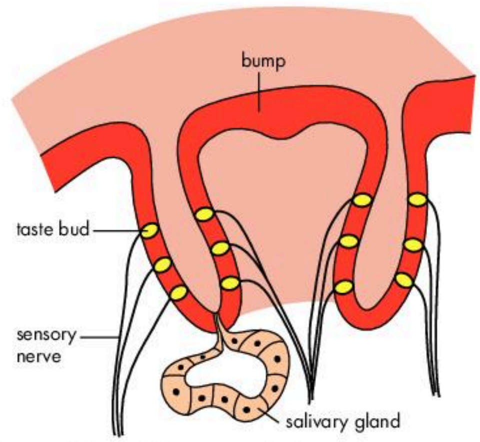
1 Carry out research on the Internet to find out how we taste our food using our taste buds. ICT
2 In the three paragraphs above, there are several statements made about the five or six different kinds of tastes buds and where they are found on the tongue. Research this information and see if you agree with it.
3 Find out how the different chemicals responsible for our tastes can stimulate the hairs on the sensory cells and set up electrical messages that are sent in to our brain. Research the 'Taste centre' in the brain that is involved with interpreting the signals so that we taste our food.
4 Find out how the taste buds are similar and different and how they can help us to appreciate the full range of all the different foods that we eat.
5 Also research the way in which we use our sense of smell (using sensory cells in our nose) to give us more information about the 'flavour' of our food. ICT
6 Use all the information you collect to prepare a Power point presentation on 'How we taste our food'.

Fun facts

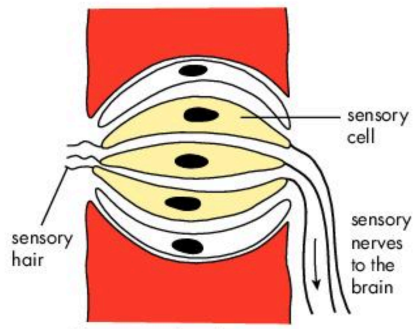
- Chillies and curry affect the heat sensors in our tongue. That is why they seem to be hot.
- There are about 10 000 taste buds in the tongue, but they become fewer as we get older. They are 0.1 mm across.
- The nose can detect more than 10 000 different odours, using 25 million smell cells inside the nasal cavity.

Questions

1 List all the things that the tongue senses.
2 How will the taste of a child differ from that of its grandmother?
3 Do you think food tastes the same to everyone? Explain your answer.



The position of the taste buds



Structure of a taste bud

KWL for the senses

Set up a KWL table for What I know, What I want to find out, and What I learned about the senses. Fill in the information for Touch and Tasting, and add what you can for Smelling, Seeing and Hearing.

Senses and stimuli	What I know	Want to find out	What I learned
Touch			
Tasting			
Smelling			
Seeing			
Hearing			

Smelling

The sense organ for smelling is the nose. It has sensory cells that are sensitive to many different chemical smells (odours) in the air. The sensory cells are high up in the nose or nasal cavity. They respond to odours being breathed into the nasal cavity and also those rising up from the food in our mouth. The smell of the food contributes to what we think it tastes like.

19.4 Our sense of smell

Materials: scented flower, perfume, strong cheese, onion, a blindfold

Method

Work in pairs:

1. Blindfold your partner. Put one of the samples quickly under their nose and ask them to breathe normally. Can they say what the odour is?
2. Now give them the same (or a different) sample. Now, ask them to sniff deeply so that they draw the odour high up into their nasal cavity. Do they name the sample correctly?
3. Continue to give the samples, with normal breathing and deep sniffing. Record the success at identifying each sample.

19.5 Pleasant or unpleasant?

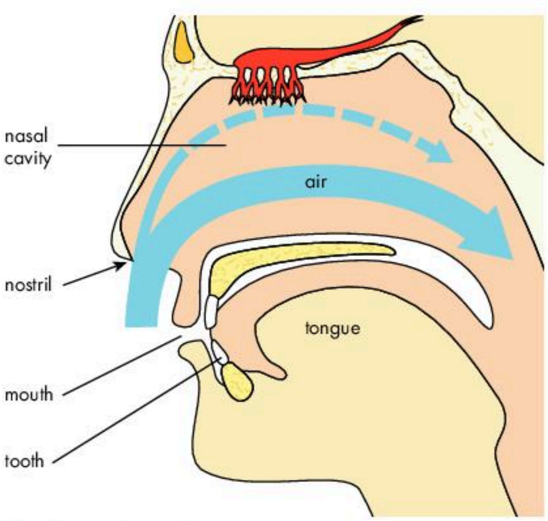
Materials: twelve objects that have strong odours

Method

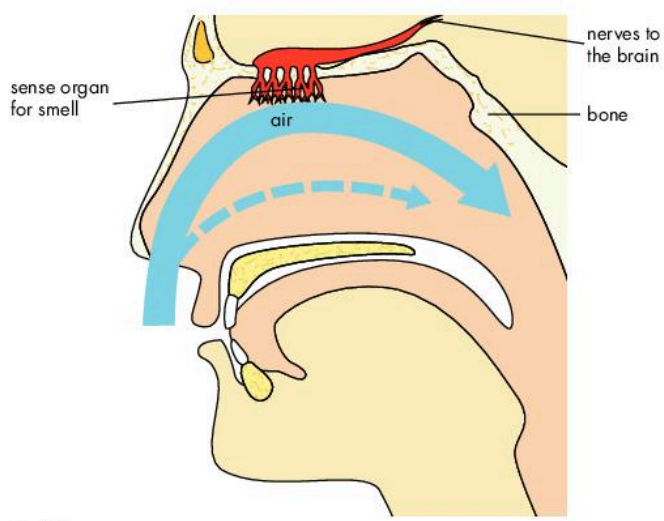
The students in class are going to find out which of the odours they find pleasant and which unpleasant.

1. Begin by making a large table on the chalkboard listing the twelve odours.
2. You could use a four-point scale:
   1 = very unpleasant
   2 = unpleasant
   3 = pleasant
   4 = very pleasant
3. Each person, for each odour, records a number in the table.
4. Do people like different odours?
5. Add up the numbers to find (a) the most unpleasant odour and (b) the most pleasant odour for your class.
6. Are the choices of the class the same as your choices?

Use the drawings below to explain what happens.



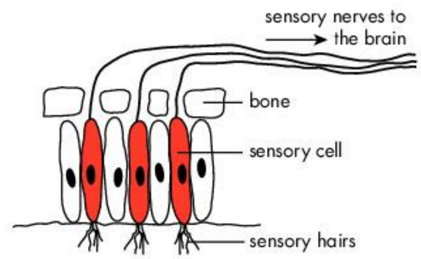
Ordinary breathing



Sniffing

How our nose works

The nose has two holes – the nostrils – through which air is drawn in. Odours also rise up from the food in our mouths. The smell cells have small hairs that are sensitive to the chemicals in the air. When the hairs and sensory cells are stimulated they set up electrical messages. These pass along the sensory nerves to an area in the brain concerned with smell. The brain then interprets the message; we smell what is in the air and in our food.



Structure of the sense organ for smell

19.6 The effect of strong smells

Materials: crushed garlic, peppermint, blindfold, stopwatch
Method
Work in pairs:
1 Blindfold your partner. Hold the garlic under their nose and ask them to sniff deeply. Record what they say.
2 They should continue to sniff deeply for one minute. At the end of the time ask them if the smell still seems as strong as before.
3 Change places and repeat the activity by smelling the peppermint. What do you find?
4 What is the importance of your findings?

19.7 Taste or smell?

Materials: crushed garlic, peppermint, apple, cooked yam, chocolate, blindfold
Method
1 Blindfold your partner.
2 Hold the garlic under their nose while you give them a cube of apple to taste. Can they tell you the food is an apple?
3 Now give them cubes of cooked yam and then chocolate. Can they distinguish these foods?
4 Change places. Use the peppermint under the nose and the three same kinds of food. Can you distinguish the foods?
5 How does what you smell affect what you taste?

▸ **See Workbook Sense organs: Nose.**

Fun facts

- The male emperor moth has the most sensitive sense of smell. With its antennae it can pick up just one molecule of the female's scent from 5 km.
- Specially trained dogs help police to find specific people by their smell.
- A snail smells and feels with its short tentacles and sees with its eyes on the ends of its long ones.

Smell and taste

- When we continue to smell a strong odour (pleasant or unpleasant), our smell cells become exhausted. We can no longer smell that odour. This could be dangerous if the odour was something that was harmful to us, such as a poisonous gas.
- When we have a cold, our nasal passages become blocked. This means that the odours from our food cannot stimulate the smell cells. Our food has less taste because we can no longer smell the odours.

What does it mean?

Sensory (receptor) cells: Special cells in the skin and in other sense organs that respond to stimuli.

Stimuli: Changes in the environment or inside our bodies.

Response: A reaction to a stimulus, such as the contraction of a muscle.

Questions

1 How does our sense of smell help us to stay safe in our environment?
2 Why is it dangerous to live near to a sewage plant that has a strong harmful odour?
3 Why should animals that produce strong smells not be reared in town areas where the houses are close together?
4 Why does our food seem tasteless when we have a cold?

Light and seeing

We cannot see anything in a completely dark room. Light must be present in order for us to see.

Light is a form of energy. Light is produced, for example, by the Sun, electric light bulbs and candles. We call these things **luminous** objects. Objects that do not produce their own light are called **non-luminous** objects. We cannot see non-luminous objects, unless they are lit up by a source of light. The light bounces off (is **reflected** from) the object and then we see it. Light travels in straight lines (see the photograph). We show this by drawing straight lines to show the light rays.

19.8 Luminous and non-luminous objects

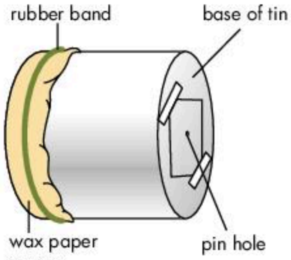
1. Look around you in the classroom and outside. List all the objects that can make their own light. For example, you can include matches and car headlights.
2. List ten non-luminous objects. How can we see these objects (a) in the daytime and (b) at night?
3. We can 'see' light being reflected when we see reflections. List five places where you have noticed reflections.

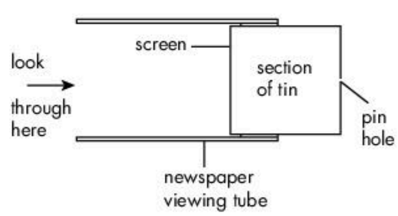
19.9 Making a pinhole camera

Materials: empty can, hammer, nail, black paper, wax paper, pin, scissors, rubber band, paper tape, newspaper

Method

1. Use the hammer to make a hole in the centre of the tin's base. Stick dark paper over it. Make a single small pin hole in the centre of the paper.
2. Use a rubber band to hold wax paper over the open end of the tin to make a screen.
3. Wrap and secure a roll of newspaper around the tin. Aim the 'hole' towards a tree outside. Look through the newspaper tube to see the picture or 'image' on the screen.
4. What does the image look like? Is it upside-down?

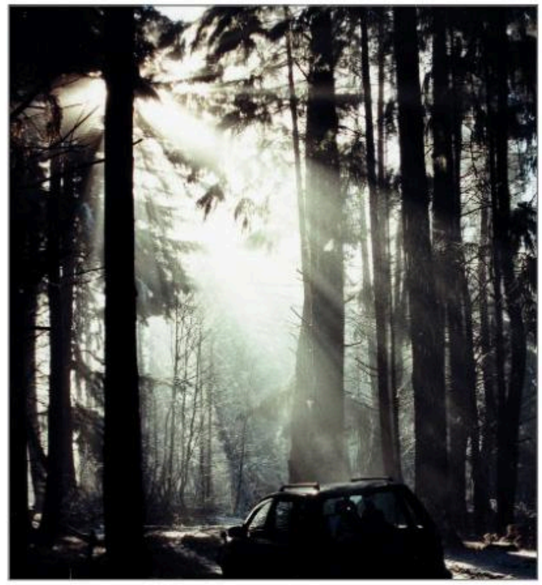




▶ **See Workbook Sense organs: Eye.**

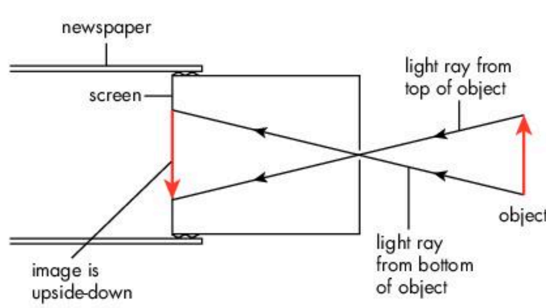
Fun facts

- Atlantic giant squids have the largest eyes: up to 50 cm across.
- The eagle has the best eyesight – it can spot its prey from high in the sky from 3 km away. If an eagle could read, it could read a book from 70 m.



Light travels in straight lines

Using a pinhole camera



How a pinhole camera works

Seeing

The sense organ for seeing is the eye. It has sensory cells, the rods and cones, in the retina. The rods and cones change the light energy into nervous impulses. These are sent along the optic nerve to the brain and we see the image.

19.10 Dissection of a mammalian eye

Materials: mammalian eye, sharp scissors, shallow dish

Method

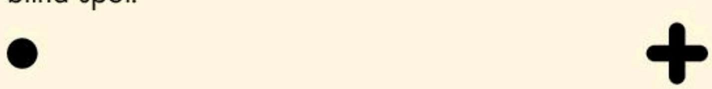
1. Observe the outside of the eye. Identify the muscles (at the sides) that move the eye in its socket. Also find the optic nerve (at the back) that takes messages away from the eye.
2. Look at the transparent front of the eye (the cornea) and then cut around its edge and remove it.
3. You will see a hole (the pupil) with the coloured iris around it. Observe the lens behind the pupil.
4. Cut around the iris and remove it. You should be able to see that the lens is held in place by ligaments.
5. Cut out the lens. If the eye is fresh, the lens will be transparent. Draw its shape.
6. Remove the jelly-like substance in the eye and look at the back surface. This is the retina. How is it different in front of the place where the optic nerve leaves the eye? This is called the blind spot as it has no rods or cones.

19.11 Our sense of sight

Materials: mirror, blindfold

Method

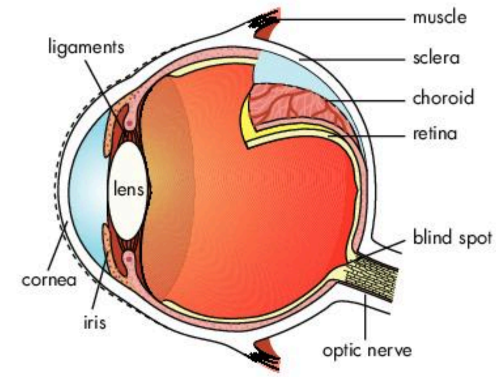
1. Look in the mirror and make an accurate labelled drawing of one of your eyes.
2. Look at the size of the pupil in your partner's eye. Now blindfold them for two minutes. Take off the blindfold and quickly note the size of the pupil. Watch for 15 seconds and report on all that you have noticed. Explain what you see.
3. Close your right eye. Hold this page about 30 cm away and look at the cross with your left eye. Bring the page slowly towards you. At a certain distance the dot will disappear. This is because it has been focused on the blind spot.



4. Hold out your left arm in front of you with your first finger pointing upwards. Close your right eye. Now use your other hand to try and touch your first fingers together. Try the same thing with both eyes open. Are two eyes better than one?

Fun facts

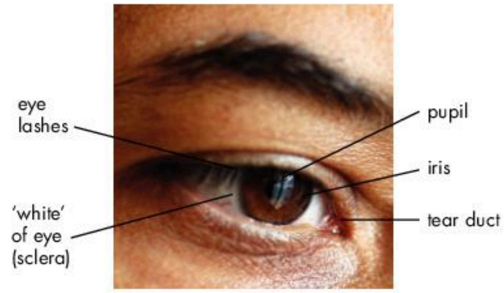
- The eyeball is about 2.5 cm across.
- There are about 125 million rods sensitive to dark and light.
- There are about 7 million cones sensitive to colours.

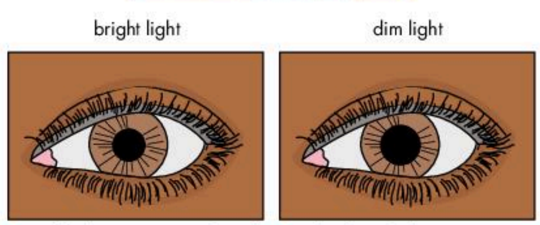


A model of an eye

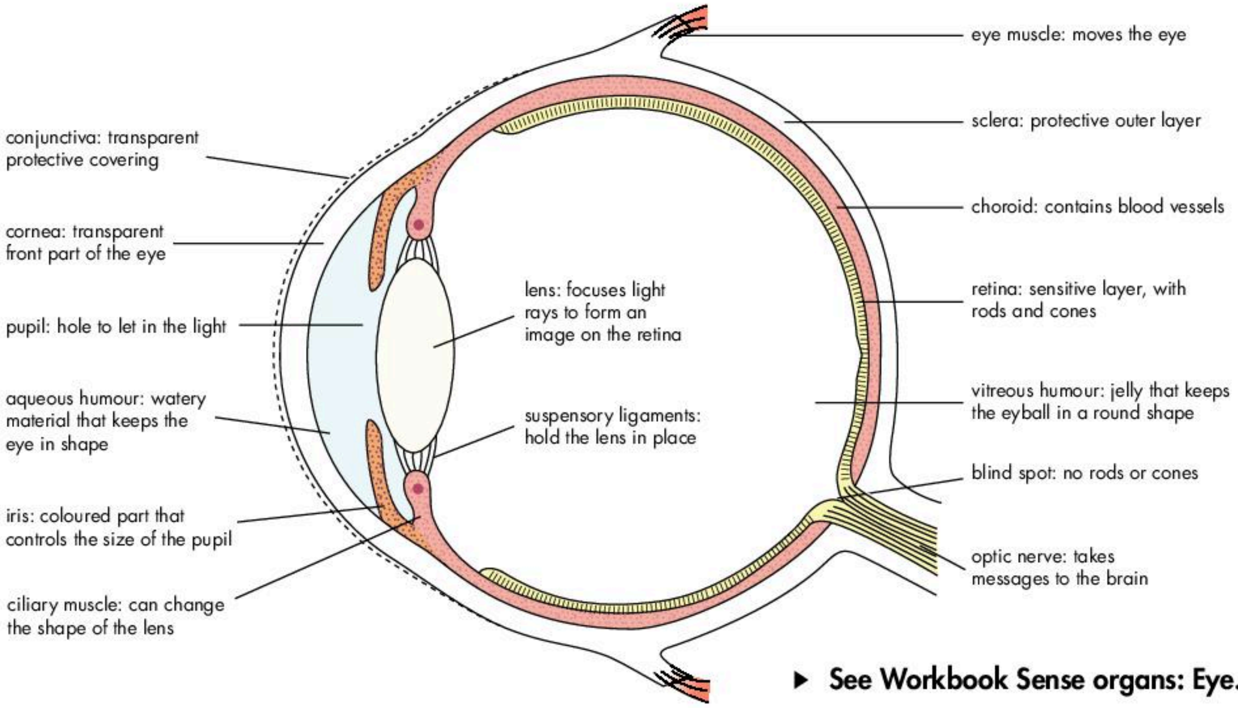
The eye has three layers

- Sclera: the tough outer layer. At the front of the eye it is the white part around the iris. In the centre of the eye it is the transparent cornea.
- Choroid: middle layer that supplies blood to the other parts. At the front of the eye it forms the coloured iris and the ciliary muscle that controls the shape of the transparent lens.
- Retina: the inner sensitive layer with rods and cones. The blind spot is where the nerve fibres leave the eye.





Pupil changes in bright and dim light



Longitudinal section of the human eye

▸ **See Workbook Sense organs: Eye.**

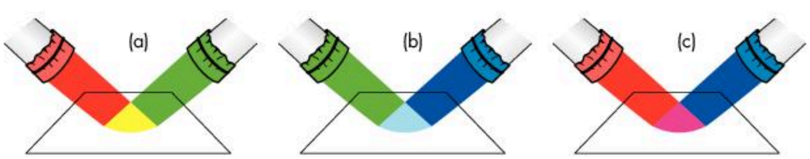
How the eye works

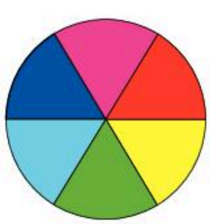
Light enters from an object through the transparent cornea. The amount of light is controlled by the size of the pupil, which in turn is determined by the iris. If the muscles of the iris contract, the pupil becomes smaller. If they relax, the pupil becomes larger. This is an automatic response to light.

The light rays are focused by the transparent lens, to form a clear upside-down image on the retina. The light stimulates the rods and cones. There are three kinds of cones, and these allow us to see in colour. The light energy is changed into nervous impulses. These are sent along nerve fibres to the optic nerve and then to a special part of the brain. Here the message is interpreted as an upright picture of the object.

Mixing coloured lights

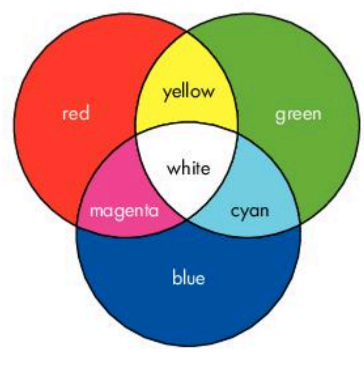
Check with your teacher to try out these activities with mixing coloured lights and using a spinwheel. Try to explain what you find out.





How do we see in colour?

There are three kinds of cones, which are sensitive to red, green and blue light. If we look at a red object, only the red-sensitive cones are stimulated and send their messages to the brain. If we look at a yellow object, both the red and green-sensitive cones are stimulated, which gives an impression of yellow. All of the colours we see are due to the different numbers of each kind of cone that are stimulated.



Questions

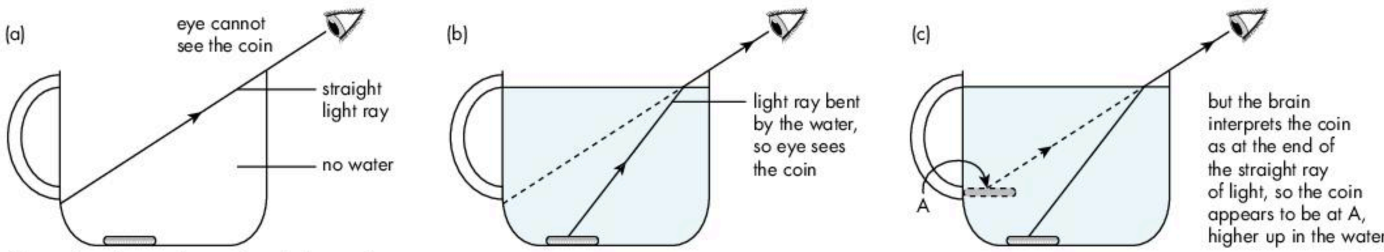
1. Why is it important that the pupil becomes smaller in bright light?
2. Why does the eye need a blood supply?
3. How do we see a magenta object?

19.12 Bending light: the coin trick

Materials: cup, coin, water
Method
1 Put the coin in the cup. Move so that your eye cannot see the coin **(a)**.
2 Stay in the same position, but slowly add water to the cup. You will now see the coin **(b)**.

Bending of light rays in water (refraction)

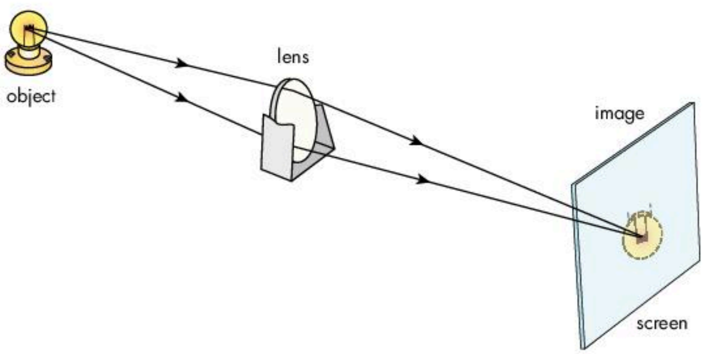
Explanation: This is because the light has been bent as it travels from the air into the water. You can see a similar thing in the photograph. Our eye imagines the coin is higher in the water than it really is **(c)**.

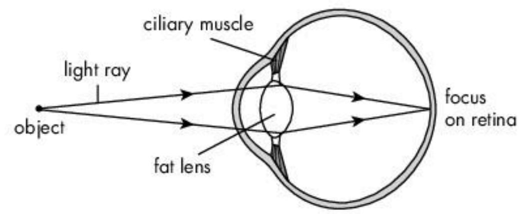


Showing how the coin trick works

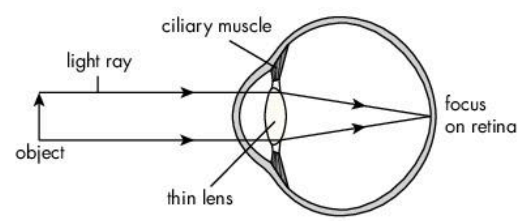
How the eye focuses

Light is also bent when it travels from the air into the lens of the eye, and out again. The lens bends the light rays so that they are focused onto the retina to form a clear image. This is shown below, which also shows that the image is upside-down.





To focus a near object, the lens needs to be fat

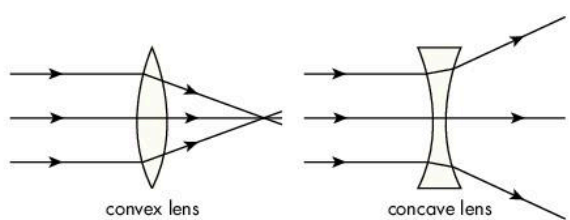


To focus a distant object the lens needs to be thin

In the eye, the lens is held by ligaments that are attached to the ciliary muscles. These muscles can make the lens fat (to see near objects) or thin (to see distant objects). This is shown in the diagrams on the right. For most people the eyes are able to make these changes automatically.

Long and short sight

- Some people can see distant objects clearly, but cannot make their lenses fat enough to view near objects. They have **long sight**. This is corrected with a convex lens.
- Other people can see near objects clearly, but cannot make their lenses thin enough to view distant objects. They have **short sight**. This is corrected with a concave lens.



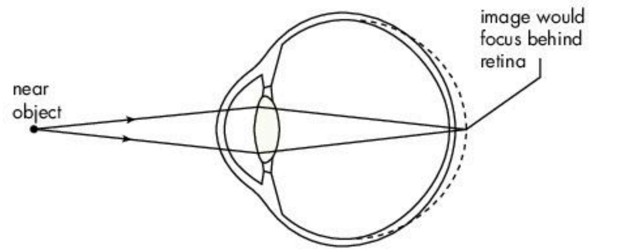
Rays brought together (converged) *Rays spread apart (diverged)*

Lenses used to correct long sight (convex) and short sight (concave)

Long sight

A person with long sight finds it difficult to see near objects clearly. The image of the object would fall behind the retina, so it would look blurred.

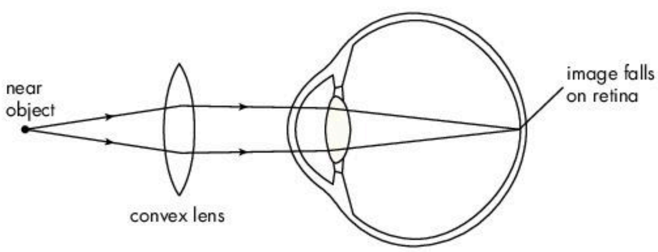
Long sight is caused by the lens being too thin or the eyeball being too short.



A person with long sight

Correction of long sight

The light rays need to be brought closer together, so that they focus on the retina. A convex lens is needed to bring together (converge) the rays. The person visits an optician and is given the correct convex lenses in spectacles or contact lenses. The image will then fall on the retina and the person will have a clear image of the object.



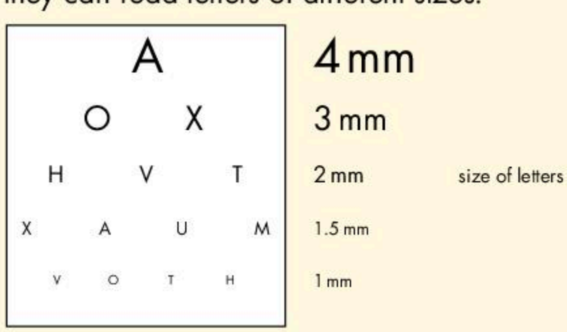
Correction of long sight with a convex lens

19.13 Eye test

Materials: paper, black pen, ruler

Method

1 Make a chart similar to the one shown below.
2 Test each person to find the distance at which they can read letters of different sizes.

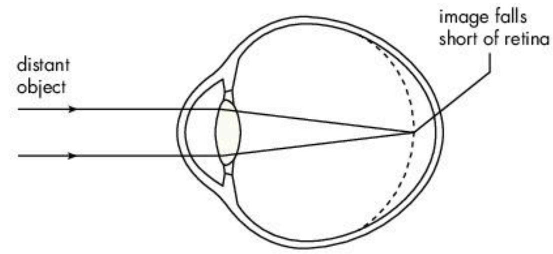


▶ **See Workbook Sense organs: Eye.**

Short sight

A person with short sight finds it difficult to see distant objects clearly. The image of the object falls in front of the retina, so it looks blurred.

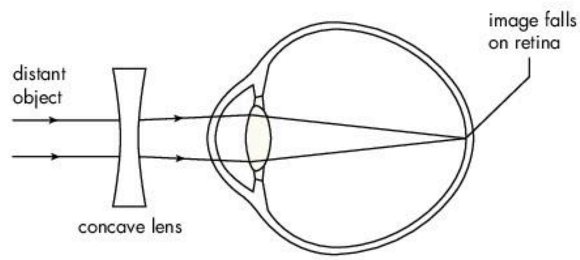
Short sight is caused by the lens being too fat or the eyeball being too long.



A person with short sight

Correction of short sight

The light rays need to be spread out more, so that they focus on the retina. A concave lens is used to spread out (diverge) the rays. The person visits an optician and is given the correct concave lenses in spectacles or contact lenses. The image will then fall on the retina and the person will have a clear image of the object.



Correction of short sight with a concave lens

Questions

1 Record all your results in a table. How do the results vary?
2 If you have someone in your class who wears spectacles, ask them to do the test with and without their glasses. What difference does it make? Do these people have short or long sight? How do you know?
3 Make a graph of your own results. Plot the distance from the eye against the size of the letters you can see. What do you find?
4 Research what other tests are carried out at the opticians. For each test, say what it is for and what can be done about any problems.
5 Research and discuss what is meant by (a) optician, (b) optometrist and (c) opthalmologist. ICT

Sound and hearing

We cannot hear anything if there is no **vibrating** object to produce sound waves. Sound waves must be present for us to hear.

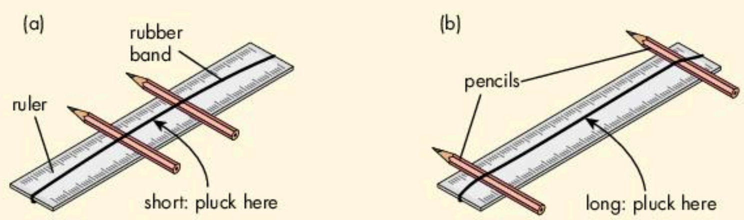
Sound is a form of energy. Sound is made, for example, by musical instruments and by people talking. Sound waves are made as something vibrates backwards and forwards and passes on these vibrations to the particles of solids, liquids or gases that are nearby.

PS 19.14 Making sounds

Materials: open tin can, cling film, rubber band, rice grains, pencil, drums, two rulers, two rubber bands, four pencils

Method

1. Stretch the cling film tightly over the top of the can and hold it on with the rubber band. Put a few rice grains on the cling film and hit it gently with a pencil. What happens?
2. Observe different drums. Hit their surfaces with your hands and with drumsticks. How are the sounds made? How are loud and soft sounds made?
3. Hold a ruler half supported near a table edge. Hit the end gently and then strongly. What difference do you see and hear? Does the larger amount of energy make a louder sound?
4. Set up two rulers as shown below. Pluck the rubber band **(a)** where the pencils are close together. Do you get a high-pitched sound? Now pluck the rubber band **(b)** where the pencils are further apart. Do you get a low-pitched sound?

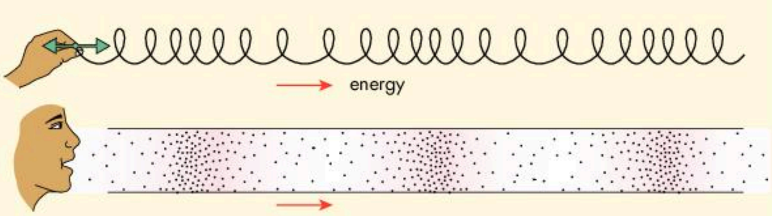


PS 19.15 Making a model of waves

Materials: long spring (called a 'slinky' spring)

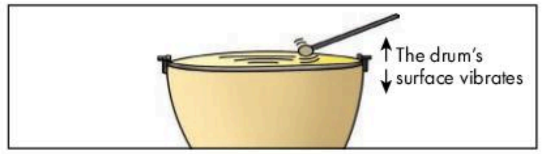
Method

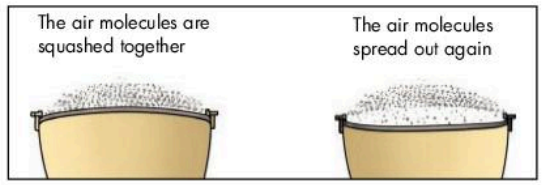
1. Move one end backwards and forwards. Observe how your 'wave' travels along the spring.
2. Compare this to the vibration of air particles as you speak.



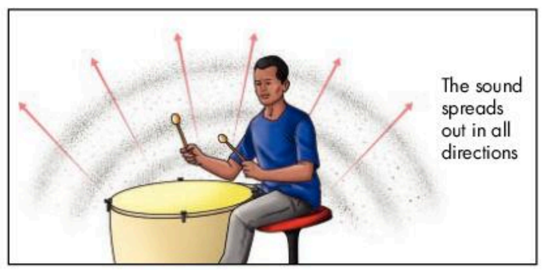
Fun facts

- Many animals hear sounds that humans cannot.
- A bat can 'see' with its ears. The bat makes ultra-sonic sounds that bounce off objects around it and help it to pin-point its prey.
- Insects hear with their feelers, crickets with their knees, and spiders with hairs on their legs.





The vibrating drum makes the molecules vibrate backwards and forwards. These molecules affect the molecules next to them. The sound spreads out.



As the drum surface is hit, it sets up vibrations of the air particles. When these travel to our ear we can hear them.

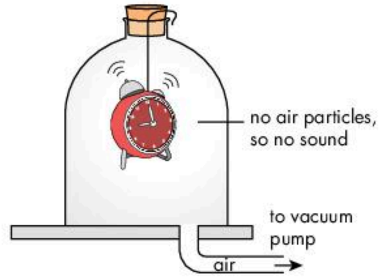
Loudness, pitch and quality of sounds

A sound wave travels by the vibrations of the particles. The particles are pushed close together (compression) and then spread apart. These waves are what we hear as sound. If all the particles are removed from around a bell, there is no longer any sound. We still see the bell being struck, but no sound is made because there are no particles. In a similar way, space is silent – there are no particles and no sounds. This is different from light waves which can travel in a vacuum through space.

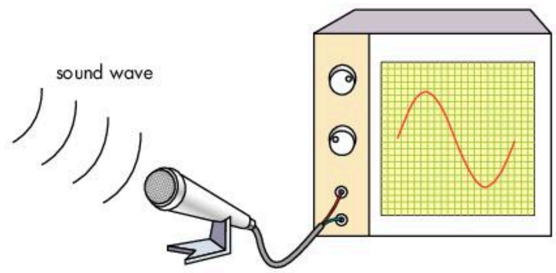
To help us to compare sounds, we can change the sound energy into a form we can see. This is just to help us; it is not what the sound waves are really like. We make use of a microphone and an oscilloscope in order to make a picture of sound waves.

The sound energy enters the microphone. It is changed into electrical energy, which goes into the oscilloscope. Here it is shown as a wave on a screen. Different sounds show as different waves, which we can compare.

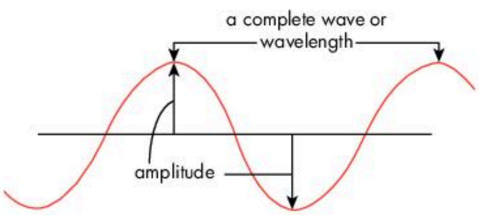
Loudness, pitch and quality are three characteristics we use to describe sounds.



The bell rings, but no sound is made in a vacuum so we cannot hear it

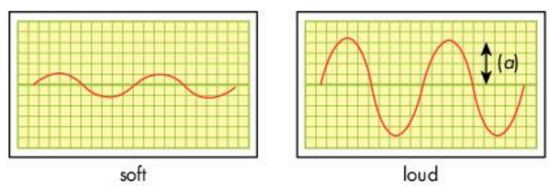


A microphone and oscilloscope make a picture of a sound wave that we can see



Loudness

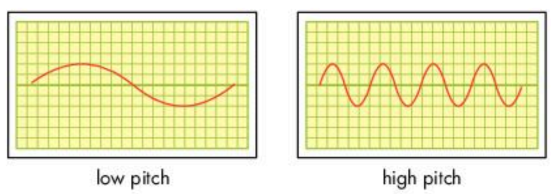
How loud or soft a sound is depends on how much energy it has. If we hit a drum surface gently it makes a soft sound. If we hit the drum more strongly it makes a loud sound. The distance up or down from the rest position is called the **amplitude**. A small amplitude shows a soft sound; a large amplitude shows a loud sound. The loudness of sounds is measured in decibels (dB).



Loudness is determined by amplitude (a). A small amplitude gives a soft sound, and a large amplitude gives a loud sound.

Pitch

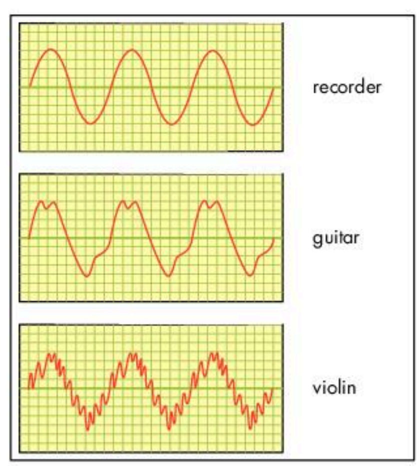
How high or low a sound is depends on how quickly it is travelling. This speed is called the **frequency**. It is equal to the number of complete waves (wavelengths) that pass a certain point in one second. If many waves are passing, then the sound has a high pitch (like a whistle). If fewer waves are passing, then the sound has a low pitch (like a cow mooing). The frequency of sounds is measured in hertz (Hz).



Pitch is determined by frequency. A low frequency gives a low sound, and a high frequency gives a high sound.

Quality

The special sound of a certain musical note depends upon the instrument that is making it. You can compare the same note played on a piano with that on an organ. The pictures on the right show the same note played on three instruments. The notes have a similar general shape, but then have their own special characteristics; this is the **quality** of the sound.



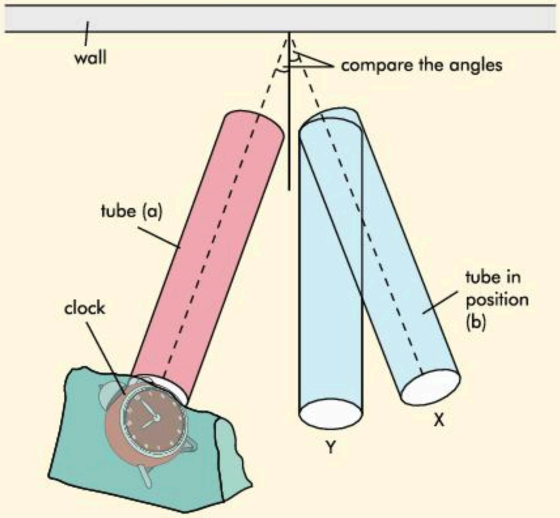
Quality of notes depends on the instrument

19.16 How sound behaves

Materials: loud ticking clock, cushion, two long cardboard tubes, paper, ruler

Method

1 Place the clock on the paper on a table near a wall. Hold the cushion behind the clock to direct its sound along tube **(a)**
2 Place the other tube in position **(b)**. Listen with your ear at X. Then move the tube to position Y. What do you notice? How can you explain your result?



3 Make marks on the paper to show where the sound is loudest. Is the angle at which the sound hits the wall the same as the angle at which it is reflected?

19.17 How does sound travel?

Materials: waterproof watch, plastic bag, bread tie, beaker of water, table

Method

You are going to compare how well sound travels in a solid, liquid and gas. Use the watch as your source of sound.

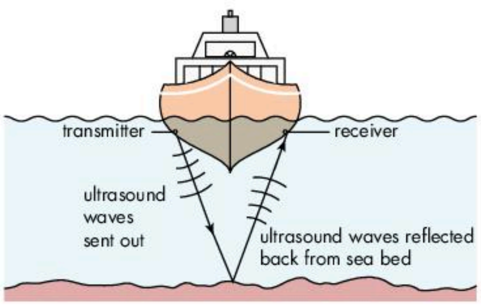
1 Lay the watch on the table. Try to judge how loud it sounds. This will be the measurement through air (a gas).
2 Now put your ear firmly against the table near the watch. Does it sound louder? This is your measurement through wood (a solid).
3 Put the watch inside a sealed plastic bag (just in case it isn't completely waterproof). Put it inside the beaker of water. Put your ear close to the glass of the beaker. This is your measurement through water (a liquid). How does the sound compare to the other two?
4 You know that the particles in solids, liquids and gases are different distances apart. Can you explain your findings based on this? What improvements can you suggest for the activity?

Fun facts

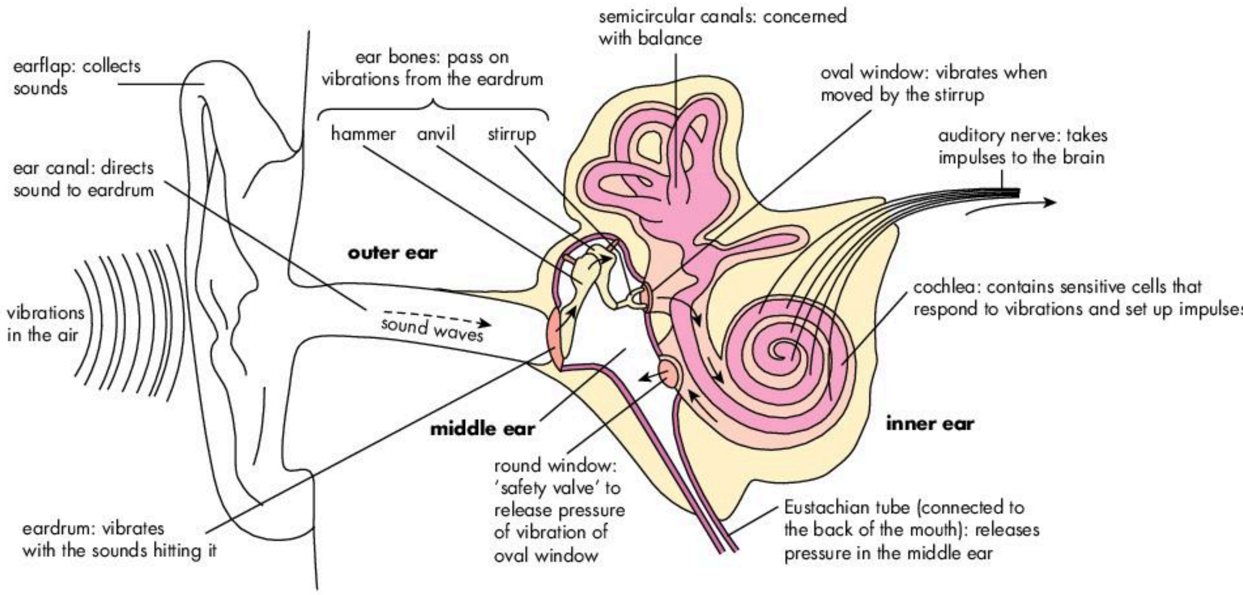
- The ear bones are the smallest bones in the body.
- The sound energy from singing can break a glass.
- Children hear a greater range of sounds than adults.

How humans use sound reflection

- **Echoes:** The echoes we sometimes hear when near a wall or mountain are reflections of the sounds we made. We usually just hear the last part.
- **Ships:** These use high frequency sounds to locate a shoal of fish or the sea bottom. The time taken between sending and receiving the sounds and the reflection is noted. This is used to work out the distance.



- **Ultrasound:** This is very high frequency sound, which we cannot hear. But it can be used, for example, to show a picture of a developing foetus. Ultrasound waves are sent into the body and reflected back from inside the uterus.



Longitudinal section of the human ear

The ear has three parts

- Outer ear: this is the earflap and the ear canal. The outer ear ends at the eardrum.
- Middle ear: this contains the three ear bones. It connects the eardrum to the round window. A tube, the Eustachian tube, runs from the middle ear to the back of the mouth to equalise pressure differences.
- Inner ear: this is filled with fluid. It contains the cochlea, which is sensitive to vibrations, and the semicircular canals, which are concerned with our sense of balance.

How the ear works

Sound waves enter by the earflaps and go into the ear canal. The waves make air particles in the canal vibrate.

The vibrations in the ear canal make the eardrum vibrate in a similar way. This makes the hammer vibrate and the sounds are passed on along and amplified (increased) by the three ear bones. This in turn makes the oval window vibrate. The round window also moves to equalise the pressure.

The movements of the oval window make the fluid in the inner ear vibrate. These vibrations are passed along to the cochlea. This sets up nerve impulses that pass along the auditory nerve to the sound centre of the brain.

▶ **See Workbook Sense organs: Ear.**

19.18 Why do we need two ears?

Materials: clock, blindfold

Method

Work in pairs:

1 Blindfold your partner. Ask them to cover one ear, so it doesn't hear anything. Hold the clock in different positions and ask your partner to point out its direction.

2 Repeat, but using two ears. In which case was your partner more accurate?

3 Change places and repeat the activity.

Explanation: Each ear receives slightly different sounds: louder and sooner on the side from which the sound is coming. The brain receives the information from both ears and uses it to work out the direction of the sound.

Quick check ☑

_________ cells in the sense organs respond to different _________ . They send nervous _________ along nerves to the spinal cord or _________ . Our eyes focus _________ waves; our ears respond to _________ waves.

Use these words to fill in the spaces as you write the sentences in your Exercise book.

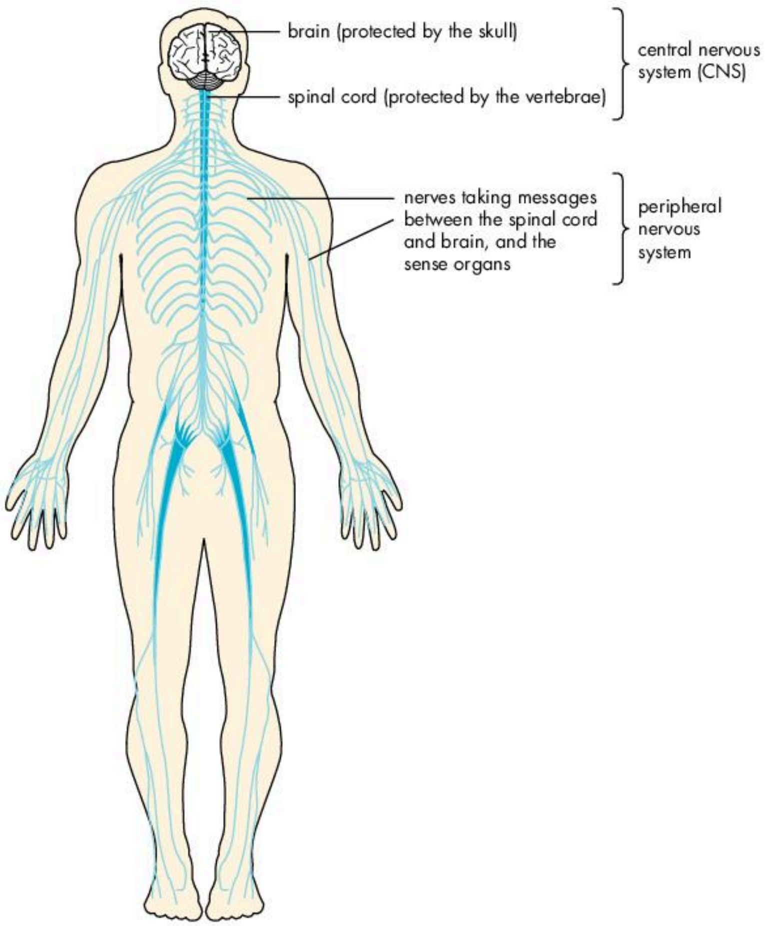
stimuli **brain** **sound**
light **sensory** **impulses**

Central nervous system

The nervous system controls our activities.
- It allows us to think, plan and learn from our experiences.
- It receives information from our sense organs, so we are aware of changes in our environment and can react to them.
- It allows us to react quickly to dangerous situations and so avoid harm.
- It controls the activities of all the other systems, such as keeping the body temperature constant.

The main part is the **central nervous system** (CNS). It is made up of:
- the brain (the expanded front part that is in the head and protected inside the bones of the skull), and
- the spinal cord (the thick cord that runs down the body, which is protected inside the vertebrae of the backbone).

The nervous system also contains a large network of nerves running throughout the body. This is the **peripheral nervous system**. The nerves are important in linking the sense organs with the spinal cord and the brain. Sensory nerves bring impulses in from the sense organs and motor nerves return the responses to muscles and glands.



Parts of the nervous system

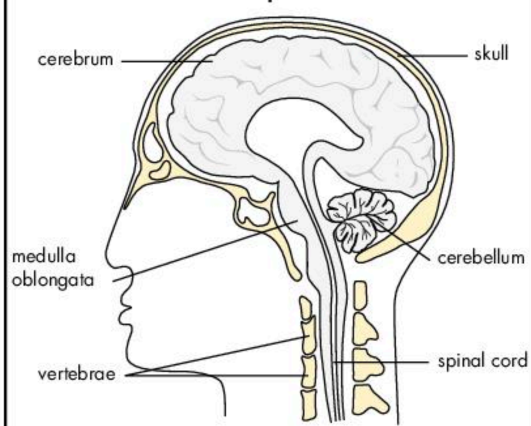
Objectives

- Identify the brain and spinal cord as parts of the central nervous system (CNS).
- Name the main parts of the brain and their functions.
- Describe how the sense organs are connected by nerves to the CNS.
- Describe a simple reflex arc.

Fun facts

- The nervous system is made up of billions of nerve cells carrying electrical impulses all over the body.
- The brain has a mass of about 1.4 kg and the spinal cord a mass of 25 g.

How is the CNS protected?



The brain and spinal cord are protected inside bone

- The brain has three parts: the large front **cerebrum**, the central **cerebellum** and the **medulla oblongata**. The brain is protected inside the bones of the skull.
- The spinal cord is the thick cord going from the base of the brain. It runs down the body inside the vertebral column, which protects it. Between the vertebrae, spinal nerves come out to go to the sense organs and other parts of the body.

The brain

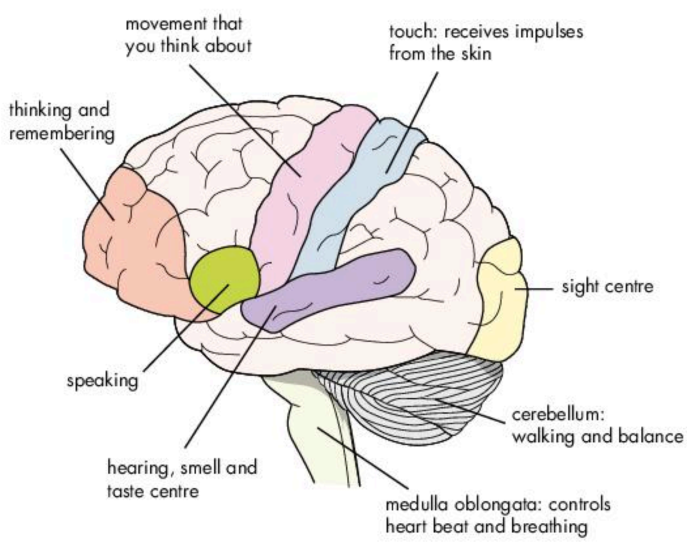
The brain is our body's computer. But it is much more powerful than any computer we could build.

The structure and functions of the brain

The brain has three parts, with different functions.

- **Cerebrum:** this is the largest front part (the forebrain). It is the main controlling centre for the whole body. It allows us to think, plan and remember. It has different areas, shown in the diagram below, which process the different impulses from the rest of the body. It is the part of the brain that allows us to think about how we should behave, based on our experience.
- **Cerebellum:** this is the middle part of the brain (the midbrain). It is mainly concerned with coordinating movements and balance. Some of the responses are automatic and some we think about.
- **Medulla oblongata:** this is the hind part of the brain (the hindbrain). It controls automatic responses in the body, for example, the heart rate, breathing and controlling the body temperature.

The cerebellum and medulla oblongata are labelled in the diagram below. All the other areas belong to the cerebrum.



▶ **See Workbook Central nervous system.**

How the brain works

Sensory nerves from the sense organs take their impulses to the brain. The brain has certain centres to deal, for example, with sight, hearing and touch. It is in the brain that the different impulses are interpreted and we understand what we have seen, heard, or felt. Without the brain we would not understand the input from the sense organs.

The brain also sets up any responses that are needed. These impulses pass along motor nerves to the muscles or glands, which then respond in the correct way.

Fun facts

- The brain's surface is very folded. If it was laid out flat, it would cover 0.2 m^2.
- The brain contains over 10 000 million nerve cells and each one can connect with 25 000 other nerve cells.
- The brain is about 2% of your body mass, but it uses 25% of the oxygen you take in.
- The brain uses the same electrical power as a 10 W bulb.
- One million new nerve connections are formed in the brain every second.
- The typical desktop computer can process 25 billion instructions in a second. The human brain can process 100 trillion instructions per second.

Questions

1 What are the functions of the nervous system?
2 What parts make up the central and peripheral nervous systems?
3 Name the three parts of the brain and give a function of each part.
4 How and why are the brain and spinal cord protected?
5 How is the brain involved in seeing and hearing?

How the brain develops

The head and brain of a baby are large compared to the rest of its body. As a baby grows, more and more connections develop between the nerve cells. This occurs as the child sees new things and is stimulated with new ideas. This process continues through education.

If a stroke damages part of the brain, another part can be trained to take over.

19.19 Measuring reaction time

Materials: ruler, pencil
Method
Work with a partner:
1 Your partner rests an arm on the table.
2 Hold the top of the ruler so the ruler is just above your partner's hand.
3 Let go of the ruler so that it falls through your partner's hand. As it falls, your partner has to try to catch it.
4 Do two trial runs. Then do five measurements: record the number on the ruler that is closest to the little finger.
5 Change places and repeat the activity.
6 How do your reaction times compare? Do you get better with more practice? How do your results compare to those of the rest of the class?
7 You could also repeat the whole activity using a pencil. Is this easier or more difficult?

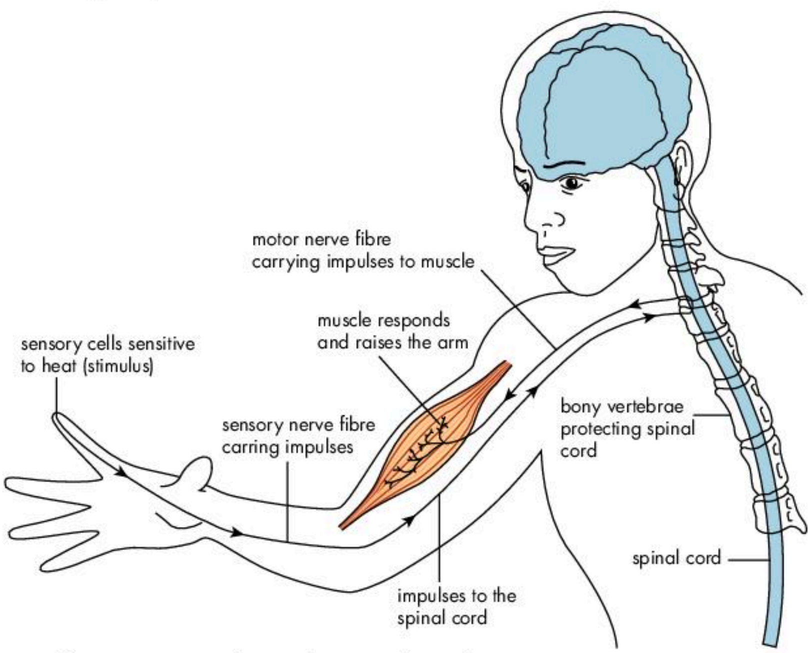
Explanation: Your eyes see the ruler falling. A signal is sent to the brain and to the muscles to grasp the ruler.

▶ **See Workbook Central nervous system.**

A reflex action

This occurs without us thinking about it.

- Some reflex actions involve the brain. For example, blinking and the narrowing of the pupil when light is shone into it.
- Most reflex actions only involve the spinal cord. For example, the quick removal of our hand from a hot or sharp object.



A reflex action involving the spinal cord

How quickly can you catch the 30 cm ruler? Do you get better with practice?

What is a reflex action?

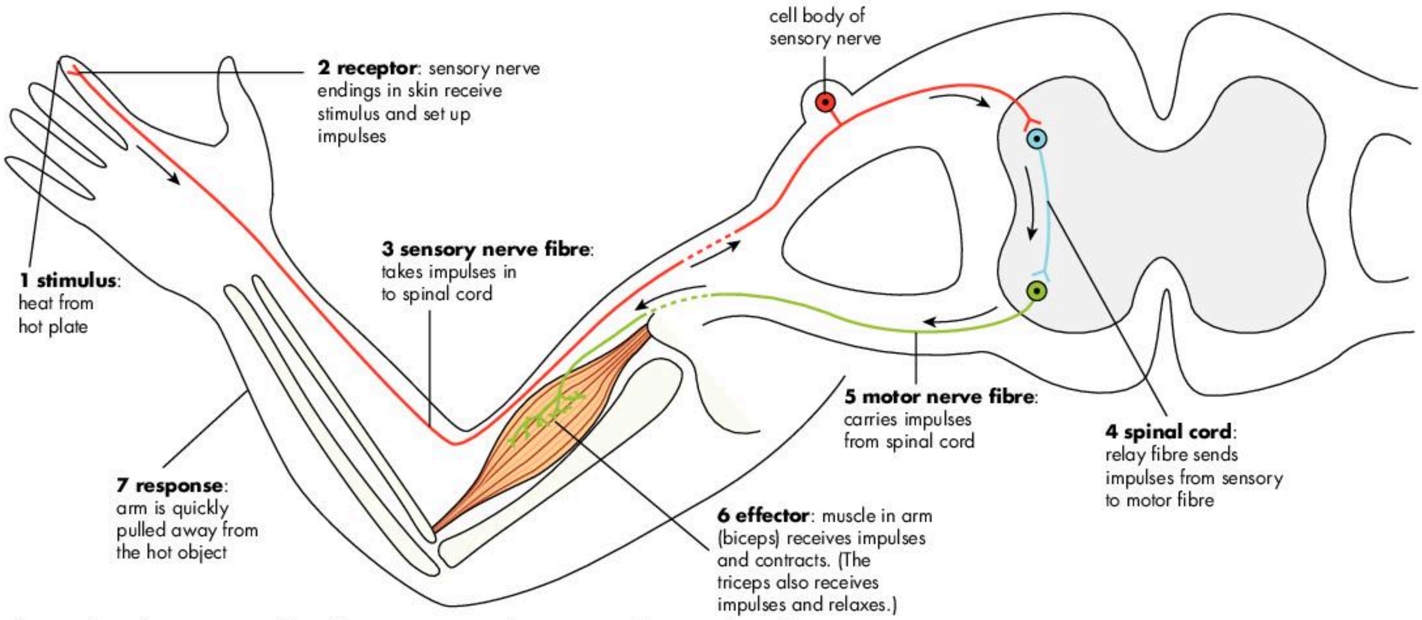
A reflex action connects the stimulus (change in conditions) to the response (action that is taken). For the pupil reflex:

Stimulus	Light shining in the eye
↓	
Receptor	Nerve endings in the retina set up message
↓	
Sensory nerve	Message sent to CNS
↓	
CNS	Brain interprets message and sends instructions
↓	
Motor nerve	Takes message to iris muscles
↓	
Effector	Part that responds (iris muscle)
↓	
Response	Pupil becomes smaller

Questions

1 Look at the diagram of the reflex action when we touch a hot object. Identify the seven parts as listed in the box above. For example, the stimulus is heat and the receptors are the heat-sensitive endings in the skin.
2 Name three sports in which you think reaction time is important. For a particular sport, explain exactly how you could improve your reaction time.

We can now look at a full reflex action and see what happens in the spinal cord. This is also called a **simple reflex arc**.



A simple reflex arc: our hand is automatically removed from a hot object

▸ **See Workbook Central nervous system.**

Involuntary and Voluntary actions

- Involuntary actions are automatic and do not involve thought.
- Voluntary actions we think about and decide what to do.

We can compare the actions in a table.

	Involuntary actions	Voluntary actions
Speed	Very quick, as they are automatic	May be slower, as we need to think about them
Purpose	To protect us from harm, especially physical danger	To take account of experience and allow us to think and develop
Control	Spinal cord or hind part of the brain	Cerebrum of the brain
Outcome	Same every time, as it is automatic	Can vary with different people or occasions
Examples	Removing hand or foot from a hot or sharp object. Blinking and pupil reflex	Any action based on thinking, memory or learning, e.g. reading

Autonomic nervous system

The autonomic nervous system controls the automatic responses of our internal organs, so they keep working properly. We don't have to think about them.

Some examples are the control of heart rate and digestion. Receptors in the organs send in impulses along the sensory nerves to the spinal cord or hind part of the brain. Here the responses are sent out to the cardiac muscles of the heart or the smooth muscles of the alimentary canal. Both of these are involuntary muscles; they respond without us having to think about the action. The salivary glands and adrenal gland are also under the control of the autonomic nervous system.

Quick check ☑

The central nervous system consists of the ________ and ________, both protected inside ________. An automatic action is called ________, controlled by the ________ or the hind part of the ________. Actions we think about are called ________, controlled by the fore ________.

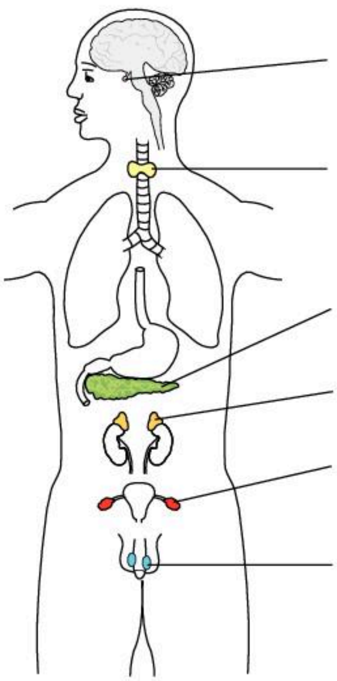
Use these words to fill in the spaces as you write the sentences in your Exercise book.

spinal cord **bone** **cerebrum**
brain **involuntary** **voluntary**

Endocrine system

You have seen how the nervous system sends messages around the body using nerves and electrical impulses. The central nervous system coordinates the body's responses to external changes in the environment based on information from the sense organs.

But the body also has another control system. This does not have nerves or impulses. It works by producing chemicals called **hormones**. These hormones are produced by special glands directly into the blood and distributed by the blood. The system of hormones and glands is called the **endocrine system**. The glands are spread throughout the body.



▸ **See Workbook Endocrine system.**

19.20 Research on hormones

Each group works on one hormone and then shares results.

1 Pituitary: find out how giants and dwarfs may be produced. List some of the hormones of the pituitary. Why is it called the 'master gland'?
2 Thyroid: find out what causes goitre.
3 Pancreas: find out the importance of insulin for a person who has diabetes.
4 Adrenal glands: find out about the 'fight or flight' hormone and its effects.
5 Ovaries: check the development of secondary sexual characteristics and the hormones produced by the ovary.
6 Testes: check the development of secondary sexual characteristics and the hormone produced by the testes.

ICT

Objectives

- Compare the nervous and endocrine systems.
- Identify the endocrine glands, their locations and hormones.
- Outline the normal and abnormal functioning of the hormones.

Why are endocrine glands also called ductless glands?

The pancreas makes the hormone, **insulin**. The cells that produce the hormone pass it directly into the blood and not into a duct. So the endocrine glands are 'without ducts', so are called ductless glands.

Comparing the nervous and endocrine systems

- The nervous system uses electrical impulses sent along nerves. Impulses are sent directly to an effector, such as a muscle. The response is rapid and does not last long. The nervous system is important for everyday interactions with the environment. It helps keep us safe and able to learn from our experiences.
- The endocrine system uses 30 chemical hormones, sent around in the blood. The hormones eventually reach their target organs and have their effects. The response is usually slow and may include long-lasting changes, such as growth. The endocrine system helps to control many reactions in the body, to keep the internal environment constant.

Comparison table

ICT

Use the information above, and what you find out in your research, to prepare a table to compare the nervous and endocrine systems.

The pituitary gland

The pituitary gland is also called the master gland. This is because its hormones directly control body functions such as growth, or control when the other glands will produce their hormones. It is like the master of the orchestra determining when each instrument will play.

The pituitary is a pea-shaped gland attached by a stalk to the **hypothalamus** at the base of the forebrain. Sensor cells in the brain monitor the levels of hormones in the blood. The results are sent to the hypothalamus, which in turn relays them to the pituitary. The pituitary then controls when other glands should increase or decrease their production. This restores a balance in the amount of hormones in the blood.

Hormones produced

- Water-balance hormone. This has its effect in the kidney and means more water is returned to the blood. The amount of urine becomes reduced.
- Growth hormone. This affects growth of bones and muscles. If too little is produced, the person may become a dwarf. Too much growth hormone can produce a giant.
- Hormone that controls the thyroid gland.
- Hormone that controls part of the adrenal glands.
- Birth hormone. This affects the uterus and starts the birth process. It works with another hormone to produce and release milk from the breasts for the baby.
- Hormones that activate the ovaries. They cause puberty and the development and release of eggs each month. They activate the ovaries to produce their own hormones.
- Hormones that activate the testes. They cause puberty and the development of sperm. They activate the testes to produce their own hormone.

The ovaries

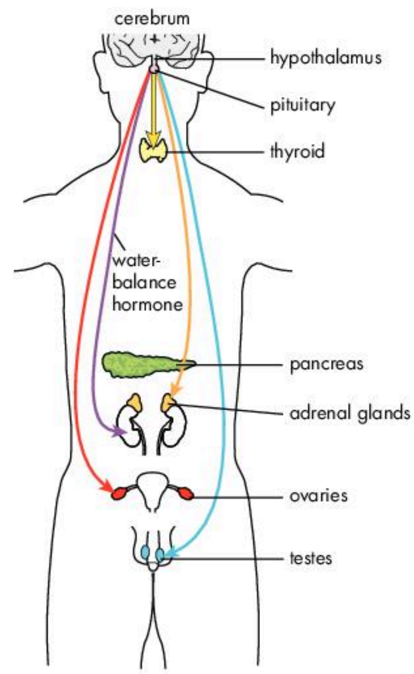
These are activated by the pituitary gland. They get a 'wake-up' call at puberty. The female sex hormones the ovaries produce cause the development of female secondary sexual characteristics and changes during the menstrual cycle.

Hormones produced

- Oestrogen. This causes the repair of the uterus wall during the menstrual cycle.
- Progesterone. This causes the uterus wall to become thick and full of blood.

The testes

These are activated by the pituitary gland. They also get their 'wake-up' call at puberty. The testes produce the male sex hormone, **testosterone**. This causes the development of male secondary sexual characteristics.



The pituitary gland produces hormones that control growth, other organs (e.g. the kidneys) and other glands (the thyroid, adrenal glands, ovaries and testes)

Questions

1 How does a conductor control an orchestra? How is this similar to the control by the pituitary gland?
2 Choose one hormone from the pituitary gland. Research and write an account of its action. ICT

Fun facts

- Immature eggs are produced in the ovary of a female baby inside the uterus. From puberty onwards, one of these eggs becomes mature each month.
- At menopause, the female sex hormones are reduced in amount and a woman no longer releases eggs.
- Testosterone is produced throughout life. This means that a man can continue to produce sperm and become a father.

▶ **See Workbook Endocrine system.**

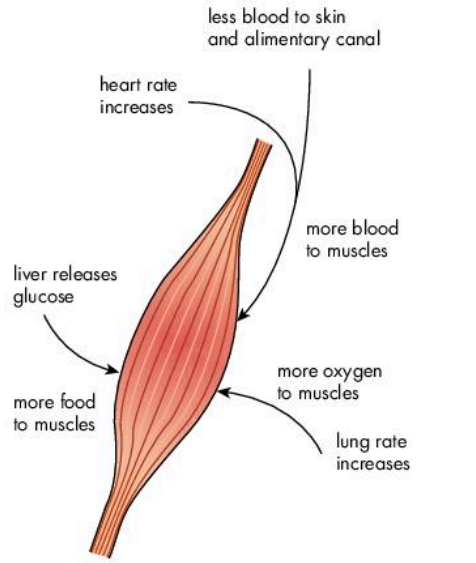
Adrenal glands

These sit like hats on top of the kidneys. Part of the adrenal gland produces hormones under the control of the pituitary gland. But the main hormone, **adrenaline**, is produced by the adrenal gland itself. It is an unusual hormone in that it acts quickly. The effect is to prepare the body for 'fight or flight'.

Effects of adrenaline

- Capillaries in the skin and alimentary canal become narrowed, so that more blood can go to the muscles.
- The heart and breathing rates are increased to send more blood and oxygen to the muscles.
- The liver releases glucose into the blood for energy.

A frightening or exciting experience can cause production of adrenaline, as in doing a sky dive.



Adrenaline is produced quickly in response to possible danger. Its effect on the whole body is to prepare the body to defend itself (fight) or escape (flight).

Thyroid

The thyroid is found in the neck in front of the trachea. It is controlled by a hormone from the pituitary gland. As a result it produces **thyroxine**. This hormone contains iodine. If the diet is short in iodine then the thyroid becomes larger, to get sufficient iodine. This can cause a swelling called a **goitre**.

Effects of thyroxine

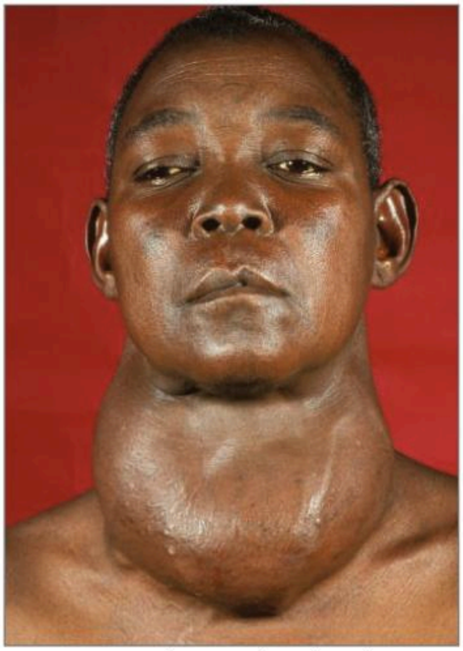
This hormone controls the rate at which body reactions occur.

- Lack of thyroxine in children causes growth to stop and can cause mental problems. This is called **cretinism**.
- Lack of thyroxine in adults can slow down activities and cause people to become very tired and to put on weight.
- Excess of thyroxine increases the rate of body activities. The person is very active, hungry and loses weight.

Treatment

- Lack of thyroxine is dealt with by pills containing levothyroxine or by giving injections of the hormone. The dose must be carefully controlled.
- If there is excess thyroxine, part of the thyroid may be inactivated or removed.

The thyroid is found in the neck



A goitre may form with a diet short in iodine

Pancreas

There are cells within the pancreas, the islets of Langerhans, which produce the hormone, **insulin**. This goes directly into the blood and is taken around the body to the cells.

Effect of insulin

- After a meal, when there is a lot of glucose in the blood, the pancreas produces insulin. It causes the cells to take up glucose, which they need for producing energy. It also changes excess glucose into glycogen for storage in the liver.
- When glucose levels are low, insulin is not produced. But other hormones cause glycogen in the blood to change into glucose. In this way the level of glucose is kept constant.

What is diabetes?

Diabetes is the disease caused by insufficient insulin. The person cannot control their glucose level. The glucose stays in the blood and is not used as fuel for energy in the cells. The person is therefore tired and weak. They may also be very thirsty and pass a lot of urine.

The glucose level rises in the blood and some is excreted in the urine. This is the main way that a doctor can identify that a person is suffering from diabetes. In the past, people died because of diabetes.

Eating a special diet can sometimes control diabetes, or the person may need to take regular injections of insulin. Genetic engineering has been used so that insulin can now be made by yeast or bacteria. The human gene that has the instructions for making insulin is inserted into the yeast or bacterium and this then produces insulin.

Type 1 and Type 2 diabetes

Type 1 diabetes usually develops in childhood or teenage years. It is often inherited. The pancreas does not produce insulin and the person will need injections throughout life.

Type 2 diabetes has also been called adult-onset diabetes. It usually develops in adults, especially if they are overweight. But it can also occur during childhood. It develops, either where the pancreas does not produce enough insulin or where the body's cells do not react to insulin. Exercise and reducing body weight can help to avoid developing Type 2 diabetes.

Symptoms of diabetes

These can develop in a few days or weeks in young people, or over a few months in adults:

- feeling very thirsty
- passing a lot of urine
- feeling very tired
- losing weight and muscles.

Living with diabetes

Diet can help:

- Avoid eating high carbohydrate food, especially with sugar.
- Eat lots of green vegetables.

Treatment aims to keep the blood glucose as normal as possible:

- The person is shown how to test the blood to check the glucose level and how to give injections of insulin.
- The exact amount of insulin and when to give it before meals has to be carefully controlled.

Diabetics can live a full and active life, for example, Sir Stephen Redgrave (who has Type 2 diabetes) has won gold for rowing in five successive Olympics.

Testing kit and injector for a diabetic

Quick check ☑

The ________ is the master gland. It produces ________ hormone and controls several other organs, including the ovaries and ________. The adrenal glands make ________. The thyroid makes ________ and the pancreas makes ________.

Use these words to fill in the spaces as you write the sentences in your Exercise book.

testes **pituitary** **thyroxine**
adrenaline **growth** **insulin**

Questions

Answer these questions in your notebook

For questions **1–30** answer **A**, **B**, **C** or **D**.

1 The chemical substances in our environment to which we respond can be called
A responses **B** impulses
C stimuli **D** sense cells

2 Which of these statements about responses is correct?
A Only animals respond to stimuli.
B All organisms need to respond to stimuli.
C Organisms need sense organs in order to respond to stimuli.
D All organisms respond quickly to stimuli.

3 Our skin can
A predict the exact temperature
B predict the temperature to 5 °C
C predict the temperature to 1 °C
D judge warmer and colder

4 The most sensitive part of our skin is on
A our feet **B** our forehead
C our fingertips **D** the back of the hands

5 What is the outermost layer of the skin?
A epidermis **B** dermis
C dead cells **D** layer of fat

6 Our tongue responds to
A sweet and salt **B** sour and bitter
C hot and cold **D** all of the above

7 The sensory cells on our tongue are
A the taste buds
B the bumps on the tongue
C only found at the back of the tongue
D only found at the sides of the tongue

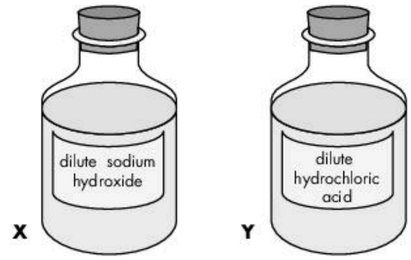
8 Which of these pairs of senses are related?
A eyes and ears
B nose and tongue
C eyes and tongue
D skin and ears

9 Which is our largest sense organ? The organ responsible for
A seeing **B** smelling
C feeling **D** hearing

10 A pinhole camera and the eye are different because in the eye
A light rays come from an object
B light rays are focused by a lens
C an image is made
D an upside-down image is produced

11 Where is the aqueous humour?
A in the lens **B** in front of the lens
C in the cochlea **D** behind the lens

12 The diagram below shows two bottles of chemicals, X and Y.



The safest way to decide what they are is to
A taste them both **B** smell them both
C heat them both **D** read the labels

13 The answer to Question **12** shows the importance of our sense of
A hearing **B** smell
C sight **D** taste

14 Which of these parts is NOT involved in balance and co-ordination?
A muscles **B** medulla oblongata
C cerebellum **D** semi-circular canals

15 Movement of the hammer is caused by movement of the
A eardrum **B** anvil
C oval window **D** stirrup

16 Which statement is true?
A Frequency is measured in Hz.
B Loudness is measured in Hz.
C Frequency is measured in dB.
D Amplitude is measured in Hz.

17 The central nervous system is made up of the
A brain only
B spinal cord only
C brain and spinal cord only
D brain, spinal cord and nerves

18 Which is the main part of the brain helping you think about this question?
A cerebellum **B** hearing centre
C cerebrum **D** medulla oblongata

19 What is the main part that protects the brain?
A bone **B** skin
C blood vessels **D** muscles

20 In a reflex action of moving the hand away from a hot object,
A sensory skin cells are sensitive to heat
B impulses travel to the spinal cord
C muscles cause the arm to be raised
D all of the above

21 Which of these parts is NOT involved in an involuntary action?
A spinal cord **B** cerebrum
C cerebellum **D** medulla oblongata

22 The effectors that respond to motor nerve impulses are
A muscles only
B glands only
C muscles and glands
D endocrine glands only

23 Sensory nerve fibres take impulses
A from the spinal cord to the sense organs
B from the sense organs to the spinal cord
C from the spinal cord to the brain
D from the brain to the sense organs

24 Which of these is a difference between the central nervous system and the endocrine system?
A electrical impulses or chemicals
B quick or slow response
C short-term or long-term effects
D all of the above

25 Which of these is NOT an endocrine gland?
A pituitary **B** adrenal gland
C kidney **D** thyroid

26 Cretinism may be caused by a lack of
A adrenaline **B** thyroxine
C insulin **D** oestrogen

27 Which of these is the fight or flight hormone?
A adrenaline **B** thyroxine
C insulin **D** oestrogen

28 Which of these cause the secondary sexual characteristics?
A adrenaline **B** thyroxine
C insulin **D** oestrogen

29 Which hormone is in short supply in a diabetic?
A insulin **B** adrenaline
C progesterone **D** growth hormone

30 Which of these chemicals would you use to test the urine of a diabetic?
A Benedict's solution
B copper sulphate solution
C sodium hydroxide solution
D alcohol (ethanol)

For questions **31–51** write the answers in your notebook.

31 What is (a) a stimulus and (b) a response?

32 (a) List the senses and the parts responsible for each one. (b) Which stimuli do each sense organ respond to?

33 How do the sense organs (a) work in a similar way (b) work in a different way from each other?

34 Describe an activity to show that we cannot rely on our sense of temperature.

35 Describe an activity to find the areas of the tongue that are sensitive to different tastes. Draw a sketch of the tongue to show your results.

36 As well as the four food flavours, what else is the tongue sensitive to?

37 (a) Why does our food seem tasteless when we have a cold? (b) Why are our senses of smell and taste related?

38 How are each of our senses important in keeping us safe in the environment?

39 (a) Describe an activity to make and use a pinhole camera. (b) What property of light is shown by the activity? Explain your answer using a diagram.

40 (a) Draw a simple longitudinal section of the human eye. (b) Label and annotate important parts. (c) Use your diagram to explain how we see.

41 (a) Draw a simple longitudinal section of the human ear. (b) Label and annotate the important parts. (c) Use your diagram to explain how we hear.

42 If you were (a) blind or (b) deaf list three problems you might have, and say how you would try to overcome them.

43 If you were a town planner in charge of designing a new area of housing, what suggestions would you make for reducing the likelihood of noise pollution?

44 Name the parts of the brain and give two functions of each part.

45 Your friend says that we see with our brain. Write (a) two sentences to support this statement and (b) two sentences to contradict it. Evaluate what you have written; what is your own conclusion?

46 (a) Name three reflex actions. (b) How do they differ from voluntary actions?

47 Explain how our senses, in combination with reflex actions and our brain, keep us safe in the environment.

48 Why are endocrine glands called 'ductless'?

49 How are the nervous system and endocrine system (a) similar and (b) different?

50 Draw a labelled diagram of the endocrine system. Add arrows to show how the pituitary gland controls the action of other organs.

51 Choose a named hormone. (a) Where is it produced? (b) What is its action? (c) What is the result of a deficiency?

Key ideas

- All organisms respond to changes in the environment, called stimuli.
- Our senses are sight, hearing, smell, taste and touch. We use them to sense stimuli.
- The stimuli and sense organs are light (eyes), sound (ears), chemicals (nose and tongue) and temperature and touch (skin).
- Different sensors in the skin respond to heat, cold, light touch, pain and pressure. Different parts of the skin are more sensitive than others.
- Taste buds for sweet, salt, sour and bitter are found on different parts of the tongue.
- Our sense of smell also responds to chemicals in our food: part of the taste of our food is its smell.
- In the eye, light waves are focused by the lens to produce a smaller, upside-down image of the object onto the retina.
- The retina has sensitive cells: rods for black and white vision and cones sensitive to red, green and blue, which are used for colour vision.
- The brain interprets the upside-down image making it the right side up.
- Sound needs particles in order for it to travel.
- The loudness of sounds is determined by the amplitude, and pitch by the frequency.
- Vibrations in the air are passed on to the cochlea and impulses sent to the brain. Very loud noises can cause noise pollution and damage to the ear.
- Our ear also contains our sense of balance.
- The central nervous system consists of the brain and spinal cord, both protected inside bone.
- The brain has the cerebrum: thinking and voluntary actions, the cerebellum: walking and balance and the medulla oblongata: heart and breathing rates.
- The peripheral nervous system consists of the nerves. Sensory nerve fibres bring in impulses to the spinal cord and motor nerve fibres carry impulses from the spinal cord.
- Most involuntary reflex actions are dealt with in the spinal cord, e.g. moving the hand away from a hot surface.
- The endocrine system consists of endocrine glands transporting their hormones via the blood.
- The pituitary is the master gland. The thyroid makes thyroxine, the adrenal glands make adrenaline and the pancreas makes insulin.

▶ **See Workbook Sensitivity and co-ordination.**

Problems

1 Work in pairs: (a) Recap the work you did on the structure of a neurone. Research and discuss how the parts are arranged. ICT
(b) Make your own large labelled drawing of a neurone and label the parts.
(c) Brainstorm in your group suitable materials you could use to represent the parts of a neurone.
(d) Follow the steps of the Engineering design process to Engage (ask questions), Explore (imagine), Elaborate (plan), Execute (create), Explain (assess, improve and report) and Evaluate to make your model.
(e) Join your model with others to make a network.

2 Work in a group: (a) Recap the work you did on the structure of the eye. ICT
(b) Make a large labelled diagram.
(c) Brainstorm in your group suitable materials you could use to represent each part.
(d) Follow the steps of the Engineering design process to make your model eye.

3 Work in a group: (a) Research and discuss the various areas of the brain. ICT
(b) Research the functions of each part of the brain and use the information to add notes to a labelled diagram.
(c) Examine a longitudinal section through the brain and identify the different kinds of material of which it is made.
(d) Brainstorm in your group suitable materials you could use to represent each part.
(e) Follow the steps of the Engineering design process to make a model brain.

4 Work in a group: (a) Research and discuss how a reflex action works. ICT
(b) Find out about the experiments done by Pavlov with his dogs.
(c) Make a large labelled diagram to show how the dogs received stimuli and how they reacted using a reflex action.
(d) Make a list of some actions in our body that are reflex actions. Why are reflex actions important?

Unit 20

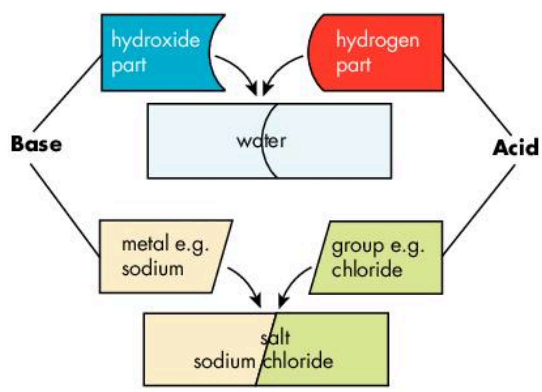
Acids and alkalis

1 *(a) Common household acids and (b) Common household alkalis. How do we use each one?*

This unit will help you to:

- identify many common substances as acids, alkalis and salts
- use laboratory and homemade indicators to distinguish between acids and alkalis
- identify alkalis as soluble bases
- describe the uses of commercial acids, alkalis and salts
- carry out experiments on the reactions of acids and alkalis
- investigate how neutralisation occurs and how it is important
- write word equations and balanced chemical equations.

2 *Student using indicators to test for acids and alkalis*



sodium hydroxide + hydrochloric acid →

NaOH + HCl

sodium chloride + water

NaCl + H_2O

3 *Neutralisation between a base and an acid to produce a salt and water only*

Acids, alkalis and indicators

Everything is made of chemicals. Everything we use is built up from elements. The common elements in household chemicals are carbon, hydrogen, oxygen, chlorine, sulphur and nitrogen. These combine to form the useful compounds, or mixtures of compounds, which we use around the home. Many of the substances also have chemical names, as shown in the table.

Objectives

- Identify alkalis as bases that dissolve in water.
- Identify acids, alkalis and neutral substances by using litmus paper and universal indicator.
- Make and use homemade indicators.

20.1 Classifying household chemicals

Materials: test tubes or small containers, plastic spoons, baking powder, cooking oil, Andrews liver salts, sugar, vinegar, washing-up liquid, moth balls, other substances of your choice, water, litmus paper

Method

Carry out the following tests. Then record your results in the Workbook Acids, alkalis and indicators.

1. Appearance: liquid or solid, powder, colour?
2. Solubility: does it dissolve in water, does it float or sink, does it react with water?
3. Acid, alkali or neutral: use litmus paper (acid turns blue litmus red, alkali turns red litmus blue, neutral no change).
4. Use: How is it used in the home?

Some household chemicals. Identify which ones are dangerous. These should be handled carefully.

▶ **See Workbook Acids, alkalis and indicators.**

Household chemicals

Kitchen chemicals	Bathroom chemicals	Laundry chemicals	Farm / garden chemicals
Table salt (sodium chloride)	Toothpaste	Bleach	Fertiliser
Cane sugar (sucrose)	Mouthwash	Detergent	Weed killers
Vinegar (ethanoic acid)	Deodorant	Soap	Insecticides
Kerosene oil	Soap	Sodium carbonate (washing soda)	Slug bait
LPG (liquid petroleum gas)	Shampoo	Fabric softener	Rat poison
Vegetable cooking oil	Shaving cream	Water	Quicklime (calcium oxide)
Margarine	Talcum powder	Stain remover	Paint
Baking soda (sodium hydrogencarbonate)	Air freshener		White spirit
Baking powder	Hairspray		
Seasoning salt (monosodium glutamate)	Floor polish		
Matches	Rubbing alcohol		
Washing-up liquid	Petroleum jelly		
General cleaner	Nail polish		
Oven cleaner	Hydrogen peroxide		
	Andrew's liver salts		
	Epsom salts (magnesium sulphate)		
	Milk of magnesia (magnesium hydroxide)		
	Toilet bowl cleaner		

20.2 Finding the constituents

Materials: household substances and labels, for example: mouthwash, box of detergent, soap wrapper, antacid, insect spray, alcohol, face cream, hand lotion, toothpaste

Method

1 Look at each label in turn. List all the ingredients. Classify each ingredient as an element, mixture or compound.
2 Try to identify the elements present in the mixtures and compounds.
3 Which is the most commonly used chemical in the home?
4 For each household substance, predict if it will be acidic, alkaline or neutral.

20.3 Using indicators

Materials: distilled water, baking soda, vinegar, the substances from the previous activity plus others of your choice, red and blue litmus paper, universal indicator paper

Method

Record your results in the Workbook Acids, alkalis and indicators.

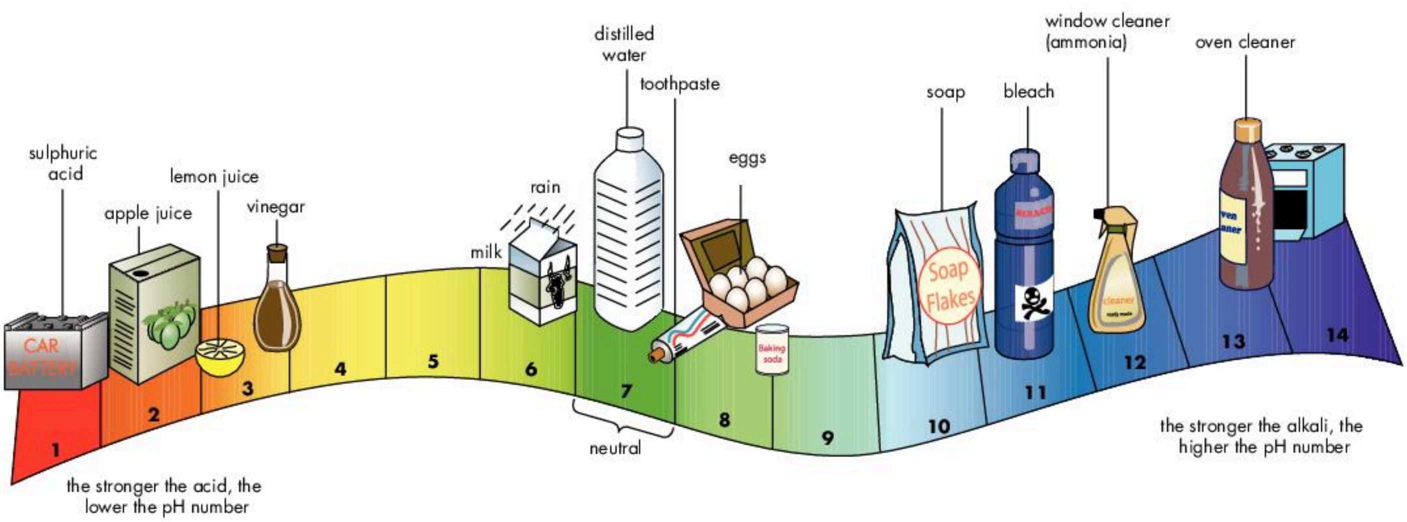
1 Test distilled water, baking soda and vinegar with both red and blue litmus paper. Record your results.
2 Make solutions of all the substances in distilled water. Test this with universal indicator paper. This has a colour code from pH 1 to pH 14. So it shows how strongly acidic or alkaline a solution is. Record your results.
3 How do your results with the two indicators compare?
4 How do the results compare to the diagram below?

Fun facts

- Indicators are also chemicals. They contain dyes, or mixtures of dyes, which change colour with pH.
- Many household chemicals are neutral. This makes them safe to use.
- Other chemicals are very dangerous, e.g. sulphuric acid (in car batteries), bleach, drain cleaners and rat poison.

pH scale

- Acids and bases are described on a scale called the **pH** scale.
- The pH describes the concentration of hydrogen ions that are formed.
- An acid forms a lot of hydrogen ions. It has a pH below 7.
- Pure water or a neutral solution forms as many hydrogen ions as hydroxide ions (a pH of 7).
- A base does not produce hydrogen ions. Instead, it produces hydroxide ions. It has a pH above 7.
- Acids and bases are identified with chemicals called **indicators**. These change colour at different pH.
- Litmus indicator is red in acids, blue in bases and purple in neutral solutions.
- Universal indicator is a mixture of indicators, which gives different colours over the whole pH range.



pH values of common chemicals

Describing acids

Strong acid	Weak acid
• Makes a large number of hydrogen ions. • Can be used for class work but must be treated carefully. E.g. hydrochloric and sulphuric acids.	• Makes few hydrogen ions. • Can be used for class work but must NOT be drunk. E.g. carbonic acid, vinegar (ethanoic acid) and citric acid.

Concentrated acid	Dilute acid
• Contains very little water and a lot of acid. • Very dangerous to handle; not used for class experiments. E.g. concentrated hydrochloric or sulphuric acid.	• Contains a lot of water and a small amount of acid. • Can be used with care but must NOT be drunk. E.g. dilute hydrochloric or sulphuric acid.

PS 20.4 Taking accurate pH readings

Materials: substances from the previous activities and others of your choice, chemicals in the laboratory, universal indicator paper, pH meter

Method

1 Use small samples of each chemical. Test it with universal indicator paper. Record the names and the pH values.
2 Your teacher will repeat step 1, using a pH meter. This gives a more accurate reading. Compare the two readings.
3 How do your results compare to the table below?

	pH	Examples in the home	Examples in the laboratory
Strong acids	1–2	Car battery acid, stomach acid	Sulphuric, nitric and hydrochloric acids
Weak acids	3–6	Lemon juice, soda water, milk	Carbonic acid
Neutral	7	Distilled water	Distilled water
Weak alkalis	8–11	Toothpaste, soap, baking soda,	Limewater, sodium hydrogencarbonate
Strong alkalis	12–14	Ammonia solution, washing soda, oven cleaner	Ammonium hydroxide, sodium and potassium hydroxides

UK 20.5 A pictorial pH scale

ICT

Use the work done so far on acids and alkalis, and search for other information.
Make an individual pH scale based on the pH of the household chemicals measured. Write the names of the chemicals instead of the numbers by the different colours on the scale. Then cooperate in class to produce a larger version.

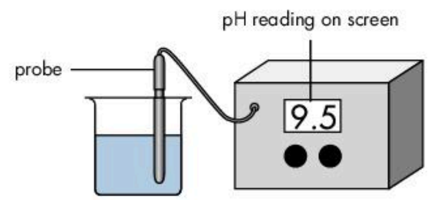
What does it mean?

Ionises: Changes to ions in solution.

Acid: Contains hydrogen atoms; it ionises to produce positive hydrogen ions in solution. A strong acid is more fully ionised than a weak one.

Base: A substance that reacts with an acid to produce a salt and water only, e.g. metal oxides and hydroxides. Bases are soluble or insoluble.

Alkali: A base that can dissolve in water; it ionises to produce negative hydroxide ions in solution. A strong alkali is more fully ionised than a weak one.



A very simple pH meter. The probe is placed in the test solution and the pH reading is shown on the screen.

Fun facts

- The pH inside a body cell is 6.8 and in the blood it is between 7.35 and 7.45.
- The acid in your stomach could burn your skin. There is special mucus in the stomach to protect the cells.

Questions

1 Why do indicators change colour?
2 Why do different indicators change to different colours in acids and alkalis?
3 Is the reaction between an acid and an indicator a chemical or physical change? Explain your answer.
4 (a) Why are weak acids not usually dangerous? (b) What would be their likely pH?
5 (a) Why are weak alkalis not usually dangerous? (b) What would be their likely pH?

20.6 Using commercial indicators

Materials: acids and alkalis used in the laboratory (e.g. dilute hydrochloric and sulphuric acids, dilute sodium and ammonium hydroxides), examples of commercial indicators, test tubes, test tube rack, droppers

Method

1. Each group should choose one acid, one alkali and one indicator.
2. Put a few drops of your indicator into the acid and the alkali. Observe any changes.
3. Record your group's results in a large table drawn on the chalkboard for your class.
4. Check that the results are consistent (that the same colours are recorded for the same solution and indicator by different groups). Do your results agree with those below?

Indicator	Colour in acid	Colour in alkali
Litmus	red	blue
Methyl orange	red	yellow
Phenolphthalein	colourless	pink
Bromothymol blue	yellow	blue

20.7 Making your own indicators

Materials: hibiscus petals, beetroot, red cabbage, pestle and mortar (or sharp knife), beaker, solvent (rubbing alcohol, white rum or surgical spirit) distilled water, vinegar, lime juice, dilute acid and alkali

Method

1. Choose one of the plant materials.
2. Cut or pound some with a little solvent to extract the dye (use petals from 10 hibiscus flowers in 5 cm^3 of solvent).
3. Filter your indicator and use the liquid to test substances of known pH. Then test substances with unknown pH. Record all your results in a large table set up for the class.
4. How do your results compare to using litmus paper?

▶ **See Workbook Acids, alkalis and indicators.**

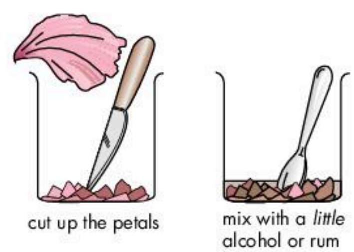
Fun facts

- Litmus is a dye that is extracted from some kinds of lichen.
- The leaves of red cabbage contain anthocyanins that can be extracted, They turn red in acid and purple–blue in alkalis.

Indicators

There are two main groups:

- Range indicators (universal indicator) that contain several dyes and can therefore give different colours over the range from pH 1 to pH 14.
- Acid-base indicators that are used only to indicate if a solution is acidic or alkaline. Litmus and methyl orange are examples. They are often used when acids and bases are mixed and can show the point of neutralisation. You will look at this later in the unit.



Making an indicator from hibiscus

Quick check ☑

Chemicals can be ________, ________ or ________. Litmus is an ________ that turns red in ________ and blue in ________. The ________ in universal ________ change to different colours in weak and ________ solutions of ________ and ________.

Use these words to fill in the spaces as you write the sentences in your Exercise book.

strong **alkalis** **dyes** **acids** **neutral** **indicator**

Reactions of acids and alkalis

You will now investigate the properties, uses and reactions of acids and alkalis in the laboratory and in everyday life.

20.8 Know-Want-Learn: KWL chart

1 Prepare a KWL chart for your group.

What we know	What we want to know	What we learned

2 Based on discussion, in the first column write what your group knows about acids and alkalis. Include both physical and chemical properties, and laboratory and household examples.
3 In a similar way complete the second column.
4 Discuss your tables with other members in the class and check them with your teacher.
5 Later, when you have completed the work on acids and alkalis, fill in the last column in the table.

▸ **See Workbook Reactions of acids.**

20.9 Kitchen chemistry: acids

Materials: fur scale from a kettle (calcium carbonate), washing soda (sodium carbonate), baking soda (sodium hydrogencarbonate), baking powder (baking soda plus tartaric acid), plastic egg box, marker pen, water, knife, lime, homemade indicator

Method

Do this activity at home (check with your adults).

1 Set up your egg box container and label it so that you have three compartments each and add your solid chemical substances (see the diagram).
2 Add a little water to each of the compartments labelled **(a)**. Observe and write your results in a table.

	Water (a)	Homemade indicator (b)	Lime juice (c)
Calcium carbonate			
Washing soda			
Baking soda			
Baking powder			

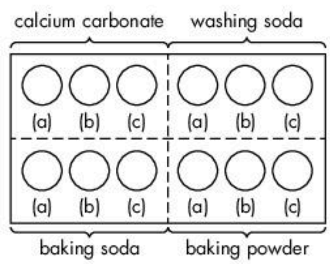
3 Add a little homemade indicator to each of the compartments labelled **(b)**. Observe and record.
4 Cut the lime in half. Squeeze some of the lime juice into each of the compartments labelled **(c)**. Observe and record.

Objectives

- Describe the reactions, properties and uses of acids.
- Describe the reactions, properties and uses of bases.
- Identify characteristics and uses of acids and bases in everyday life.
- Write balanced equations.

Fun facts

- Washing soda is alkaline (pH 11) and baking soda slightly alkaline (pH 8).
- The hydrogencarbonate radical, also called bicarbonate (HCO_3) has a valency of minus 1.



Label and put your chemicals into the egg box compartments.

Questions

1 How does calcium carbonate react with **(a)** water **(b)** pH indicator **(c)** lime juice? Explain your answers.
2 How does washing soda react with **(a)** water **(b)** pH indicator **(c)** lime juice? Explain your answers.
3 How does baking soda react with **(a)** water **(b)** pH indicator **(c)** lime juice? Explain your answers.
4 How does baking powder react with **(a)** water **(b)** pH indicator **(c)** lime juice? Explain your answers.
5 All the solid chemicals are carbonates or hydrogencarbonates. **(a)** How are they similar in their reaction with acid? **(b)** What gas do you think has been formed?

Chemical reactions of acids

Now you can investigate the reactions of dilute acids with metals. Acids contain hydrogen. Some metals can take the place of the hydrogen and push it out as hydrogen gas. The other substance produced is a **salt**. A salt usually contains a metal combined with a radical from the acid. For example:

magnesium + sulphuric acid = magnesium sulphate + hydrogen
(metal) + (acid) = (salt) + (hydrogen)

$$Mg + H_2SO_4 = MgSO_4 + H_2$$

20.10 Reacting acids with metals

Materials: calcium, magnesium, aluminium, zinc, copper, dilute hydrochloric acid, test tubes, rack, sandpaper, splints

Method

Record your results in the Workbook Reactions of acids.

1. Put five test tubes in a rack and add about 10 cm^3 of dilute hydrochloric acid to each one.
2. Clean small samples of the metals with sandpaper to remove surface chemicals and leave the pure metal.
3. Add the calcium to a test tube. How do you know there is a chemical reaction? Test the gas by putting a lighted splint into the neck of the test tube. What happens? What is the gas?
4. Repeat Step 3 with each of the other metals.

Questions

1. Do all the metals react with the acid in the same way?
2. Which of the metals is (a) most and (b) least reactive?
3. Write word equations for each of the metals that react with the hydrochloric acid.
4. Write word equations and balanced chemical equations for the reactions.

20.11 Reacting acids with carbonates

Materials: sodium carbonate (washing soda), sodium hydrogencarbonate (baking soda), calcium carbonate, spoons, dilute hydrochloric acid, test tubes, glass rod, limewater

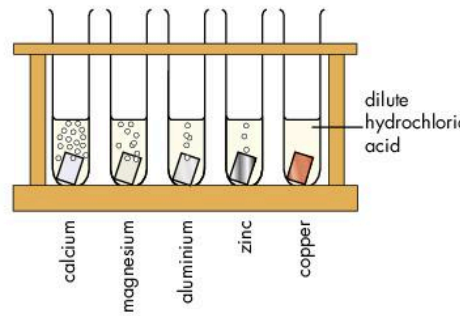
Method

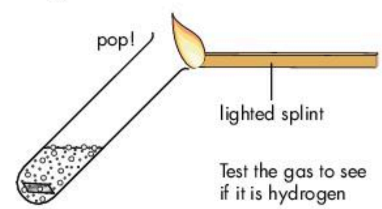
Record your results in the Workbook Reactions of acids.

1. Put three test tubes in a rack and add about 2 cm^3 of dilute hydrochloric acid to each one.
2. Put a quarter spoonful of sodium carbonate into a test tube. Observe and record what happens. Test any gas by holding a drop of limewater on a glass rod in the neck of the tube. What happens? What is the gas?
3. Repeat step 2 with the other chemicals.
4. Write word equations and balanced chemical equations.

Acids with metals

This is a displacement reaction. More reactive metals displace the hydrogen in acids more easily (and vigorously) than less reactive metals do. From your experiments, list the metals from the most to the least reactive.



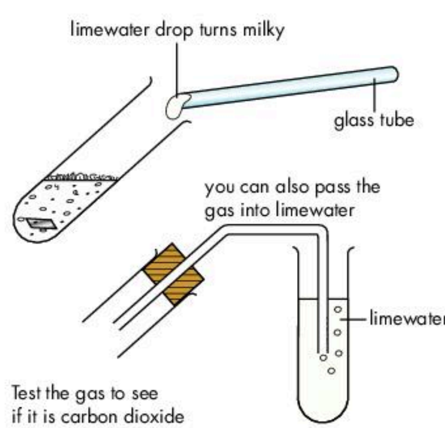


Test the gas to see if it is hydrogen

Acids with carbonates or hydrogencarbonates

With acids, a carbonate or hydrogencarbonate (bicarbonate) makes carbon dioxide and water, plus a salt based on which acid was used, e.g.

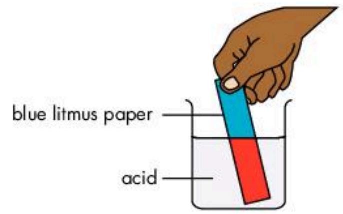
sodium carbonate + hydrochloric acid → sodium chloride + carbon dioxide + water

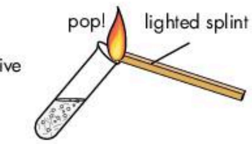


Test the gas to see if it is carbon dioxide

Examples and properties of acids

- Acids have a low pH. The pH is below 7.
- Acids turn blue litmus paper red.
- Acids have a sour taste. But you must **never** taste acids in the laboratory because they are very harmful. Acids such as citric acid in lemons are weak and can be tasted.
- Many acids destroy body tissue. They are corrosive. If you have an accident, wash the acid off quickly with lots of water.
- Acids can produce hydrogen ions.
- Acids neutralise solutions containing hydroxide ions.
- Acids react with several metals to release hydrogen.
- Acids react with carbonates to release carbon dioxide.





Common acids in the laboratory

Hydrochloric acid, HCl. Forms chlorides with metals.

Sulphuric acid, H_2SO_4. Forms sulphates with metals.

Nitric acid, HNO_3. Forms nitrates with metals.

Common acids in nature

Citric acid in citrus fruits such as lemons and oranges.

Ascorbic acid (vitamin C) in fruits and vegetables.

Formic acid in ants and bees. Ants squirt the acid at enemies. Bees inject acid with their sting.

Acetic or ethanoic acid is the acid in vinegar.

Hydrochloric acid in the stomach to aid in digestion.

Lactic acid builds up in working muscles and makes them ache.

Amino acids are the building blocks of proteins.

How acids react

- Hydrogen is released when acids react with some metals. A salt is also made, e.g.:

  zinc + sulphuric acid = zinc sulphate + hydrogen

  $Zn + H_2SO_4 = ZnSO_4 + H_2$

- Carbon dioxide is released when acids react with carbonates and hydrogencarbonates. A salt and water are also made, e.g.:

  hydrochloric acid + calcium carbonate

  $2HCl + CaCO_3$

  = calcium chloride + carbon dioxide + water

  $CaCl_2 + CO_2 + H_2O$

- Salt and water only are made when acids react with bases, e.g.:

magnesium oxide (base) + nitric acid (acid) = magnesium nitrate (salt) + water (water)

$MgO + 2HNO_3 = Mg(NO_3)_2 + H_2O$

sodium hydroxide + sulphuric acid = sodium sulphate + water

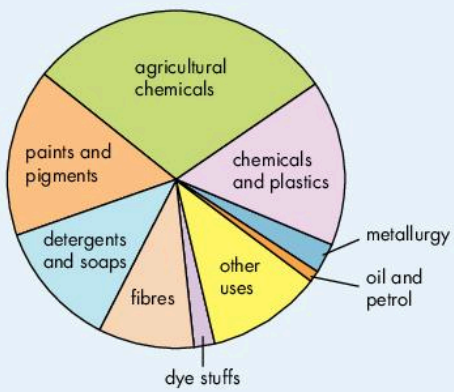
$2NaOH + H_2SO_4 \quad Na_2SO_4 + 2H_2O$

Fun facts

- Normal rain has a pH of 6.5. Acid rain has a pH 5.7 or lower. The lowest record was pH 2.83 over the Great Lakes in the USA in 1982.
- Acid rainwater wears away limestone (calcium carbonate) to form caves.

Questions

1 The pie chart shows how industry uses sulphuric acid. Use the information to answer the questions. ICT



(a) List the four main uses of sulphuric acid.

(b) What percentage of acid is used for each of these purposes? (You will have to work out the % based on the angles.)

2 Acid rain contains sulphuric acid.

(a) How will this react with limestone (calcium carbonate)?

(b) Write the word equation.

(c) Write a balanced chemical equation.

Examples and properties of bases

- Bases have a high pH. The pH is above 7.
- Bases turn damp red litmus paper blue.
- Bases have a bitter taste. But you must **never** taste bases in the laboratory because they are very harmful. A base such as Milk of Magnesia (magnesium hydroxide) can be tasted.
- Many bases destroy body tissue. They are corrosive. They burn the skin worse than acids do. Wash them off quickly.
- Bases often feel soapy. But you must **never** touch bases in the laboratory with your hands because they are very harmful.
- Bases are usually made of a metal together with oxygen (e.g. calcium oxide) or the hydroxide ion (e.g. calcium hydroxide).
- Bases can produce hydroxide ions.
- Bases neutralise solutions containing hydrogen ions.
- Bases that dissolve in water are called **alkalis**, e.g.:

calcium oxide + water = calcium hydroxide

$$CaO + H_2O = Ca(OH)_2$$

Common alkalis in the laboratory

Sodium hydroxide, $NaOH$. This is called caustic soda. Used to make soap and glass, and in the manufacture of paper and other fibres.

Potassium hydroxide, KOH. Used in medicine and making soap.

Calcium hydroxide, $Ca(OH)_2$. This is called slaked lime. It is used in cement. A solution of calcium hydroxide in water is called limewater. It is used in the test for carbon dioxide.

Magnesium hydroxide, $MgOH$. Used as an antacid in 'milk of magnesia'.

Sodium hydrogencarbonate, $NaHCO_3$. This is also called sodium bicarbonate and bicarbonate of soda. It is used in baking to supply carbon dioxide, and in fire extinguishers and antacids.

Common alkalis in nature

- Wasp stings are alkaline.
- Chalky soils are alkaline.

How alkalis react

- Sodium hydroxide can be used to test for metals. Most metal hydroxides are insoluble and have characteristic colours. Sodium hydroxide is used to make these, e.g.:

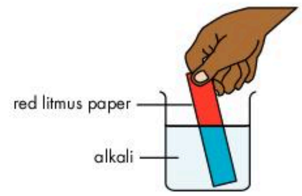
sodium hydroxide + copper sulphate (soluble)

= sodium sulphate + copper hydroxide (insoluble, blue precipitate)

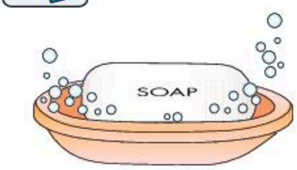
- Salt and water only are made when bases react with acids. The oxide or hydroxide part combines with the hydrogen in acids to make water.

calcium oxide + nitric acid = calcium nitrate + water

$$CaO + 2HNO_3 = Ca(NO_3)_2 + H_2O$$



corrosive



soapy feel

Alkalis

- Alkalis are bases that dissolve in water, e.g. sodium oxide and calcium oxide. They form hydroxides.
- Apart from sodium and potassium hydroxide, most hydroxides are insoluble. Calcium hydroxide is partly soluble.

Fun facts

- Sodium hydrogencarbonate is used in fire extinguishers on its own or with an acid to produce carbon dioxide.
- Indigestion tablets (antacids, e.g. magnesium hydroxide) work by reducing the acid in the stomach.

Using bases in the laboratory

- Sodium and potassium hydroxides can be used as pellets or as solutions to absorb carbon dioxide.
- Calcium hydroxide is partly soluble in water. Its solution is limewater. When carbon dioxide is bubbled through limewater, it goes milky.

Questions

1. Prepare a table to compare the properties of acids and alkalis.
2. Write the names and chemical formulae of five acids and five alkalis.

Describing alkalis

Strong alkali	Weak alkali
• Makes a large number of hydroxide ions. • Can be used for class work but should be treated carefully. E.g. sodium and potassium hydroxide.	• Makes few hydroxide ions. • Can be used for class work but must NOT be drunk. E.g. ammonia in water (also called ammonia solution).

Concentrated alkali	Dilute alkali
• Contains very little water and a lot of alkali (e.g. pellets of caustic soda (sodium hydroxide) are dissolved in water. • Very dangerous to handle; not used for class experiments. E.g. concentrated sodium or potassium hydroxide.	• Contains a lot of water and a small amount of alkali. Made by diluting concentrated alkali or using fewer pellets with water. • Can be used with care but must NOT be drunk. E.g. dilute sodium or potassium hydroxide.

▶ **See Workbook Reactions of alkalis.**

PS 20.12 Kitchen chemistry: alkalis

Materials: fur scale from a kettle (calcium carbonate), washing soda (sodium carbonate), baking soda (sodium hydrogencarbonate), baking powder (baking soda plus tartaric acid), plastic egg box, marker pen, water, knife, bleach, window cleaner, litmus paper, homemade indicator

Method

Do this activity at home (check with your adults).

1 Test small samples of the bleach and window cleaner with **(a)** litmus paper and **(b)** your homemade pH indicator. Are the bleach and window cleaner both alkalis? (If your homemade indicator is bleached white, then dilute the bleach or window cleaner with water before using it in your experiment.)

2 Set up your egg box container as before and label it so that you have three compartments each and add your solid chemical substances.

3 Add a little water to each of the compartments labelled **(a)**. Observe and write your results in a table like the one below.

	Water (a)	Bleach (b)	Window cleaner (c)
Calcium carbonate			
Washing soda			
Baking soda			
Baking powder			

4 Add a little bleach to each of the compartments labelled **(b)**. Observe and record.

5 Add a little window cleaner to each of the compartments labelled **(c)**. Observe and record.

What does it mean?

Insoluble bases: Do not dissolve in water, e.g. copper and iron oxides.

Soluble bases: Dissolve in water. Soluble bases are called alkalis.

Basic oxide: A metal combined with oxygen. It dissolves in water to make an alkali, e.g. magnesium oxide (MgO) dissolves in water to make magnesium hydroxide ($Mg(OH)_2$).

Acidic oxide: A non-metal combined with oxygen. It dissolves in water to make an acid, e.g. carbon dioxide (CO_2) dissolves in water to make carbonic acid (H_2CO_3).

Fun facts

- The name 'alkali' means from the ash of plants.
- A concentrated alkali can be as corrosive as a concentrated acid. They must both be treated with great care.
- Spinach, cucumber, broccoli, avocado and celery are all alkaline foods.

Questions

1 Are bleach and window cleaner alkaline solutions? How do you know?

2 How does calcium carbonate react with **(a)** water **(b)** bleach **(c)** window cleaner? Explain your answers.

3 How does washing soda react with **(a)** water **(b)** bleach **(c)** window cleaner? Explain your answers.

4 How does baking soda react with **(a)** water **(b)** bleach **(c)** window cleaner? Explain your answers.

5 How does baking powder react with **(a)** water **(b)** bleach **(c)** window cleaner? Explain your answers.

6 All the solid chemicals are carbonates or hydrogencarbonates. **(a)** How are they similar in their reaction with alkali? **(b)** Is any gas formed?

Chemical reactions of alkalis

Now you can investigate the reactions of dilute alkalis with metal and ammonium salts.

20.13 Reacting alkalis with salts

Materials: iron chloride, copper sulphate, ammonium chloride and dilute sodium hydroxide solutions; test tubes, test tube rack, red litmus paper

Method

Record your results in the Workbook Reactions of alkalis.

1. Put three test tubes in a rack and add about 10 cm^3 of dilute sodium hydroxide solution to each one.
2. Add a small amount of iron chloride solution to the first sample. (a) What do you observe? (b) What do you think has happened?
3. Add a small amount of copper sulphate solution to the second sample. (a) What do you observe? (b) What do you think has happened?
4. Add a small amount of ammonium chloride solution to the third sample. (a) What do you observe? (b) What do you think has happened? (c) Place damp red litmus paper in the neck of the tube to test if an alkaline gas has been produced.

Questions

1. Which of the salts react with the alkali in a similar way? How do the products vary?
2. What is produced when sodium hydroxide and ammonium chloride interact?
3. Write word equations and balanced chemical equations for the reactions.

Alkalis with metal salts

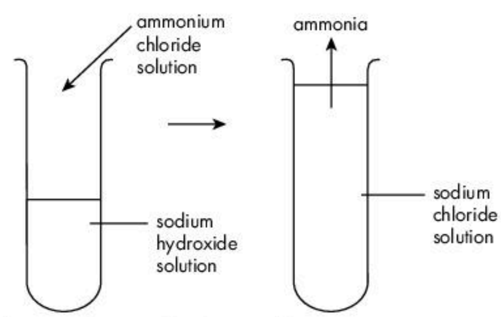
The hydroxide ion joins with a metal ion to form an insoluble hydroxide precipitate of a certain colour.

Use the word and chemical equations in the box below to write ionic equations for the reactions between the metal salts and sodium hydroxide.

Alkalis with ammonium salts

The hydroxide ion joins with the ammonium ion to form ammonia gas and water.

Use the word and chemical equation in the box below to write an ionic equation for the reaction between ammonium chloride and sodium hydroxide.



Ammonia gas is given off

Alkalis contain hydroxide ions in solution. The hydroxide ions can join with metal or ammonium ions.

iron chloride	+	sodium hydroxide	=	iron hydroxide	+	sodium chloride				
$FeCl_3$	+	$3NaOH$	=	$Fe(OH)_3$	+	$3NaCl$				
copper sulphate	+	sodium hydroxide	=	copper hydroxide	+	sodium sulphate				
$CuSO_4$	+	$2NaOH$	=	$Cu(OH)_2$	+	Na_2SO_4				
ammonium chloride	+	sodium hydroxide	=	sodium chloride	+	ammonia	+	water		
NH_4Cl	+	$NaOH$	=	$NaCl$	+	NH_3	+	H_2O		

Quick check ☑

Acids ionise to make ________ ions and alkalis make ________ ions. Many metals produce ________ gas and carbonates produce ________ with acids. Metal salts make insoluble ________ and ammonium salts make ________ with alkalis.

Use these words to fill in the spaces as you write the sentences in your Exercise book.

hydrogen **ammonia** **hydroxide** **carbon dioxide** **hydroxides**

Neutralisation and making salts

Objectives

- Carry out neutralisation and explain what happens.
- Describe everyday uses of neutralisation.
- Identify different ways of making salts and write balanced equations.

Acids and alkalis can neutralise the effect of each other when they interact in equal amounts at the same concentration. The reaction is called **neutralisation**.

The hydrogen ions from the acid combine with the hydroxide ions from the alkali to form water. The solution is no longer either acid or alkaline; it is neutral. At the same time, a salt is formed by the joining of the metal (from the alkali) and the radical (chloride, sulphate, etc.) from the acid.

Acids also combine with insoluble bases, e.g. copper oxide, in a similar way, so we can write the general equation:

Acid + Base = Salt + Water

The acid and base have to be used in the correct strengths and amounts so there are no hydrogen ions or hydroxide ions 'left over'. We know that the reaction is complete when the solution becomes neutral. So we use an indicator that changes colour to tell us when neutralisation has occurred.

20.14 Kitchen chemistry: neutralisation

Materials: lime juice, window cleaner (dilute ammonia solution), litmus paper, homemade indictor, plastic egg box container, spoons, eye dropper

Method

Do this activity at home (check with your adults). Ask your teacher for a piece of litmus paper to take home.

1 Pour a little window cleaner (ammonia solution) into a plastic egg compartment and test it with a small piece of litmus. If the litmus becomes bleached, then dilute the window cleaner until you get a colour change to blue. You can also test the ammonia solution with your homemade indicator. Observe and record the colour changes.

2 Put a sample of lime juice into another compartment of the egg box, and test it with a small piece of litmus paper and with your homemade indicator. Observe and record the colour changes.

3 Put out fresh samples of lime juice and ammonia solution. Add a small piece of litmus paper to the lime juice.

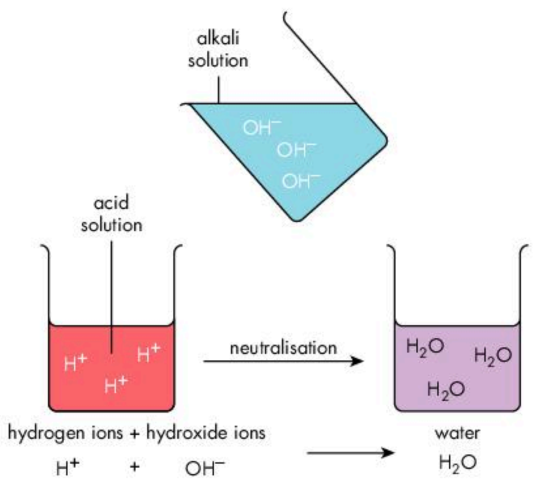
4 Now, carefully, drop by drop add fresh ammonia solution to the lime juice containing the litmus paper. After each drop, stir the liquid with a spoon. Observe and record what happens to the colour of the indicator.

5 Continue step 4 until the litmus paper changes colour. If this does not happen, you will need to adjust the strengths of your acid and alkali solutions.

Explanation: When the litmus paper changes, the hydrogen ions in the acid have balanced or neutralised the hydroxide ions in the alkali. We say that neutralisation has occurred.

Fun facts

- Copper oxide is a base because it reacts with acids and neutralises them to make salt and water only, but it is not an alkali because it does not dissolve in water.
- Acid plus metal carbonate or hydrogencarbonate give salt and water but also produce carbon dioxide.
- If we are given the name of a salt formed during neutralisation we know which acid and alkali made it.



Neutralisation

Neutralisation has occurred when the litmus paper changes colour to purple

During neutralisation, the hydrogen and hydroxide ions join in pairs to make water. The metal part of the alkali also joins with the radical from the acid to make a salt (see diagram).

20.15 Neutralisation

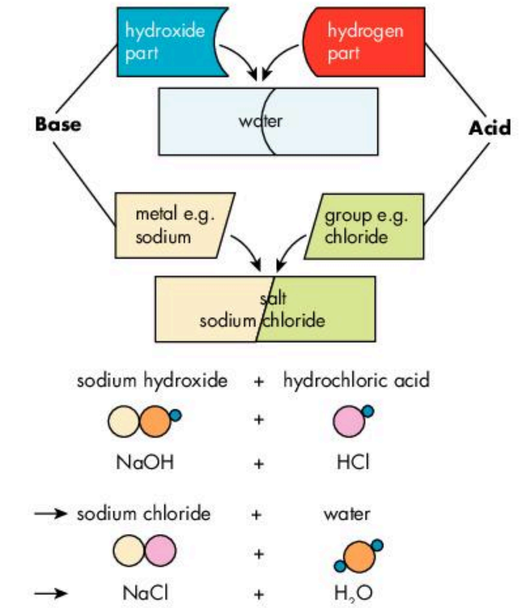
Materials: litmus solution, glass rod, dropping pipettes, dilute hydrochloric acid, dilute sodium hydroxide solution, two small measuring cylinders, beaker

Method

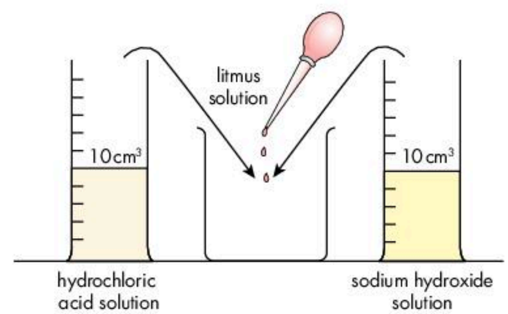
Record your results in the Workbook Neutralisation.

1 Use a measuring cylinder to measure 10 cm^3 of dilute hydrochloric acid. Put this is in a beaker with a few drops of litmus indicator.
2 Use another measuring cylinder to measure 10 cm^3 of dilute sodium hydroxide solution. Pour about 8 cm^3 of this into the acid in the beaker. Stir with the glass rod.
3 Now add the remaining alkali, drop by drop using the dropping pipette. Stir between each addition. Observe and record any colour changes. Why do you think this is important?
4 How much alkali do you need to neutralise the acid? How do you know when neutralisation has occurred? If the acid and alkali are of exactly the same strength you should find that equal amounts will neutralise each other.
5 Feel the beaker in which neutralisation has occurred. Is it an endothermic or an exothermic reaction?

▶ **See Workbook Neutralisation.**



How a salt and water are formed during neutralisation



Carefully add sodium hydroxide solution to hydrochloric acid until the litmus just changes colour. This is neutralisation.

Naming of salts and chemical equations

Acid	Salt	Acid	Salt
Hydrochloric	chloride	Sulphuric	sulphate
Nitric	nitrate	Carbonic	carbonate

Let us look at an example:

base + acid → salt + water

sodium hydroxide + sulphuric acid → sodium sulphate + water

$$NaOH + H_2SO_4 \rightarrow Na_2SO_4 + H_2O$$

This does not balance; need more Na atoms in reactants, so:

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + H_2O$$

Now there are more O atoms in reactants than products, so:

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$

Check all the atoms. It is now a balanced equation.

$$2NaOH + H_2SO_4 = Na_2SO_4 + 2H_2O$$

Now try these and see the Question box on the right.

1 Ammonium hydroxide + nitric acid
2 Sodium hydroxide + carbonic acid

Questions

1 For each of the following salts, list the alkali and acid that could be used to make them (a) sodium chloride (b) magnesium sulphate (c) copper chloride (d) potassium nitrate (e) iron sulphate (f) copper carbonate.
2 For each of the answers above (a)–(f), write the word equation and balanced chemical equation.
3 Which salt would be made if dilute hydrochloric acid neutralises dilute ammonium hydroxide? Write the word equation and balanced chemical equation.

Uses of neutralisation

20.16 Treating indigestion

Materials: dilute hydrochloric acid, indigestion tablets (or baking soda), spoon, 'milk of magnesia' (or magnesium hydroxide), dropping pipette, test tubes, test tube rack, litmus paper

Method

Record your results in the Workbook Neutralisation.

1 Put about 2 cm^3 of dilute hydrochloric acid into two test tubes. Add a strip of litmus paper to each one.
2 Break up half an indigestion tablet, or use a similar amount of baking soda. Add this a little at a time to the acid. Observe and record what happens.
3 Add milk of magnesia or magnesium hydroxide a drop at a time to the other test tube containing acid. Observe and record what happens.

Questions

1 Were you able to neutralise the acid in both cases?
2 Write the word equation and balanced chemical equation for one of the reactions.

20.17 Treating stains

You have been provided with small pieces of cloth with stains on them. You also have baking soda (an alkali), and white vinegar and an aspirin tablet (both weak acids). You can also ask for any other equipment or chemicals that you need. Design and carry out an activity to remove the stains by using neutralisation. Report on your findings.

We can summarise some uses of neutralisation.

- Treating indigestion. Problems of indigestion can be caused by excess acid in the stomach. The acid is neutralised by a weak alkali called an **antacid**. Examples are bicarbonate of soda and milk of magnesia.
- Treating insect stings. Ant and bee stings are acidic. They can be neutralised by an alkali, bicarbonate of soda. Wasp stings are alkaline. They can be neutralised by a weak acid, vinegar (ethanoic acid).
- Avoiding tooth decay. The acids produced by bacteria in the mouth can be neutralised by alkaline foods, such as cheese. Teeth can also be cleaned with toothpaste, which is alkaline.
- Acid stains, such as tea, coffee, red wine or fruit can be neutralised and removed with an alkali (sodium hydrogen-carbonate). Alkaline stains, such as sweat, can be removed by an acid (white vinegar or crushed aspirin).

Fun facts

- People have more than a cupful of hydrochloric acid in their stomachs. The acid has a pH of 1–2.
- Bacteria act on the sugars in our food to produce acids that can wear away the enamel of our teeth.

20.18 Investigating toothpaste

You have to design an activity:

1 Find the accurate pH value of three samples of toothpaste.
2 Find out how much of each kind of toothpaste is needed to neutralise a given amount of acid. (For example, you could choose a certain volume of vinegar or lime juice.)

Design your activity and check it with your teacher. Make sure it is a fair test. Then carry out and report your results. Were all the kinds of toothpaste equally good at neutralising the acid?

The photograph shows a bee using the sting at the end of its body.

Questions

1 Why does a weak acid lessen the pain of a wasp sting but not that of a bee sting? What would you use for a bee sting, and why?
2 Why is it better to end a meal with cheese rather than with sweet fruit?
3 Why is it more useful to clean one's teeth after a meal than before a meal?

20.19 Plants and pH

Materials: test tubes, barium sulphate, distilled water, soil samples, peat, universal indicator paper
Method
Testing for pH
1 Put a little soil in a test tube and mix it with barium sulphate and distilled water. Why do you use distilled water and not tap water?
2 Cover the top and shake the tube vigorously. The barium sulphate makes clay particles stick together, so they sink.
3 Pour off the clear liquid into another test tube. Test it with universal indicator paper.
4 Test several soil samples, and peat, in a similar way. Record the pH of each one.

Growing plants
5 By reference to the table on the right, choose soils you think would be (a) suitable and (b) unsuitable for growing lettuce seeds. Set up a fair test to check your prediction.
6 Grow the plants in pots for two weeks. Water them both with distilled water. Report on your results in class. You can then plant the seedlings in the garden.

20.20 Improving soils

Work in groups:
You have been given two samples of soil (one is acidic and the other is alkaline). You also have some slaked lime (calcium hydroxide) and an acidic fertiliser (ammonium sulphate). You can ask for any other equipment or chemicals that you need.

ICT

1 Find out which soil is which.
2 Design and carry out an activity to apply what you know about neutralisation to improve both of the soil samples.
3 Present proof that you have achieved your objective. Write a report on your findings to the local Farmers' Cooperative with your recommendations.

Improving soils: Different plant crops grow better in soils with different pH values. Though most plants grow best in slightly acid soils.

- If a soil is too alkaline, we can add an acidic fertiliser such as humus, peat, or a commercial fertiliser such as ammonium sulphate.
- Rain and artificial fertilisers make a soil more acidic. Clay soils are also often acidic, and can be as low as pH 4. Lime (calcium oxide) or slaked lime (calcium hydroxide) can be added to neutralise the acid, for better plant growth.

pH range	Plants that grow best
4.5 – 6.0	Potato
5.5 – 7.0	Carrot, tomato
6.0 – 7.0	Lettuce. onion
6.0 – 7.5	Cabbage, grass

pH ranges suited to different plants

Fun facts

- Plants grow best in slightly acid soils because this helps them to take up mineral salts more easily.
- Compost contains humus, which is slightly acid. It helps to improve the structure of the soil and decays further to release mineral salts.

Other uses of neutralisation

- Phosphoric acid is used to remove rust (iron oxide) from metal surfaces. The acid is weak enough to only dissolve the rust slowly and can then be washed off the clean metal surface.
- Tartaric acid (in baking powder) is used to remove limescale (calcium carbonate) from inside kettles. The weak acid does not attack the metal and does not leave an unpleasant taste.
- Nettles have an acid sting that can be soothed by using a dock leaf that contains an alkali.

Questions

1 Choose three examples of reactions that make use of neutralisation. Write the word and balanced chemical equations.
2 At the beginning of this unit you set up a **KWL** chart.
Look at your chart again and fill in what you have now learned about acids and alkalis. If there are still things you need to find out then research them online.

ICT

Making salts

A salt is an ionic compound with a positive metal or ammonium ion combined with a negative non-metal ion. Two examples are sodium chloride and ammonium nitrate.

Acids contain hydrogen. Many salts are formed when all or part of this hydrogen is replaced by a metal or ammonium ion. When hydrochloric acid and sodium hydroxide neutralise each other, the sodium ions replace the hydrogen in the hydrochloric acid and form the salt, sodium chloride.

20.21 Making common salt (sodium chloride)

Materials: dilute hydrochloric acid, dilute sodium hydroxide solution, two small measuring cylinders, beaker, water, evaporating dish, heating apparatus

Method

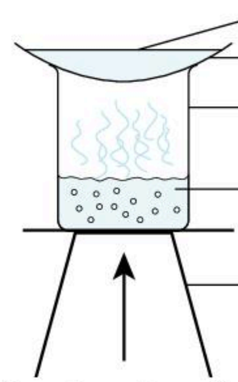
1 Repeat the neutralisation experiment with dilute hydrochloric acid and dilute sodium hydroxide. Use the same acid and alkali as you used then, and exactly the same amounts, but do not add any litmus solution.
2 Put the resulting neutralised solution in an evaporating dish.
3 Heat this over a beaker of water as shown in the diagram.
4 When the liquid has almost evaporated, take it off the heat. Let it cool. Observe and report all your findings.

Questions

1 What chemicals were in the evaporating dish when you started heating the solution?
2 What was driven off and what was left behind?
3 Write word and balanced chemical equations for the neutralisation.

- We can make many salts by neutralisation, when acids react with bases containing a metal or ammonium ion. This is the reaction of acids with:
  (a) metal oxides or metal hydroxides
  (b) ammonia gas or ammonium hydroxide.
- Acids also reacts with:
  (c) metal carbonates or hydrogencarbonates to produce a salt and water and to release carbon dioxide.
- Acids also react with many:
  (d) metals to produce a salt and to release hydrogen.
- Some salts can be formed directly in synthesis reactions:
  (e) direct combination of a metal and non-metal.
  For example, heating iron (a metal) and sulphur (a non-metal) produces the salt, iron sulphide, Sodium can also react directly with chlorine gas to produce sodium chloride.

▶ **See Workbook Making salts.**



Heat the sodium chloride solution in an evaporating dish over a beaker of water. Then allow it to cool and form crystals.

Fun facts

- Hydrogencarbonates are formed when not all the hydrogen in carbonic acid is replaced by the metal, e.g. with sodium this gives $NaHCO_3$.
- The formula for ammonia gas is NH_3, for ammonium hydroxide it is NH_4OH. The ammonium ion has a single negative charge, e.g. $(NH_4)_2SO_4$.

Preparation methods

For each of the five ways of preparing salts listed on the left, here is an example. For each pair of reactants write the full word equation and then the balanced chemical equation.

(a) copper oxide + nitric acid
(b) ammonia gas + sulphuric acid
(c) sodium hydrogencarbonate + hydrochloric acid
(d) magnesium + hydrochloric acid
(e) sodium + chlorine

Questions

1 Choose two more reactants for each method of making salts. Then write word and balanced chemical equations.
2 Suggest a way of preparing (a) magnesium sulphate and (b) ammonium nitrate. How are each of these salts used?

Uses of salts

Common name	Chemical name	Formula	Use
Table or common salt	Sodium chloride	$NaCl$	For flavouring and preserving food.
Baking soda	Sodium bicarbonate or sodium hydrogencarbonate	$NaHCO_3$	In baking and fire extinguishers and as an antacid.
Washing soda	Sodium carbonate	Na_2CO_3	For softening water.
Epsom salts	Magnesium sulphate	$MgSO_4$	As a laxative against constipation.
Chalk, limestone	Calcium carbonate	$CaCO_3$	As a building material.
Fertiliser	Ammonium nitrate	NH_4NO_3	To add minerals to the soil.

Salts are very important in our lives. We can look at some of the chemical reactions in which they take part.

- Sodium chloride: Salt is rubbed onto food or the food is placed in a strong salt solution. Osmosis occurs to draw water out of the food, which is dried and preserved.
- Baking soda: When mixed with an acid and liquid during cake making, the hydrogencarbonate ion reacts with hydrogen ions to release carbon dioxide gas to make the cake 'rise'.

$$HCO_3^-(aq) + H^+(aq) \rightarrow CO_2(g) + H_2O(l)$$

- Washing soda: Hard water contains dissolved ions of calcium and magnesium that form a scum with soap. Sodium carbonate makes these precipitate as insoluble calcium and magnesium carbonate. This softens the water so it forms a lather.

$$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$$

- Epsom salts: Magnesium sulphate crystals used as bath salts can help release stress and back pain. In the correct dosage they are made into a solution and used as a laxative.
- Calcium carbonate: This is heated in a kiln to a high temperature and it decomposes to make quicklime (CaO) and carbon dioxide.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

  The quicklime is then reacted with other materials to make cement.
- Ammonium nitrate: This helps the soil in two ways. Ammonium nitrate is acidic and can help improve alkaline soils. As it dissolves in the water in the soil, it also provides nitrate ions (NO_3^-) that can be taken up by the roots of plants to provide the nitrogen they need for building proteins.

Chemical equations

1 Write the word equation.
2 Add each chemical formula (making sure the charges balance and each molecule is neutral).
3 Count the atoms of each kind in the reactants and products and add coefficients (numbers in front of chemicals) to balance both sides.

State symbols

When we write a word equation we can use symbols to describe the state or condition of each of the reactants and products.

(aq) = aqueous (ions in solution)
(g) = gas given off
(l) = water
(s) = solid, also a precipitate

Ionic equations

The ions that are in solution in the reactants are shown with their charges together with the products made from them, e.g.

$$HCO_3^-(aq) + H^+(aq) \rightarrow CO_2(g) + H_2O(l)$$

Other chemicals that are present in the reactants and products and are unchanged in the reaction are omitted from the ionic equation.

Quick check ☑

The reaction of an acid and a base is called __________ : hydrogen ions balance with __________ ions. These reactions produce __________ and __________ only. Other ways of making __________ are to react acids with ________ or __________.

Use these words to fill in the spaces as you write the sentences in your Exercise book.

hydroxide **carbonates** **salts**
metals **water** **neutralisation**

Questions

Answer these questions in your notebook

For questions **1–34** answer **A**, **B**, **C** or **D**.

1 Which is a true statement?
A all bases are alkalis
B all alkalis are bases
C alkalis that dissolve are bases
D alkali is another word for base

2 A pH reading tells us about the concentration of
A hydrogen ions **B** hydroxide ions
C oxide ions **D** water

3 An acid has a pH
A of 7 **B** above 7
C below 7 **D** from 0 to 14

4 What colour is litmus paper in an alkali?
A red **B** blue
C purple **D** green

5 Which of these is acidic?
A pure water **B** baking soda
C limewater **D** lemon juice

6 Universal indicator can distinguish a pH
A of 7 **B** above 7
C below 7 **D** from 0 to 14

7 Which gives the most accurate pH reading?
A universal indicator **B** methyl orange
C pH meter **D** litmus solution

8 Which of these is NOT called an acid-base indicator?
A universal indicator **B** methyl orange
C litmus paper **D** litmus solution

9 The main characteristic of a strong acid is that it
A is fully ionised
B is only partly ionised
C contains a lot of water
D contains a little water

10 The main characteristic of a strong alkali is that it
A does not dissolve in water
B produces a small number of hydroxide ions
C produces a large number of hydroxide ions
D produces a large number of hydrogen ions

11 An alkali is
A a base with a pH of 8–10
B a base with a pH of 11–14
C a base that dissolves in water
D a strong base

12 Hydrogen is made when acids react with some
A non-metals **B** metals
C carbonates **D** bases

13 Carbon dioxide would NOT be made when acids react with
A bicarbonates **B** metals
C carbonates **D** hydrogencarbonates

14 What is the test for hydrogen? It
A re-lights a glowing splint
B gives a pop with a lighted splint
C turns limewater milky
D turns damp red litmus blue

15 What is the test for carbon dioxide? It
A re-lights a glowing splint
B gives a pop with a lighted splint
C turns limewater milky
D turns damp red litmus blue

16 Which is true? Ammonia is released when
A acids react with ammonium salts
B alkalis react with ammonium salts
C acids react with ammonium hydroxide
D alkalis react with ammonium hydroxide

17 What is the test for ammonia? It
A re-lights a glowing splint
B gives a pop with a lighted splint
C turns limewater milky
D turns damp red litmus blue

18 Washing soda is also called
A baking powder
B sodium carbonate
C sodium hydrogencarbonate
D bicarbonate of soda

19 Neutralisation occurs between
A two metals **B** an acid and a base
C two non-metals **D** a proton and neutron

20 In neutralisation the pH changes to pH 7 because
A there are equal numbers of hydrogen and hydroxide ions
B there are more hydrogen ions than hydroxide
C there are more hydroxide ions than hydrogen
D a salt is formed

21 What are the salts formed from sulphuric acid?
A sulphates **B** sulphides
C sulphur-salts **D** chlorides

22 Which of these salts could NOT be formed from carbonic acid?
A carbonates **B** bicarbonates
C chlorides **D** hydrogencarbonates

23 We can use neutralisation to treat
A indigestion **B** insect stings
C stains **D** all of the above

24 An ant's sting is
A acidic **B** alkaline
C neutral **D** salty

25 An acid soil would have a pH of
A more than 7 **B** 7 to 7.5
C exactly 7 **D** less than 7

26 Which of these might make the soil more acidic?
A rain **B** fertilisers
C humus **D** all of the above

27 The addition of which of these would NOT improve acidic soils?
A ammonium nitrate **B** lime
C slaked lime **D** calcium hydroxide

28 Which salt is formed when sodium hydroxide reacts with hydrochloric acid?
A hydrogen chloride **B** water
C sodium chloride **D** sodium sulphate

29 How many hydrogen atoms are there in two molecules of ammonium sulphate $(NH_4)_2SO_4$?
A 2 **B** 4
C 8 **D** 16

30 How many oxygen atoms are there in two molecules of ammonium sulphate $(NH_4)_2SO_4$?
A 2 **B** 4
C 8 **D** 16

31 If ammonium sulphate $(NH_4)_2SO_4$ reacts with sodium hydroxide, which gas would be produced?
A hydrogen **B** carbon dioxide
C oxygen **D** ammonia

32 Which of the following is the correct formula for calcium hydrogencarbonate?
A $CaHCO_3$ **B** Ca_2HCO_3
C $Ca(HCO_3)_2$ **D** $Ca_2(HCO_3)_2$

33 Which of the following is the correct formula for sodium sulphate?
A $NaSO_4$ **B** Na_2SO_4
C $Na(SO_4)_2$ **D** $Na_2(SO_4)_2$

34 Which of these reactions would NOT form sodium chloride?
A synthesis reaction of sodium and chlorine
B decomposition of sodium carbonate
C neutralisation between sodium hydroxide and hydrochloric acid
D reaction between sodium hydroxide and iron chloride

For questions **35–53** write the answers in your notebook.

35 How are acids and bases (a) similar and (b) different? Give at least five answers in each case and give three examples of each.

36 Name a base and an alkali. How are bases and alkalis (a) similar and (b) different?

37 (a) Is vinegar an acid, base or neutral? (b) How do you know? Give at least two reasons.

38 Name a chemical you use at home. (a) Give its chemical formula and (b) how it is used.

39 (a) What is the pH scale? (b) How is it useful?

40 (a) What is the difference between litmus solution and universal indicator solution? (b) How is litmus used? (c) How is universal indicator used?

41 Is methyl orange more similar to litmus or to universal indicator? Explain your answer.

42 Distinguish between (a) strong and weak acids and give examples and (b) between concentrated and dilute acids.

43 (a) Name a strong acid you would find in the home and (b) how it is used.

44 (a) Name a strong alkali you would find in the home and (b) how it is used.

45 Why do you think body cells and blood have a pH close to pH7 and kept within narrow limits?

46 Describe the action of lime juice on (a) calcium carbonate (b) washing soda (c) baking soda (d) baking powder. What gas is produced in each case?

47 (a) Name a metal that produces hydrogen when reacted with hydrochloric acid. (b) Write the word equation and a balanced chemical equation.

48 (a) Name a metal that does not produce hydrogen when reacted with hydrochloric acid. (b) How can you explain this?

49 (a) What is formed when sodium hydroxide reacts with ammonium nitrate? (b) How could you test for the gas produced and what would be the result? (c) Write the word equation and a balanced chemical equation.

50 (a) $10\,cm^3$ of a certain acid neutralised $5\,cm^3$ of a certain alkali. What can you say about the relative strength of the acid and alkali? (b) What substances would have been formed by the reaction?

51 (a) Give three examples where neutralisation is used in everyday life. (b) Choose one example and write a word and balanced chemical equation.

52 (a) Name three ways in which salts can be formed. (b) Give an example of each method and write a word and balanced chemical equation.

53 (a) Choose a salt that is used at home and give its chemical name and formula. (b) Explain how it is used and write a word and balanced chemical equation to illustrate your answer.

Key ideas

- All alkalis are bases but not all bases are alkalis. Only soluble bases are called alkalis.
- We can classify household chemicals by where they are used in the home and whether they are acids, bases, or neutral.
- Acids and bases are described on a scale called the pH scale, where the pH describes the concentration of hydrogen ions.
- Litmus indicator solution is red in acids, blue in bases and purple in neutral solutions.
- Strong acids are fully ionised to produce hydrogen ions and weak acids produce very few.
- Strong alkalis are fully ionised to produce hydroxide ions and weak alkalis produce very few.
- Dyes in indicators change colour with pH changes.
- Universal indicator can show (by the colour) the pH of a chemical from pH 0 to pH 14.
- Acid-base indicators, e.g. litmus and methyl orange have a distinct colour change between acid and base and are used to show when neutralisation occurs.
- Acids react with carbonates and hydrogen-carbonates to make a salt, water and carbon dioxide.
- Acids react with many metals to produce a salt and hydrogen.
- Alkalis react with ammonium salts to make a ammonia, water and a different salt.
- Neutralisation occurs between an acid and a base to produce a salt and water only.
- The name of the salt depends on the acid and base that are used, e.g. hydrochloric acid produces chlorides.
- The result of the neutralisation between sodium hydroxide and hydrochloric acid is sodium chloride.
- Neutralisation is an exothermic reaction.
- Neutralisation has several applications, e.g. treating indigestions, stains, soils and rust. In each case an acid and base neutralise each other.
- Neutralisation is an important way of making salts: the metal or ammonium ion comes from the base and the acid supplies the non-metal ion.
- Salts are also made when acids react with many metals and with metal carbonates and hydrogen-carbonates.
- Some salts are produced by direct combination (synthesis) between a metal and non-metal.
- Acids, bases and salts and their reactions are very important in our lives.

▶ **See Workbook Acids and alkalis.**

Problems

1 Your class has been asked to set up a display on 'Chemicals in the home' for a parent-teachers' meeting that will be held shortly. Your principal is keen that the display should appeal to younger pupils and also to the general public.

(a) Brainstorm in your group how you will tackle this problem.

(b) Include in your assignments, an Internet search for information. ICT

(c) Collect samples from home for the display and copy or design labels from the chemicals you use. Will you include any 'hands-on' activities for the visitors?

(d) Remember to consider: how we identify acids, bases and neutral chemicals as well as salts; how we group the chemicals by where they are used and the different ways in which they are used.

(e) Reassemble in your group and set up your display.

2 The display on Chemicals has been a great success. Your teacher also met the features editor at the Jamaica Gleaner, Mrs Lee. She was very impressed and wants to know if your class could prepare a series of six articles to appear in the paper on the topic of Neutralisation.

(a) Discuss the project in class. You also need to prepare a Power point presentation for Mrs Lee to show to the board before the project is approved. ICT

(b) Your class decides to split into groups: one to do the PowerPoint presentation, six to write the articles about six examples of where neutralisation is important in everyday life, and one to plan a party (as Mrs Lee has said there will be a small fee for the articles).

(c) Decide which group you want to be and begin your work. ICT
Remember any scientific terms you use will have to be explained, and you may have to do further research.

(d) Plan your article and also include drawings to help your explanations. Good Luck!

Unit 21

Embryo development and birth control

1 *A human foetus at 11 weeks. You can see the umbilical cord on the right. The head is very large compared to the body. What other features are developing?*

This unit will help you to:

- appreciate that the characteristics of an organism are determined by the parents
- describe the stages of embryo development and birth
- realise how food, alcohol, smoking and drugs can affect a developing child
- appreciate the need to react in a responsible way to your emotional and sexual development
- realise the importance of spacing pregnancies
- discuss methods of birth control.

2 *Fruit should form an important part of a pregnant woman's diet. Fruit contains vitamins, natural sugars and roughage.*

3 *Here are some examples of items used for birth control. Can you name each one and how it works?*

Embryo development

Many things must happen before an embryo begins its development in the uterus of the female. Check that you can explain each of the steps.

1 A girl grows and reaches puberty.
She begins to make eggs and her periods start. These changes are part of the menstrual cycle. There are other changes to her body (secondary sexual characteristics). The changes are brought about by hormones from the pituitary and ovary.

2 A boy grows and reaches puberty.
He begins to make sperm. There are other changes to his body (secondary sexual characteristics). The changes are brought about by hormones from the pituitary and testes.

3 The female reproductive system develops.
Each month, as part of the menstrual cycle, the wall of the uterus is prepared with blood in case the woman becomes pregnant. Muscles also develop in the uterus wall.

4 The male reproductive system develops.
Sperm are produced and also receive food and other fluids to make semen. The penis develops.

5 An egg is shed from the ovary.
An egg is released about halfway through the menstrual cycle. If it is not fertilised, then the blood that is in the uterus wall is shed as the period.

6 Egg and sperm are brought together.
During sexual intercourse, the penis is placed in the vagina of the female. Millions of sperm are ejaculated. These swim up the vagina and through the uterus. If the timing is right, the sperm can fertilise an egg, usually in the Fallopian tube.

Objectives

- Describe how characteristics are passed from parents to children.
- Outline the stages of embryo development and the functions of the structures that are involved.
- Identify and describe the main stages of birth and some problems that might occur.

21.1 Reproductive systems

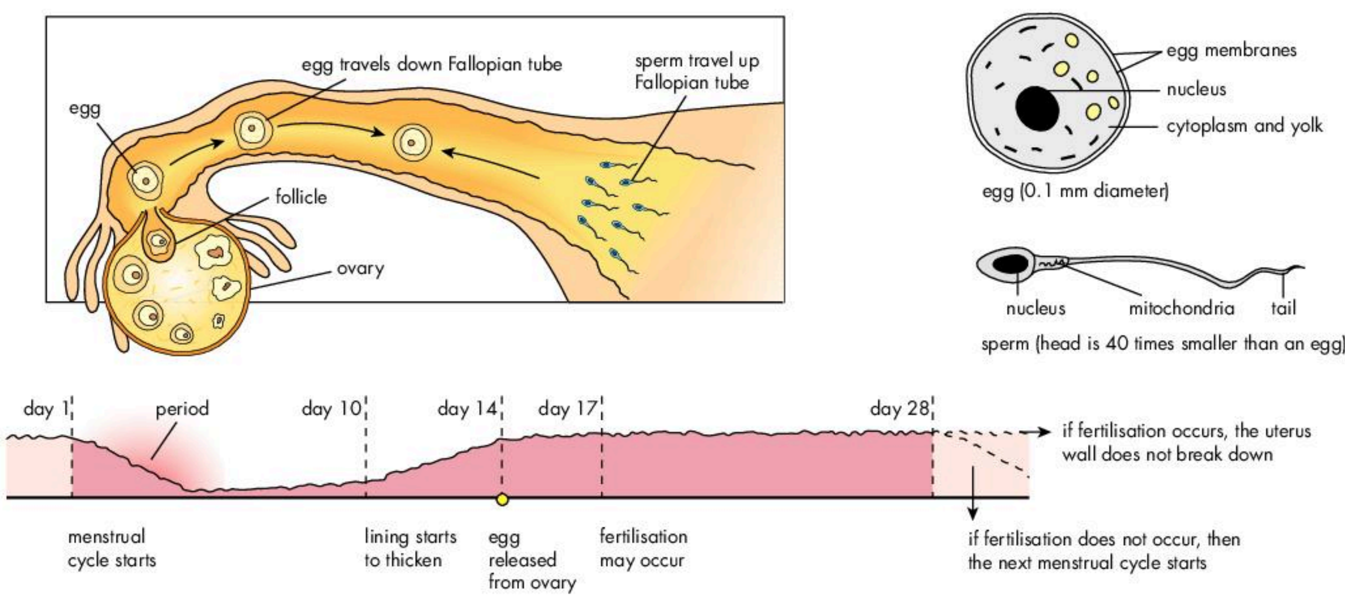
Materials: Reference books, card, drawing materials

Method

1 Develop a quiz by writing questions about human reproduction. For example: What is the menstrual cycle? What happens at the beginning, middle and end of the cycle? Use the questions to hold a quiz in class.

2 Draw large class diagrams of the male and female reproductive systems. Students take it in turns to label and annotate it (add the functions of the various parts).

▶ **See Workbook Embryo development.**



Preparation of the uterus wall and shedding of an egg. An egg and sperm (not to the same scale) are shown on the right.

What causes our characteristics?

Only if we have an identical twin can we expect to see someone who looks like us. Our characteristics are determined by our **genes** (by our DNA). Our unique set of genes is found on our chromosomes. We have 46 chromosomes inside the nucleus of each cell.

When the gametes (eggs and sperm) are made, they each contain 23 chromosomes. When the egg and sperm join (at fertilisation) our full 46 chromosome set is made. So, 23 of our chromosomes come from our father and 23 from our mother. We have a mix of genes (and characteristics) from our parents. Look at the picture of the family. Consider each child in turn and decide which of their characteristics came from their father or mother, or whether they are a mix of both.

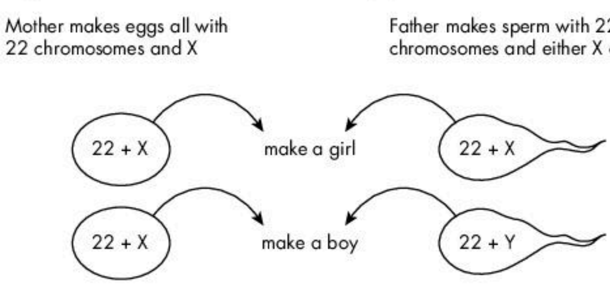
How are the children similar and different from their parents?

Boy or girl?

What determines if a fertilised egg will grow into a boy or a girl? It depends on what chromosomes are in the sperm.

Our chromosomes come in pairs. Of these, 22 pairs look the same. But pair 23 looks different in males and females. In a female the chromosomes are alike and we call them XX. But in a male, one is smaller than the other, and we call them XY.

The diagram below shows what happens at fertilisation.



One baby or two?

- Identical twins are formed from the same fertilised egg.
- Non-identical twins grow from two eggs that were fertilised at the same time (see the diagram on the right).
- Siamese twins are formed when the fertilised egg does not divide completely into two. As a result two babies develop that are joined and need to be separated after birth.

21.2 Family resemblances

Materials: Photos of families

Method

1 Each group has a photo. Discuss how you think each child got its features.

2 Look at yourself. Which of your features are like your mother?

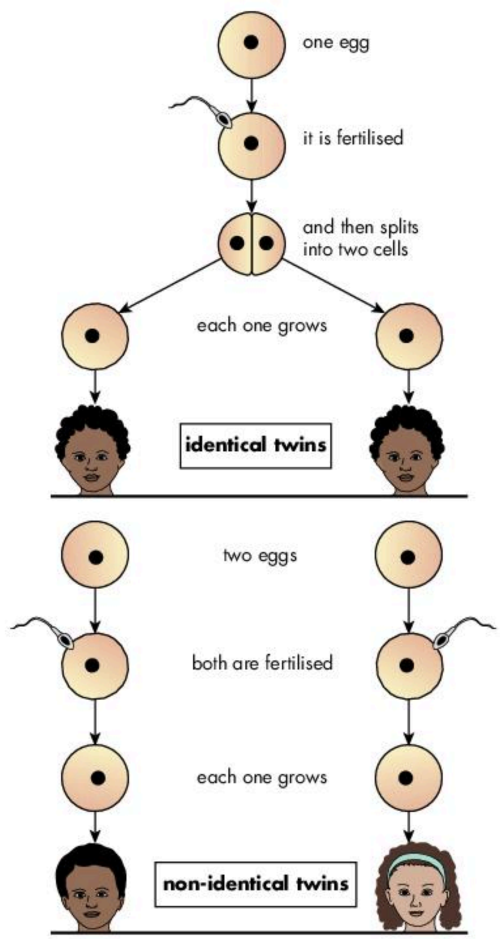
Fun facts

- There are about 20 000 genes coding for proteins inside each cell.
- Genes are made up of DNA, with millions of atoms in a molecule.

Questions

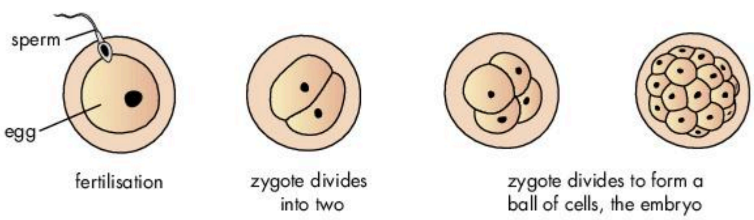
1 Are (a) identical twins and (b) non-identical twins always the same sex?

2 How do you think triplets are formed?



Fertilisation and implantation

Sperm swim 30 to 40 cm from the vagina up into the Fallopian tube. They have many mitochondria, which help them to release energy. In the Fallopian tube, one sperm joins with (fertilises) the egg. This produces the fertilised egg or **zygote**. This divides into two and then keeps on dividing. A ball of cells is formed, which becomes the **embryo**.



These cell divisions occur in the Fallopian tube. The egg has some yolk supplies for this early development. When the embryo reaches the uterus it burrows into the soft blood-filled lining. This is called **implantation**.

Growth inside the uterus

The tissues of the embryo and the mother develop to form:

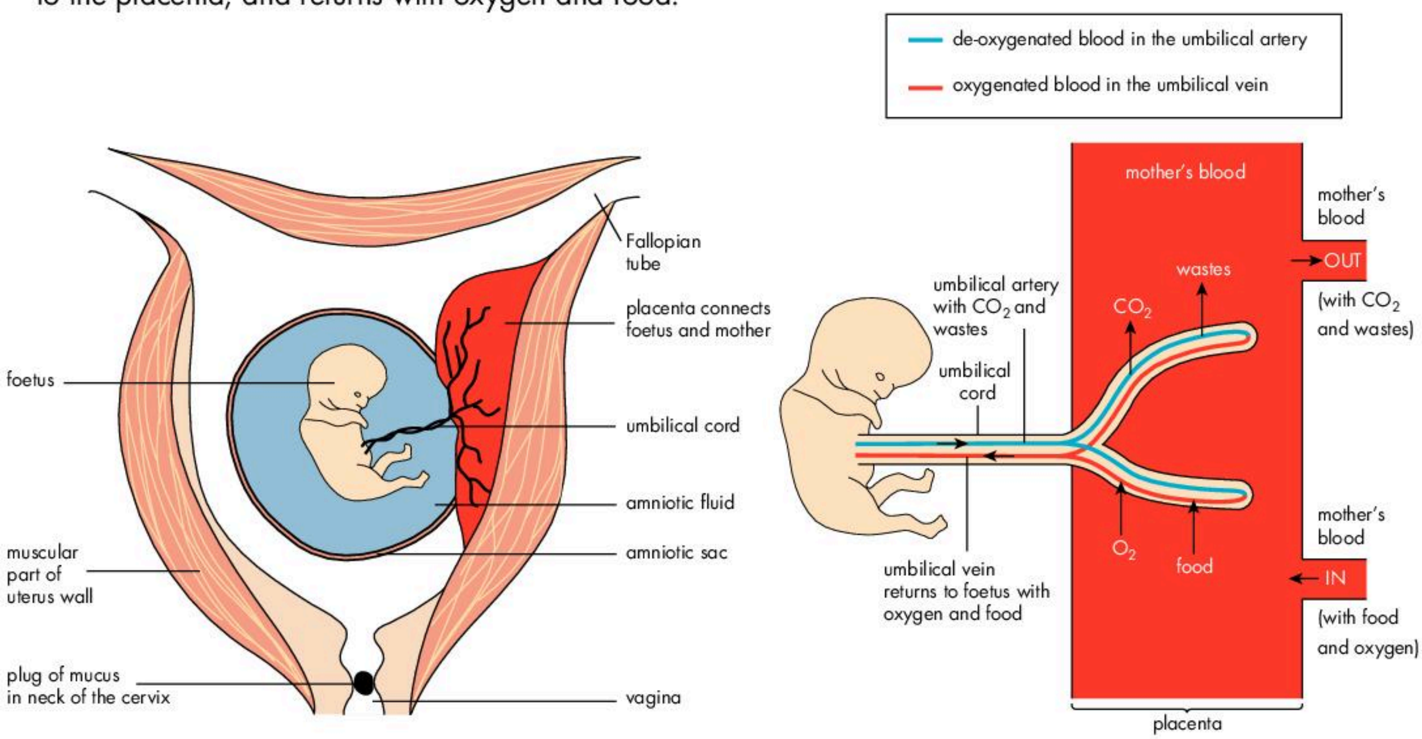
- The amniotic sac. This is a wall around the embryo. Inside it is fluid, the amniotic fluid. This keeps the embryo and foetus moist and at a steady temperature.
- The placenta. This forms in the inner part of the uterus wall. The placenta receives blood from the mother and this is in close contact with the blood vessels from the foetus.
- The umbilical cord. This carries carbon dioxide and wastes to the placenta, and returns with oxygen and food.

Questions

1. How are (a) the sperm and (b) the egg well suited for their functions?
2. Does fertilisation always mean that a woman will become pregnant? Explain your answer.
3. Why is it important that fertilisation occurs in the Fallopian tube and not, for example, low down in the uterus?
4. Explain how the foetus is cared for in the uterus.

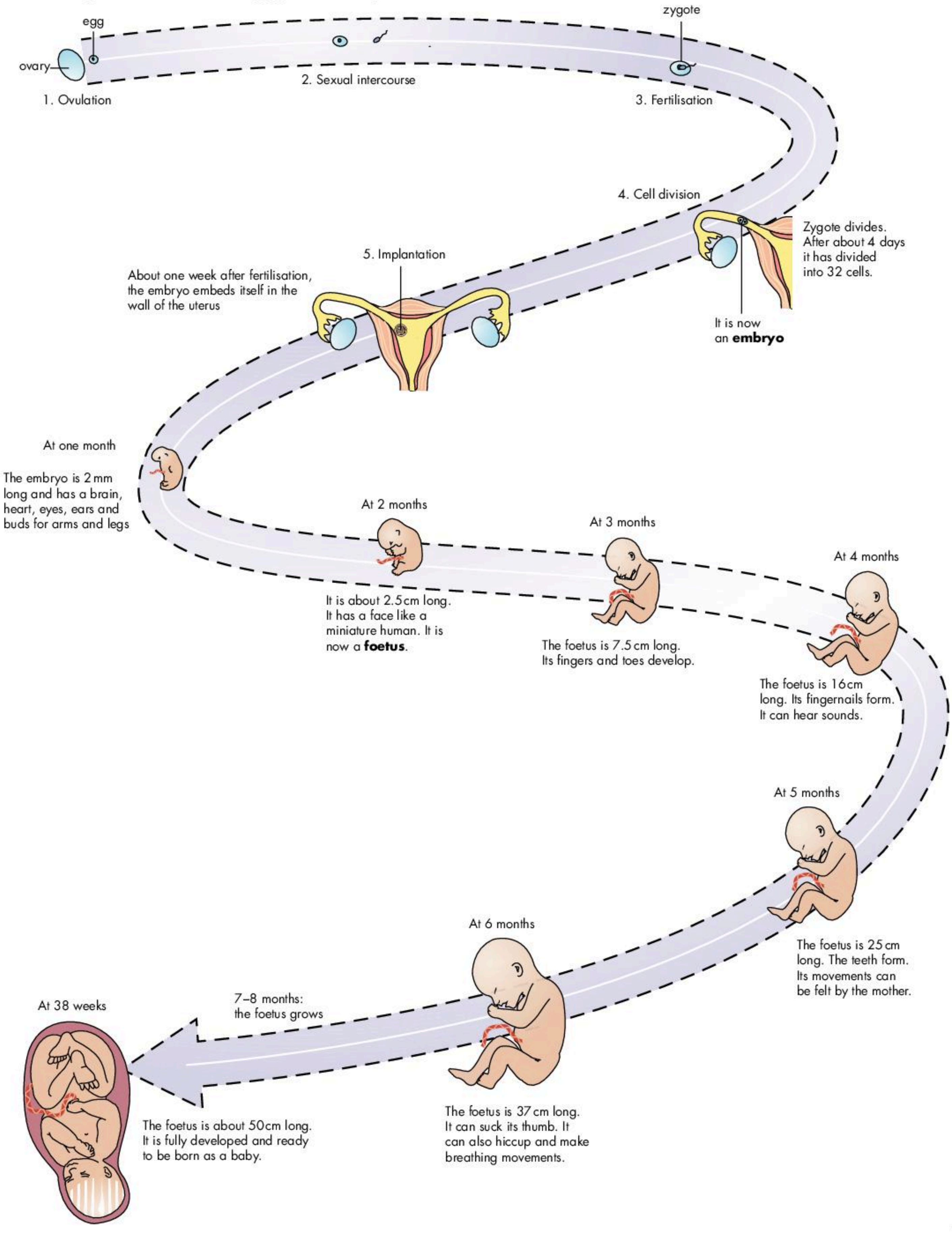
Embryo and foetus

- We use the name **embryo** for all the early development; from the ball of cells to the first eight weeks of development. An embryo does not look like a human.
- We use the name **foetus** from eight weeks onwards. The foetus looks like a miniature human.
- For convenience, we also sometimes call all the development in the uterus 'embryo development'.

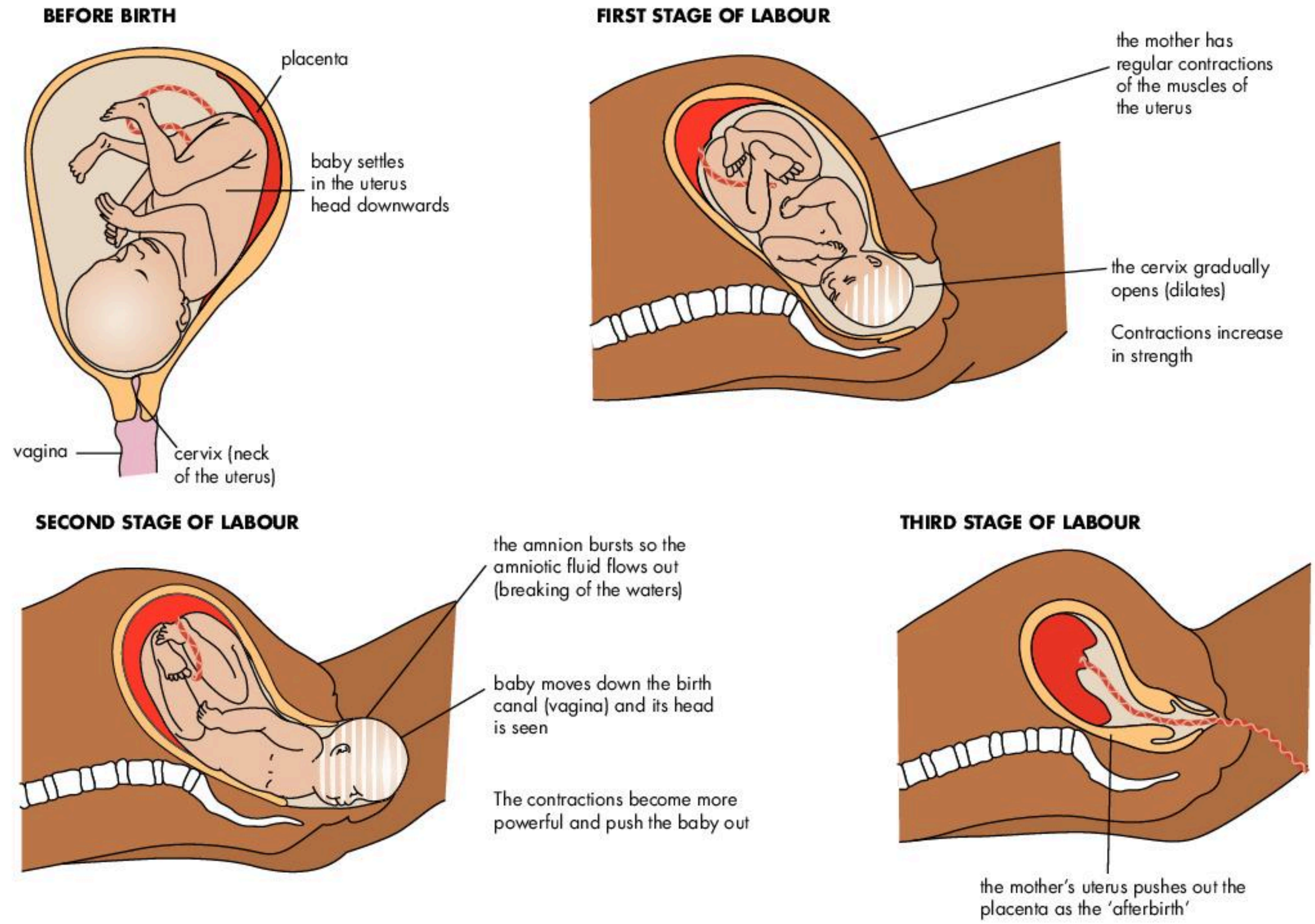


The foetus inside the uterus and how it is connected to the placenta

Development from egg to baby



Birth



The three stages of birth

After about nine months the baby settles with its head pointing downwards. The mother feels the contractions of the muscles in the uterus wall. Birth (labour) has three stages:

- **First** The neck of the uterus, cervix, gradually opens.
- **Second** The 'waters break' (the fluid in the uterus comes out). There are powerful contractions of the uterus muscles, which push the baby out. The cord is tied and cut.
- **Third** The placenta separates from the uterus wall and is pushed out of the body as the 'afterbirth'.

During birth, the father may be able to be present. He can give support and encouragement to the mother. It is a great help in the bonding of the family unit.

A newborn baby has its umbilical cord cut.

Fun facts

- A fertilised egg is 0.1 mm wide. By birth this has divided into more than 2000 million cells in all the different organs.
- At four weeks the embryo is as big as a grain of rice, and at eight weeks it is as big as a brazil nut.
- The foetus swallows liquid while it is in the uterus. It also practises breathing movements and sucks its thumb.

Questions

ICT

Research and prepare a class chart or book on development in the uterus. Illustrate the stages with pictures collected online, and from posters and magazines.

Before and after birth

Before birth, the umbilical vein (with oxygenated blood) joins the vena cava of the foetus. This blood goes to the right atrium of the heart. Before birth, there is a hole in the heart that allows this blood to go into the left atrium and then to be pumped from the left ventricle to the body. After birth the hole closes up in the next few weeks. Within seconds of birth the baby cries to open its lungs and starts to breathe.

Before birth, the foetus is supplied with food in the umbilical vein from its mother. After birth it suckles milk and gets rid of undigested food in its stools (faeces).

Before birth, carbon dioxide and urea are taken away by the umbilical cord for the mother to excrete. After birth the baby uses its own lungs and kidneys for excretion. The baby begins to make urine.

Before birth, the foetus is kept at a constant temperature by the amniotic fluid. After birth a newborn baby has to keep its own temperature constant and should be kept warm.

Before birth, the foetus floats in the amniotic fluid, which cushions it against damage. It is also inside the muscular wall of the uterus, which protects it from bumps. After birth the baby is wrapped up for security and warmth.

If the baby cannot be born through the vagina, then the mother needs an operation. Under anaesthetic, the abdomen and uterus wall are cut and the baby is lifted out. This is called a Caesarian section. The mother is then stitched together again and needs to take time to heal.

Post-natal care

A **premature** baby needs special care. It may be put in an incubator to be kept warm, given air with extra oxygen and given food through tubes.

The mother will be helped to breast feed the baby and to change its nappy and care for it. The baby needs loving attention from the whole family.

At six weeks the mother and baby will be checked at the clinic to see that all is well. From 3 months onwards a full programme of vaccinations of the baby will begin. These protect against polio, TB, measles and whooping cough and others.

Fun facts

- Babies are usually born head first.
- A newborn baby is pale and has blue eyes even though its parents are dark-skinned and brown-eyed. The colour of the skin and eyes develop after birth.
- The stump of the umbilical cord is kept dry and it drops off in seven to ten days. The scar is the navel.

Questions

Research and prepare a class chart showing how activities are carried out before and after birth. Illustrate your chart with pictures you collect and ones you draw yourselves. ICT

Fun facts

- A full pregnancy lasts 266 days from fertilisation. This is about 280 days (40 weeks, 9 months) from the beginning of the last period
- The youngest surviving baby was 128 days early: born at less than 22 weeks.

UK 21.3 The cost of a child

In small groups try to work out the cost of a child.

1 List all the things a baby needs in its first year, e.g. equipment, clothes, food, toys, time. Work out the cost of disposable nappies (do one day, then multiply). If instead you used cotton nappies how much would it cost? (Remember costs of washing the nappies – water, detergent, power, time.)
2 What extra costs are there when the child starts kindergarten and primary school? Include uniforms, shoes, books, transport, lunch money, etc.
3 Discuss your findings with other groups. What ways of making savings can you suggest?

Technological advances

Premature babies

Through technological advances it is becoming possible to save younger and younger **premature** babies. The baby's development is incomplete and it may have difficulty in breathing and feeding. It is kept warm in an incubator where it receives oxygen and food and continues its growth and development.

Premature baby in an incubator

'Test tube' babies

This describes fertilisation that is done outside the body. It is also called **IVF** (in vitro fertilisation). A ripe egg is taken from the woman's ovary. It can be fertilised by sperm from the partner or from a donor. When the fertilised egg has started to divide it can be put back into the uterus to develop.

If the sperm has come from a donor, this can be challenging later when the baby grows up and if he wants to know who his father is.

Fertility drugs

These are special hormones given to the woman to make her ovary release more eggs. There are also fertility drugs available for men. Both these kinds of drug increase the likelihood of pregnancy, in fact twins or triplets can result.

Surrogate mothers

This is when the ball of cells is put back into a woman who did not give the original egg. This surrogate mother has the pregnancy on behalf of another couple.

It can create problems for the original couple as they are not completely involved in the pregnancy and cannot control the actions and health of the mother. It is also a problem for the woman who has the pregnancy and gives birth to the baby as she may become attached to it and not want to give it up.

Cloning

In 1997, Dolly the sheep was produced at Roslin Institute. She was a clone, identical to her mother. Since then cloning has produced many other species of animals, such as cats and racehorses.

21.4 Reproductive issues

Each of the following things has already happened. Discuss in your group what you think about these issues.

1 Fertility drugs can be given, so that many babies are born at once.
2 To date, the oldest woman giving birth was 66, using donor eggs.
3 Eggs can be collected and frozen so that a mother may use them later on to have a baby.
4 Women may become pregnant with sperm from a dead husband.
5 After IVF, embryos can be selected and then grown to
   (a) be girls or boys as parents wish, or
   (b) be a match for a brother or sister to donate tissues to them.
6 Women can give birth to their own grandchildren.
7 Babies are born with DNA from three 'parents'.

Quick check ☑

__________ is the joining of egg and sperm. The zygote divides to make the __________, which grows into the __________. It gets oxygen and food from the __________ via the umbilical __________, and gets rid of carbon dioxide and other wastes through the umbilical __________.

Use these words to fill in the spaces as you write the sentences in your Exercise book.

placenta **foetus** **artery**
embryo **fertilisation** **vein**

A healthy pregnancy

There are many things the mother-to-be and father-to be can do to prepare for a healthy baby. There are also some things that they should avoid for the baby's sake.

Teenage pregnancies

If a young teenager becomes pregnant there can be some additional problems and points to consider.

Unplanned The pregnancy is likely to be unplanned, so neither parent would have taken the advice about a healthy diet, stopped smoking, or avoided infections and drugs. So the baby may run additional health risks. It is even possible for a girl to become pregnant before she has her first period.

Physical The baby will take from the teenage mother things that the mother still needs for her own growth, such as iron, calcium and protein. This can lead to anaemia and stunted growth. A young teenager has herself not yet finished growing. Her body is too young to take the strain of carrying a baby and her muscles are not very strong. Her hipbones may also be too narrow for the baby's head, so the birth could be dangerous for both mother and baby.

Emotional A young teenager having a baby can also suffer a lot of emotional problems. The teenager will also not have the same opportunities to enjoy the social interactions of the teenage years and may therefore resent the baby. These considerations also apply to the father.

Financial If the father is also young, then the couple will not have the financial resources to look after themselves and a baby. They will also be less well qualified.

Educational Expecting and then caring for a baby also upsets the mother's education. She also may not be able to attend prenatal classes and so be less well informed about pregnancy and childcare. Missing school could also mean she would not get such a good job and so have less money to support herself and the baby, so causing more strain for herself and the father.

An important doctoral study was carried out by Vonna L C Drayton and reported in 1999. It assessed the Women's Centre of Jamaica Foundation (WCJF) Programme started in 1978.

This programme enabled mothers of 16 and younger to return to school. A sample of 260 mothers of 12–16 years who gave birth in 1994 was interviewed in 1998. It was found that program me participants were on average one and a half times more likely to complete secondary school. Also, only 23.5% of repeat pregnancies were found in programme participants.

Objectives

- Discuss the possible effects of teenage pregnancies.
- Describe the importance of an appropriate diet during pregnancy.
- Identify the effects of diet, alcohol, drugs and smoking on the developing embryo.
- Discuss the importance of prenatal care.

UK 21.5 Teenage pregnancies

Discuss these questions in your group. Use the class ideas to prepare a poster about teenage pregnancies.

1 What effects will a teenage pregnancy have on (a) a girl and (b) a boy in secondary school?
2 What advice would you give to a teenage girl who is having sexual intercourse? What are the most likely reasons for this activity?
3 What help would be most useful to teenage girls (a) to prevent them becoming pregnant and (b) to help those who did become pregnant?
4 What advice would you give to teenage boys and men who become involved with young teenage girls?
5 Summarise the effects of teenage pregnancies on (a) the mother, (b) the father, (c) the child, (d) the wider family and (e) the country.
6 Visit the National Family Planning Agency or online, to collect data from different parishes in Jamaica. Plot graphs to illustrate the incidence of teenage pregnancy. ICT
7 Research the rate of infant mortality (number of deaths under 1 year old per 1000 live births) in Jamaica. Compare the overall figures and those for teenage pregnancies.
8 Hold a class discussion to consider all the information you have found and present some guidelines and advice.

Planning for pregnancy

There are some things that a couple can do to plan for a healthy pregnancy before the woman becomes pregnant.

- Exercise and become a healthy body weight.
- Check you are having a healthy diet.
- Make sure the woman has either had German Measles as a child, or had two vaccinations with the MMR vaccine.
- Avoid drinking alcohol to excess. During pregnancy a woman is advised not to drink alcohol.
- Stay faithful and do not have sexual intercourse that could pick up sexually transmitted infections.
- Avoid illegal drugs and be careful with prescription drugs.
- Cut down or stop smoking. During pregnancy a woman is advised not to smoke.

There is more information in the rest of this Unit.

How does a woman know if she is pregnant?

- During early adolescence, periods can be irregular. They can also be delayed because of travel or sickness. But if a healthy woman is trying for a baby and misses her period she is likely to be pregnant. If she misses two periods it is almost certain she is pregnant. A home pregnancy test or test at a clinic can be used to confirm the pregnancy.
- The woman may feel sick, especially in the mornings. Her breasts may feel tender. She has to urinate more often and may get easily upset. She may also feel more tired and dizzy.

Having a healthy diet

Plan ahead. Both parents should try to have a healthy diet before the woman becomes pregnant. If the mother-to-be is too heavy, or underweight, she should try to address these issues before becoming pregnant.

Realise the mother's role. Everything for the embryo and foetus has to go via the placenta and the umbilical vein. This can be the pathway for useful things for the developing baby, or it can carry harmful foods, drugs or micro-organisms.

Eat for your baby's health. For example:

- Folic acid. A daily 400 microgram supplement is recommended from before pregnancy to at least the 12th week. Useful foods are callaloo, brown rice, black-eyed beans, bread and breakfast cereals. Folic acid helps to avoid problems in the development of the nervous system, such as spina bifida.
- Protein and iron. These are needed for the baby's growth and blood. Useful foods are lean meat, fish, eggs, beans and peas.
- Calcium. This is needed for the baby's bones. Good foods are milk, cheese and yoghurt. Skimmed milk and low fat yoghurt have the same amounts of protein and calcium as their full-fat equivalents.

Fun facts

- During pregnancy a woman makes 30% more blood: this is why she needs more iron and may feel faint.
- Her heart rate also increases: this can sometimes lead to high blood pressure.

What does it mean?

Miscarriage: When a pregnancy ends naturally before about the 24th week. Doctors also call this an abortion.

Abortion: This term is used by most people to mean the artificial ending of a pregnancy before the 20th week. Most abortions are carried out before the 12th week.

Illegal abortion: An abortion not carried out in a hospital; there is a high risk of infection and likelihood of long-term damage to the mother.

Premature: When a baby is born early and has a chance of survival. The age of foetus depends a lot on the medical care that can be given.

Stillbirth: When a foetus dies in the uterus or a baby is born dead.

Cot death: Also called SIDS (sudden infant death syndrome). A baby (usually in its first year) dies suddenly in its sleep. There are several causes.

▸ **See Workbook A healthy pregnancy.**

Hints for a healthy diet

- Eat starchy foods to supply energy.
- Eat lots of fruit and vegetables.
- Eat more fish.
- Cut down saturated fat and sugar.
- Eat less salt.
- Get active and try to be a healthy weight.
- Drink plenty of water.
- Don't skip breakfast.
- Make changes to your diet slowly.

Foods to avoid

- Liver. This is high in iron and vitamins, but it is not recommended in pregnancy. This is because it is high in vitamin A, and this could build up in the mother's body and may harm an unborn baby.
- Cod liver oil supplements. These have a similar problem of high vitamin A. It is better to eat 2–3 servings of fish a week with one or two of them being an oily fish.
- Ripened soft cheeses. These are less acidic and more likely to grow bacteria such as *Listeria*. It is better to eat hard cheeses such as cheddar. Or to have cottage or processed cheese.
- Leftovers. When pregnant, a woman may be more easily upset by bacteria that cause food poisoning. The micro-organisms can also harm a developing baby, especially in early pregnancy. So take extra care when re-heating any leftover food. A pregnant woman should also avoid raw or lightly cooked eggs, meat or fish, and unpasteurised milk and its products.
- Foods high in sugar or fat. Some examples are cakes, crisps, pastry, full-sugar fizzy drinks and full-fat milk and milk products. These foods are also low in many vitamins and minerals. They should only be eaten occasionally.
- Fried foods. Use fats that are high in polyunsaturated fats, such as sunflower, soya or corn oil.

Planning healthy meals in pregnancy

In early pregnancy a woman sometimes suffers from morning sickness. This can be helped by having a dry biscuit before getting up. A pregnant woman may also find it suits her better to have three smaller meals and to have snacks in between. If she is diabetic she may need to seek additional advice.

The picture below shows the proportion of different food groups that can form the basis of healthy meals in pregnancy.

Daily servings

You can use these guidelines to help plan healthy meals for the day. Take into account the advice previously given.

- 9 servings of bread, rice, potatoes, pasta and other starchy foods. Choose wholegrain where possible.
- 7 servings of fruits and vegetables. Eat them raw where possible, or only lightly cooked to retain vitamins.
- 3 servings of milk and dairy foods such as cheese and yoghurt.
- 3 servings of meat, fish, eggs, beans and nuts and other non-dairy sources of proteins.
- Only use a little of foods and drinks high in fat and/or sugar.

21.6 Planning meals

Work in pairs or small groups:

1 Prepare a table of the most important food constituents for a developing embryo and foetus. For each one, list four foods that would be good sources.

2 Consider the food groups and the guidelines for the number of healthy servings of each one. In your group, decide on a plan for how to prepare a full day's menu of three meals and three snacks. For example, you may decide to have two servings of starchy foods for breakfast. Present your guidelines in an attractive and interesting way.

3 Now make menus for a healthy and unhealthy meal and snack for a pregnant woman. Different groups can choose different meals and snacks. Share the menus in class. Choose the best three meals and three snacks for a full-day healthy menu. Think about how to include a lot of variety into the menu. For example, choose different kinds of fruits and vegetables.

4 You might also like to check the energy value of your recommended menus!

▶ **See Workbook A healthy pregnancy.**

Alcohol and its effects in pregnancy

Drinking excess alcohol has effects on everyone. For example, the alcohol can make people more likely to have accidents and can damage the brain cells and liver.

The present advice is that there is no safe limit to the amount of alcohol a pregnant woman can have. The risks are greatest during the first three months. This means it is best to give up alcohol while pregnant. As a great deal of damage could be done before the woman knows she is pregnant, it is best to give up alcohol when trying for a baby.

Alcohol rapidly gets into the blood and can cross the placenta. Binge drinking, of five or more units on one occasion, is more dangerous than one unit on a few occasions. Too much alcohol can cause:

- birth defects, such as the way the baby's face, organs and brain develop
- miscarriage and premature birth
- learning difficulties because of damage to the brain
- physical problems with movement and coordination.

HIV and its effects in pregnancy

HIV and AIDS have effects on everyone: the person who is infected and their partner and family. Although there are drugs available, HIV/AIDS is still a life-threatening disease. HIV can also infect the next generation.

As a young teenager, now is the time to make your life plan. If in the future you want to have a family, then now is the time to decide on how you will behave to avoid HIV.

If a pregnant woman believes she may have become infected with HIV, there are some things she can do:

- Be tested for the virus. If the test is negative, she could have a further test at 6 months (this is because she may be infected without it showing). If a test is positive, then antiretroviral drugs will have to be given.
- Plan to have a Caesarian section. Where this is carried out carefully, there is less risk of infecting the baby.
- Decide not to breastfeed her baby. There is a considerable risk of passing on the virus when breastfeeding.

The drugs that are most recommended are a mix of at least three anti-HIV drugs. This treatment is called highly active antiretroviral therapy (HAART). Without treatment, about 25% of babies born to HIV-positive mothers will be born HIV-positive. However, the combination of methods listed can cut the transmission to 2%. Another drug, zidovudine, can also be given to the newborn baby for four to six weeks.

If HAART is not available, transmission can still be cut by taking zidovudine from 28 weeks of pregnancy, and for one week for the newborn baby. An additional injection of nevirapine is given during birth and to the baby.

What is a unit of alcohol?

One unit is about:

- half a pint of regular beer or lager
- a quarter pint of stronger beer or lager
- a small glass of wine
- two-thirds of a bottle of alcopop
- a small glass of sherry
- a single measure of spirits.

21.7 HIV/AIDS

ICT

1. Research HIV and how it is transmitted and leads to AIDS. You could prepare questions to use in a quiz for the class.
2. Discuss various actions a young teenager should take in order to avoid catching HIV and suffering from AIDS.
3. Prepare a poster warning of the dangers of HIV infection for the person and for the unborn child.
4. Carry out research to find the numbers of mothers and babies infected with HIV. Also find out about the most up-to-date treatments available.

Scary facts

- In Jamaica, according to UNAIDS figures, only 56% of people with HIV/AIDS are receiving treatment with antiretroviral drugs (ARVs).
- Transmission of HIV from mothers to babies accounts for about 70% of the cases of HIV in children. Of these 30% occur in the uterus and 70% around the time of birth.

Questions

1. Outline the dangers from (a) alcohol and (b) HIV on the mother and her developing embryo and foetus.
2. What treatment is recommended for mothers who are HIV-positive? What effect does this have on the likelihood her baby will become infected?

Drug abuse and pregnancy

Drugs could have both short- and long-term effects on the mother. Some of them would also have bad effects on the developing embryo and foetus. The best advice is to avoid illegal drugs whether pregnant or not.

Marijuana This has been found to damage the DNA of eggs and sperm. Regular use during pregnancy has been linked to reduced growth of the foetus and low birth weight.

Ecstasy The mothers took other drugs as well, so the results are not clear. But there were more limb and heart defects than would otherwise be expected.

Cocaine This is very serious. It can cause miscarriage, brain damage, death of the foetus or separation of the placenta that can kill both the mother and developing baby. The drug reduces the supply of food and oxygen to the foetus so it is born small. Cocaine can also pass over in the breast milk. Women who stop using cocaine in pregnancy reduce their risk of having premature or low-birth weight babies.

Heroin Around half of the babies born to heroin-addicted mothers are premature or born dead. Women who are addicted should not just quit, as the withdrawal symptoms would harm the embryo. The mother should use the alternative, methadone and be under medical care. At birth, the baby will also be addicted and have to undergo medical help to overcome withdrawal symptoms.

Prescription drugs

When you are trying for a baby or think you may be pregnant, it is very important to check any drugs that you take. If you can manage without them, then don't take them – especially during the first three months.

Thalidomide was a drug used from 1957 to 1961 in 50 countries. Although not tested on pregnant women, it was prescribed to them to reduce morning sickness and to help them sleep. As a result 12 to 20 000 babies were affected, with miscarriages, brain damage and flipper-like limbs.

The rhesus factor

People are either Rh+ or Rh– depending on whether or not they have the Rhesus factor in their blood. If a woman is Rh– there may be a problem if her partner is Rh+ and she is expecting a Rh+ baby. One of two things can be done:

- An antigen against the Rhesus factor (anti-D) is injected into the mother before the first child is born. This neutralises any D antigen from the foetus and problems are avoided.
- If a Rh– mother is expecting her second Rh+ baby, she may produce antibodies against the baby's blood. In this case the baby will need a large blood transfusion when it is born.

Avoid taking drugs during pregnancy

Questions

1. What are the dangers of cocaine (a) to the mother and (b) to the developing foetus and embryo?
2. Explain the treatment that is suggested for a heroin addict who finds out that they are pregnant. How will the baby be affected?
3. Thalidomide was prescribed early in pregnancy. How is this related to the kinds of damage it caused?
4. What is the Rhesus factor? Why is it important that a woman is tested? What can be done to help produce a healthy baby?

▶ **See Workbook A healthy pregnancy.**

German measles

German measles is caused by a virus. If a child is infected, it is a harmless disease with a rash, fever, swollen glands and cold-like symptoms. It only lasts a few days. Babies and young children can also be vaccinated against it as part of the MMR vaccine. This stands for mumps, measles and Rubella (German measles). Two doses should be given.

Before a woman becomes pregnant she should have a test to see if she is immune to German measles. If not, then she should be vaccinated and wait a month before becoming pregnant (the vaccine contains weakened virus that could harm an embryo or foetus).

If a non-immune pregnant woman is infected with German measles in weeks 0–13, there is up to a 90% risk the foetus will be affected. There may be miscarriage, problems with sight or hearing or with heart or brain defects. The risk of problems is low after week 16.

Prenatal care

'Prenatal' means 'before birth', so this is care given to a pregnant woman at a clinic, from about 12 weeks onwards. General health will be checked such as weight, height and blood pressure.

It is important to have prenatal care at a clinic. Any problems can then be treated. For example, discussions can include:

- Confirming the pregnancy and giving the possible birth date.
- Talking about any lifestyle changes for diet, drugs, etc.
- Taking blood to check for anaemia and the Rhesus factor.
- Checking for STIs and HIV and deciding on treatment.
- Checking for Down's syndrome by taking some amniotic fluid, though this carries a small risk of miscarriage.
- Having regular visits during the pregnancy to check on the growth of the foetus, including an ultrasound scan.
- Checking the mother's health to see all is well.
- Talking about labour and doing breathing exercises and having advice on labour.
- Making arrangements for the birth at home or in hospital.

▸ **See Workbook A healthy pregnancy.**

Smoking and pregnancy

Smoking has effects on the mother herself. The long-term effects mean it is more likely that she will suffer from heart disease, emphysema and lung cancer. Smoking could also have effects on the foetus and embryo.

The risks include miscarriage, slow growth and low birth weight, premature babies and stillbirth. Even after birth, children of smoking parents have an increased risk of developing chest infections, asthma, 'glue ear' and cot death. If the parents still smoke, there is also danger from 'passive smoking'.

It is best to stop smoking before the pregnancy. But there will be some benefit whenever smoking stops.

21.8 Prenatal care

Work in small groups:

1 Students role play two pregnant women at a prenatal clinic, one who is following good advice and one who is not.
Make up the discussion:
(a) between the two women, and
(b) between each woman and the nurse or doctor at the clinic.

2 Do further research on one aspect of prenatal care that interests you. ICT

3 In class discuss the importance of prenatal care and prepare a poster or movie. Prepare questions to be used during a press conference.

4 Write an essay on 'The effects of diet, diseases and drugs on the developing embryo and foetus'.

Quick check ☑

To help have a healthy pregnancy it is important for the mother to have a healthy ________, and not to ________ or to take ________ or ________. She should also avoid infections such as ________ and ________ measles. She will get helpful advice from the ________ clinic.

Use these words to fill in the spaces as you write the sentences in your Exercise book.

HIV **diet** **drugs** **prenatal** **German** **smoke** **alcohol**

Birth control methods

Birth control methods reduce the likelihood of sexual intercourse leading to pregnancy.

Who might use birth control methods?

There are four main groups of people who might want to use birth-control methods for family planning.

(a) Young teenagers: Some teenagers may wish to have sexual intercourse. But, for many reasons, there are dangers in the girl becoming pregnant. Both the girl and her partner will wish to use contraceptive methods, especially methods that give protection against STIs.

(b) Older teenagers and those who are at university or are still building up their financial resources: This group of people will be enjoying social interactions and want to interact with a wide group of friends. They may not yet have met the special person they would want to commit to in a long-standing relationship. They still value their independence and do not yet want the responsibility of being a parent.

(c) Couples: These are people who are in a committed long-term relationship, which includes marriage and common law marriage. These couples may want to space their families for the sake of the mother and the children. For example, having children close together can cause problems for:

- The mother's health: she may become very tired or anaemic. She may also not be able to breastfeed her baby.
- Finances: the mother will not be able to work and there may not be enough money available.
- The children's health: they may not have enough food.

(d) Women over 37 and before the menopause: Older mothers have an increasing risk of having babies with Down's syndrome. Blood tests of the mother are increasingly reliable or tests of the amniotic fluid can be done (but this means some risk to the foetus). A Down's syndrome baby usually has three copies of one of the chromosomes (chromosome 21). This can cause learning disabilities (from mild to severe), heart defects, hearing and sight problems and upset thyroid function.

How do birth control methods work?

Natural birth control methods do not use contraceptives. They rely on the couple avoiding sexual intercourse on fertile days.

Artificial birth control methods depend on barriers, chemicals or surgery to prevent fertilisation and implantation.

(a) Barrier methods include condoms, cap and diaphragm.

(b) Chemical methods include spermicides and contraceptive pills, patches and injections, and 'morning-after' pills.

(c) Surgical methods include inserting IUDs, or having a tubal ligation (women) or vasectomy (men).

Objectives

- Discuss reasons why couples would want to use birth control methods.
- Discuss different methods used for birth control, including how each one prevents pregnancy.

Boy with Down's syndrome using a wood plane

21.9 Making decisions

Work in small groups:

1 Make a list of reasons why couples might want to use birth control.

2 Should both men and women take responsibility for the decisions?

3 In the discussions, have you (a) expressed your own ideas and (b) taken account of other viewpoints?

Fun facts

- Contraceptives have been developed for elephants. The vaccine is given to the female by a dart. The eggs can then no longer be fertilised.
- It is estimated there may be 9 billion people in the world by 2070 (there were only 4 billion in 1980).
- After world population reaches 10 billion, it is likely to start decreasing.

Natural methods of birth control

Some couples, because of their personal beliefs, prefer not to use chemicals or artificial devices to prevent fertilisation. But they may still wish to choose when their babies are conceived. There are several alternatives available, but these are not as effective for preventing pregnancy as artificial methods. They also offer no protection against STIs such as HIV.

Withdrawal In this case, the man withdraws his penis from the vagina before he releases large numbers of sperm in an ejaculation. However, this is not very reliable. This is because some sperm may escape into the vagina. It is also difficult to determine exactly when the ejaculation occurs.

The other natural methods depend on calculating when, during the woman's menstrual cycle, an egg is not likely to be present.

Advantages: natural, no expense, no chemicals, or barriers.

Disadvantages: not very reliable, no protection from STIs, cannot be used with irregular cycles or if cycles are upset, for example, due to travel, illness, fatigue, or breastfeeding.

Rhythm method The woman needs to track her menstrual cycle for at least six months. Sperm can live in the female reproductive system for 5 to 7 days. But an egg can only live for 24 hours. Using the shortest and longest menstrual cycles, the woman can work out which are the days when pregnancy would be most likely.

Billings method This method helps the woman to recognise her fertile period by changes in her secretions and how her vagina feels. There is an increase in mucus leading up to ovulation. There are also temperature changes that can be recorded. Help can be given at a Family Planning Clinic to help a woman identify her fertile period.

Standard days method This works on data collected for many women. Ovulation usually occurs at the mid-point in the cycle. If a woman has a regular 28-day cycle, there is a 30% chance she will ovulate on the 14^{th} day. There is a 60% it will be one day before or after the mid-point and a 78% chance it will be two days before or after.

Note that this means, even with a regular 28-day cycle, that there is a 12% chance that ovulation will be more than two days each side of the mid-point. It is because of this unpredictability that natural methods are not very reliable.

This method can be used for any woman who has a regular cycle of 26 to 32 days. But, if the cycle is irregular, for example sometimes 28 days and sometimes 31 days, then it cannot be used. Also, if the menstrual cycles are shorter than 26 days or longer than 32 days, the method cannot work.

For regular 26–32 day cycles, the fertile period is days 8–20. To avoid conception, the couple should not have intercourse on these days.

▶ **See Workbook Birth control methods.**

Using the Rhythm method

First day of period = day 1 of cycle

To calculate the safe period *before* ovulation:
Take the shortest cycle and subtract 19.
So, if the shortest cycle is 26 days, then

26 – 19 = 7.

The safe period would be from days 1 to 7.

To calculate the safe period *after* ovulation:
Take the longest cycle and subtract 10.
So, if the longest cycle is 32 days, then

32 – 10 = 22.

The safe period would be from day 22 until your cycle starts again.

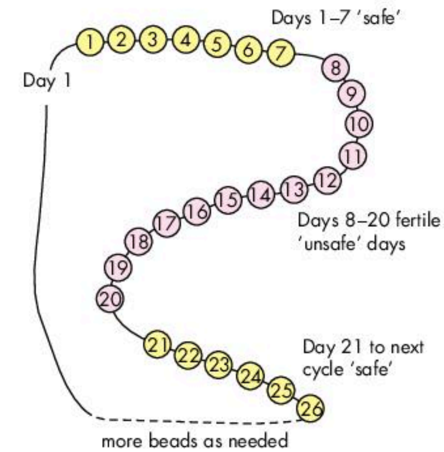
This means that the fertile ('unsafe') period would be days 8–21. If the couple wished to avoid pregnancy, they should not have sexual intercourse on these days. Or, they should use some kind of contractive.

Using the standard days method

This method can only be used if the woman has regular menstrual cycles of 26, 27, 28, 29, 30, 31, or 32 days. If the cycles are irregular, or shorter or longer than these, the method does not work.

The fertile ('unsafe') period would be days 8–20.

A series of beads can be used to help the woman track her fertility, as shown below.



Barrier methods of birth control

These methods use a physical barrier to stop the sperm and egg from meeting. When used together with spermicide cream, they are very effective. They also protect against STIs.

Condom

This is a thin rubber sheath. It is best covered with spermicide cream to kill any sperm. The condom is put onto the penis before intercourse. When the sperm are ejaculated they are caught inside a little sac at the closed end of the condom.

After intercourse, the condom is carefully removed so as not to spill any sperm.

Advantages: very reliable when used with spermicide cream, readily available and a good protection against STIs.

Disadvantages: it needs pre-planning to buy and use them.

Diaphragm or cap

This is a rubber dome with a metal spring around the edge. Before it is used it is covered with spermicide cream. It is then put into the vagina so that the metal spring fits around the cervix. This can be done some time before intercourse. The cap should be left in place at least six hours after intercourse to be sure that any sperm have been killed.

Advantages: the woman is responsible, it can be put in before intercourse and with spermicide cream it is very reliable. It can also be re-used with fresh amounts of spermicide cream.

Disadvantages: it takes practise to fit it and it offers only limited protection from STIs.

Female condom

This is a long condom made from a kind of plastic. It can be used together with spermicide cream. The woman fits the condom inside her vagina some time before sexual intercourse. It has a ring at its closed end that is pushed into the vagina and fitted over the cervix. During intercourse the penis is inserted into the condom and this collects the sperm. After intercourse the woman carefully removes the condom.

Advantages: the woman is responsible and it protects against STIs such as HIV.

Disadvantages: it is more expensive than male condoms, may be difficult to find a supplier and it also takes practise to fit it.

Chemical methods of birth control

Chemicals are used to kill or stop development of the sperm or eggs. In this way, they are not available for fertilisation.

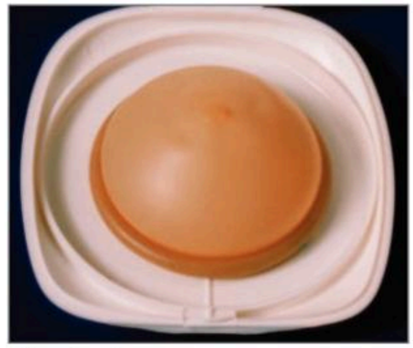
Spermicide cream

It kills the sperm.

Advantages: it is easy to use.

Disadvantages: it is not very effective on its own. When used with a barrier method it makes that method very reliable.

The condom or sheath



The diaphragm or cap

Spermicide cream

This is a cream that can be used together with any other method. It kills any sperm that may have escaped. For example, it makes any barrier method much more reliable.

Questions

1 (a) What are the main differences between natural and artificial contraceptive methods?
(b) What would be the reasons for using each one?

2 What are the advantages and disadvantages of using male or female condoms?

▶ **See Workbook Birth control methods.**

Chemical methods of birth control (cont.)

Contraceptive pills

Many pills contain oestrogen and progesterone. The hormones stop eggs being released by the ovary. They also thicken the mucus near the cervix making it difficult for the sperm to get into the uterus. They also thin the uterus lining so that implantation is less likely. The woman takes a hormone pill each day at the same time for 21 days. There is then either a break for 7 days, or 7 non-hormone pills (in a 28-pill pack). After 28 days, the next packet is started.

Advantages: the woman is responsible, the pills can be taken in a regular way and they do not interfere with intercourse.

Disadvantages: there are some health risks. They should not be taken if the woman is over 35, smokes or has heart problems. If a pill is taken late, the contraceptive effect may be lost.

With 21 pills, they are taken one a day and then 7 pill-free days for the period. With 28 pills, there are 21 hormone pills and 7 non-hormone ones containing sugar or iron.

Contraceptive patches or rods

These are patches or small rods containing female hormones. They are implanted under the skin's surface. They steadily release hormones into the body. They have the same effects as the contraceptive pill. There are some rods that can remain effective for up to three years.

Advantages: have the advantages of contraceptive pills, but the woman does not have to remember to take them each day.

Disadvantages: as with contraceptive pills, they are not suitable for everyone, do have some health risks and do not give any protection against STIs.

Male hormone contraceptives

Trials have been carried out. For example, a hormonal implant of testosterone under the skin every four months and an injection of progesterone every three months. This stopped sperm production, but was later reversible.

The main disadvantage, as with the contraceptive pill, is that this would give no protection against STIs.

Contraceptive injections

Depo provera is an injection of hormones. This is given every three months. It has the same effects as the contraceptive pill. It is the most effective form of birth control.

Advantages: as for contraceptive patches and rods.

Disadvantages: as for the patches and rods. It may take up to a year after the last injection to become fertile again.

A contraceptive patch

'Morning-after' pills

If a woman has had sexual intercourse without using an effective contraceptive, she can use a 'morning-after' pill. The pills contain either oestrogen and progesterone, or progesterone only.

The first dose of two pills should be taken within 72 hours of having sexual intercourse. The second dose of two pills is taken 12 hours later. The pills stop an egg being produced, or stop a fertilised egg from becoming implanted.

Advantages: very effective, especially if the first dose is taken within 24 hours of intercourse. The pills have been shown not to harm the baby and they can be used more than once.

Disadvantages: they may make the woman feel sick. They cannot be used as a regular contraceptive.

Questions

1 In what ways are the female hormone methods (a) similar and (b) different?
2 Choose two hormone methods. What reasons would a woman have for preferring each of the methods?
3 Why is it important to have a health check before using hormone methods?

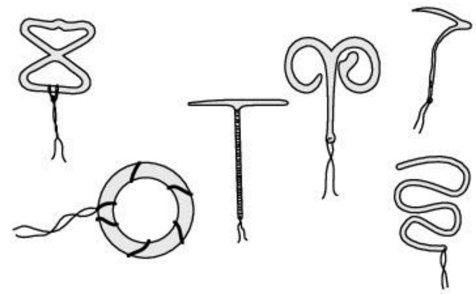
IUDs

IUD is short for intrauterine device. It is a small, T- or coil-shaped object that is put into the uterus by a doctor. It can be left in for 5 years or so. When removed, the woman can become pregnant. There are two main kinds:

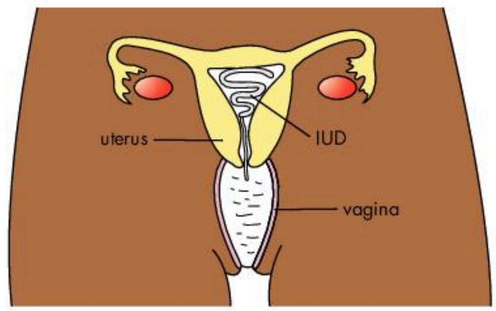
- Hormone IUD. This has a progesterone that thickens the mucus near the cervix. It also thins the uterus wall to prevent implantation. The periods may also stop. When removed, it may take some time for the woman to become fertile again.
- Copper IUD. The copper kills sperm. The IUD also thins the uterus lining, so preventing implantation. This IUD can also be used as an emergency contraceptive if it is inserted within five days of having unprotected sex.

Advantages: long-lasting, no daily pills, very reliable and can be used by women over 35.

Disadvantages: no protection against STIs, can cause pelvic infections (especially with any STI) that affect fertility.



Different shapes of IUDs



An IUD in place

Surgical methods of birth control

These methods should only be chosen if the couple is certain they do not want to have any more children.

Tubal ligation

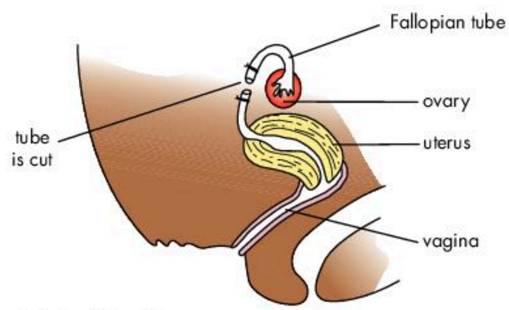
This is for women. The tubes (Fallopian tubes) are clipped and cut. It is done under a general anaesthetic. The woman will need a week off work. This operation permanently prevents eggs getting into the uterus.

Vasectomy

This is for men. The vas deferens in the scrotal sac are clipped and cut. It is done under local anaesthetic. The man can return to work in one or two days. He still has sperm in his semen for a few months. So the couple needs to use another contraceptive. The man continues to ejaculate, but the semen does not contain sperm. The procedure can sometimes be reversed.

Advantages: the operations mean there is no longer a need to worry about contraception.

Disadvantages: they are usually permanent, give no protection against STIs and the operations have slight health risks.



A tubal ligation

Questions

1 (a) What are the advantages of using an IUD instead of contraceptive pills? (b) What are the advantages of using contraceptive pills instead of an IUD?

2 What should a couple consider very carefully before they have a tubal ligation or a vasectomy? Why?

▸ **See Workbook Birth control methods.**

***Quick check* ☑**

The Rhythm method is a ________ method of birth control. Artificial methods use ________ such as ________, and chemical hormones in ________ pills and patches. An ________ can be fitted into the uterus. A vasectomy and ________ ligation are sterilisation operations.

Use these words to fill in the spaces as you write the sentences in your Exercise book.

IUD **barriers** **contraceptive** **tubal** **natural** **condoms**

Questions

Answer these questions in your notebook

For questions **1–33** answer **A**, **B**, **C** or **D**.

1 When do menstrual cycles begin?
A at puberty in girls
B at puberty in boys
C at puberty in boys and girls
D when a woman has sexual intercourse

2 What happens when a woman becomes pregnant?
A she has a very heavy period
B the menstrual cycles become irregular
C the menstrual cycles become longer
D the menstrual cycles stop

3 Where does fertilisation most commonly occur?
A ovary **B** testis
C Fallopian tube **D** cervix

4 Which statement is true?
A the egg is larger than the sperm
B the egg is smaller than the sperm
C sperm have yolk stores for providing energy
D eggs have a tail for swimming

5 Which chromosomes are present in the sperm?
A 22 + X or Y **B** 22 + Y
C 46 + X or Y **D** 46 + X

6 Which chromosomes are present in the egg?
A 22 + X or Y **B** 22 + Y
C 46 + X or Y **D** 22 + X

7 How many eggs are needed to make non-identical twins?
A 1 **B** 2 **C** 3 **D** 4

8 How many eggs are needed to make Siamese twins?
A 1 **B** 2 **C** 3 **D** 4

9 What is formed at fertilisation?
A an egg **B** a sperm
C a zygote **D** a foetus

10 Which of these substances travel along the umbilical vein?
A carbon dioxide and oxygen
B food and wastes from the foetus
C carbon dioxide and other wastes
D oxygen and food to the foetus

11 At what time does an embryo change into a foetus?
A at implantation **B** at 4 weeks
C at 8 weeks **D** at 12 weeks

12 How does a foetus get oxygen before birth?
A by its lungs **B** from the mother
C by the amnion **D** through the cervix

13 The afterbirth is
A the placenta **B** the amniotic fluid
C the umbilical cord **D** the newborn baby

14 How long is a full-term pregnancy from the beginning of the last period?
A 240 days **B** 266 days
C 280 days **D** 290 days

15 Which of these is needed for healthy nervous system development of the embryo and foetus?
A iron **B** calcium
C protein **D** folic acid

16 Which of these is needed for healthy bone development of the embryo and foetus?
A iron **B** calcium
C protein **D** folic acid

17 Which of these is NOT dangerous to the foetus?
A HIV **B** smoking
C a cold **D** alcohol

18 Which parts of the diet are most important for a healthy pregnancy?
A fruits, vegetables and fatty foods
B salty and sweet foods
C meat and fatty foods
D fruit, vegetables and starchy foods

19 If a woman is addicted to heroin, what is most likely to happen to her baby? It will
A not be affected **B** be born dead
C also be addicted **D** be premature

20 Smoking by the mother can lead to:
A miscarriage **B** premature baby
C SIDS **D** all of the above

21 What do German measles and HIV have in common? They are both caused by
A bacteria **B** viruses
C protists **D** deficiency diseases

22 The danger from which of these can be avoided by having vaccinations?
A HIV **B** German measles
C SIDS **D** deficiency diseases

23 What can travel from the mother to the embryo and foetus?
A food **B** oxygen
C viruses **D** all of the above

24 Which of these methods should NOT usually be used by women over 35?
A contraceptive pill **B** condom
C IUD **D** diaphragm

25 Contraception can involve
A natural methods **B** contraceptive pills
C condoms **D** all of the above

26 Why is a barrier method of contraception the most healthy method? Because it
A is the most effective method
B is the cheapest method
C is the easiest to use
D gives protection against STIs

27 Where is a diaphragm used?
A on the penis **B** in the uterus
C around the cervix **D** in the vagina

28 What do the contraceptive pill, patch and rod have in common with Depo provera? They all contain
A spermicides **B** female hormones
C male hormones **D** common chemicals

29 Where is an IUD used?
A around the cervix **B** in the vagina
C on the penis **D** in the uterus

30 Which of these contraceptives are given as injections?
A contractive pills **B** Depo provera
C morning-after pills **D** contraceptive patches

31 How many active pills are there in a packet of contraceptive pills?
A 7 **B** 14 **C** 21 **D** 28

32 What is cut during a vasectomy?
A vas deferens **B** Fallopian tubes
C testis **D** urethra

33 Which birth control method cannot be reversed?
A IUD **B** tubal ligation
C contraceptive pills **D** contraceptive rods

For questions **34–59** write full answers in your notebook.

34 (a) What is the menstrual cycle? (b) Why is it important?

35 Outline five steps that have to occur before fertilisation can happen.

36 Why do you have the features you do?

37 How are boys and girls formed?

38 Explain, with a diagram, the difference between identical and non-identical twins.

39 What are Siamese twins? How are they separated?

40 Draw (a) a simple labelled diagram of a foetus in the uterus and (b) a diagram to show how the foetus exchanges substances with the placenta.

41 Make a table to summarise the main changes that occur from fertilisation to birth.

42 (a) What are the three stages of birth? (b) Explain how each stage is important.

43 Explain how the foetus and baby are cared for before and after birth.

44 (a) What is a premature baby? (b) List three causes of premature babies. (c) How are they cared for and why is this important?

45 Choose one reproductive issue that you have studied in this Unit. Write down your own opinions about it.

46 Explain four things that a woman who is planning to become pregnant can do to help ensure a healthy pregnancy.

47 Explain to a young couple that want to have a baby which are the most fertile days in the woman's menstrual cycle when conception is most likely.

48 List four things that (a) should be and (b) should not be in a healthy diet for a pregnant woman. Choose two of the items and explain your choice.

49 List three things that happen as a foetus grows and identify a food constituent that would help with each development.

50 Why are the first three months considered the most important for foetal growth?

51 Why are (a) alcohol abuse and (b) drug abuse especially dangerous for a pregnant woman?

52 How should a teenager, who later wants to have a baby, behave in her personal life? Consider her choice of friends, use of alcohol, illegal drugs or cigarettes and the partners she has intercourse with.

53 How can a teenage boy or man behave in a responsible way towards a young teenager or woman?

54 Why is it true that only barrier methods such as condoms give protection against STIs such as HIV?

55 How can using a condom be made more effective at helping to prevent conception?

56 Explain how a couple in a committed relationship could make use of a natural method of birth control.

57 Outline the advantages and disadvantages of four different methods of birth control.

58 (a) Write an essay on what you have learned about in this Unit. Include five things you know now that you did not know before. (b) Have the discussions in the Unit made a difference to how you will behave? (c) What advice would you give to young people of your age?

59 (a) What are some topics you would still like to find out about? (b) Work with a partner to do research on the Internet and in reference books to find answers to your questions. ICT

Key ideas

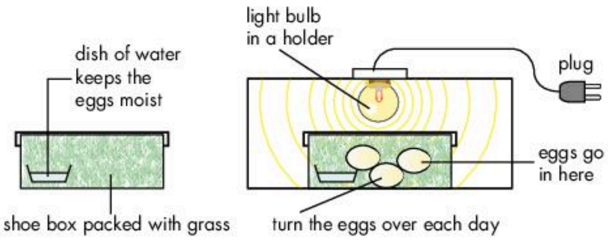
- At puberty girls begin making eggs and boys begin making sperm.
- An egg is shed each month from the ovary, about halfway through the menstrual cycle.
- If fertilisation does not occur, the thickened uterus wall sheds blood as the period.
- If fertilisation occurs, the zygote divides into a ball of cells and implants in the uterus wall.
- Cell division and cell specialisation occur to make all the organs of the body.
- From 8 weeks development the embryo is called a foetus and looks like a miniature human.
- The foetus is connected to the placenta. It receives food and oxygen in the umbilical vein and gets rid of carbon dioxide and other wastes in the umbilical artery.
- The foetus is protected by the amniotic fluid, amniotic sac and uterus wall.
- During birth the cervix is first widened. Then the waters break and the uterus pushes out the baby. This is followed by the placenta (the afterbirth).
- Things dangerous for the baby can pass from the mother along the umbilical cord.
- To help have a healthy pregnancy a woman should have a healthy diet and avoid alcohol, illegal drugs, smoking and infections such as HIV.
- Before becoming pregnant a woman should check if she is Rhesus negative, is immune to German measles or has an STI such as HIV.
- She should have the necessary treatment, including vaccinations for German measles if necessary, before becoming pregnant.
- Helpful advice, blood tests and checking the growth of the foetus are done at prenatal clinics.
- Natural contraceptive methods do not involve chemicals or contraceptive devices. They depend on identifying the unfertile (safe) period and only having sexual intercourse at this time. They are not as reliable as artificial methods.
- Artificial contraceptive methods depend on using barriers (condoms, cap, diaphragm), chemicals (spermicides, contraceptive pills, patches and injections and morning-after pills), IUDs and surgical operations (tubal ligation, vasectomy).
- Each contraceptive has advantages and disadvantages. A couple needs to choose which method suits them best at different times.
- Only barrier methods give protection against STIs such as HIV. An IUD or hormone treatment, together with a condom would be most effective.

▶ **See Workbook Embryo development and birth control.**

Problems

1 Research how different animals, for example birds or reptiles, meet their needs inside the egg. Prepare an illustrated account of what you find. ICT

2 (a) Use the Engineering Design Process to make a homemade incubator for chicken's eggs. Here is an example to give you an idea.



(b) Get some fertile farm eggs and put them in the damp grass. Turn them over each day.

(c) You can keep your eggs warm by attaching a light bulb to the top of a larger box (as shown in the diagram).

Each group can make their own design and see if you can incubate the eggs to produce chicks in about three weeks' time.

(d) Examine a chicken's egg and identify the parts that are important for providing food, protection and oxygen. Make labelled diagrams.

3 Your Science curriculum has the following suggestion for an activity.
Debate on the moot: 'Be it resolved that condoms should be distributed in secondary schools'.
Decide if you agree or disagree with the statement and then make up an argument to persuade other members of your class to consider your opinions.
You need to critique, analyse, develop logical arguments, think critically, communicate and collaborate. Your arguments should reflect an understanding of teenage sexuality and the effects of teenage pregnancy.

Answers to Quick check

Introduction: Working like a scientist (3)

Page 11

Scientists use the scientific **method** and engineers use the engineering **design** process to solve **problems**. ICT stands for **information** and **communication** technology and it makes use of a **binary** code.

Page 17

We measure **physical** quantities using units. We can add **prefixes** to change the value of **base** units. We use a **derived** unit (cm^2) to measure **area**. The **precision** of a numeral is given in significant figures.

Page 21

The **independent** variable is on the x-axis. The slope of a graph is the **gradient**. Speed is the distance over **time** and is measured in **ms^{-1}**. **Velocity** is speed in a certain direction. Acceleration is measured in **ms^{-2}**.

Unit 16 Transport in living things

Page 29

Diffusion occurs in gases, liquids and solids in solution. **Osmosis** is the movement of water particles through a **partially** permeable membrane, such as the **cell** membrane. A strong sugar solution would have **fewer** and pure water have **more** water particles.

Page 37

Osmosis is a special case of **diffusion** and is the process by which water enters the plant. Flowering plants contain **xylem**: transports water and salts up the plant and **phloem**: distributes **food** around the plant. **Transpiration** is the process by which water leaves the plant.

Page 49

Red cells transport **oxygen**; **carbon dioxide** is dissolved in the plasma. **De-oxygenated** blood returns from the body in veins to the **right** atrium of the heart. Blood leaves from the **left** ventricle into the aorta. We can exercise and eat a healthy diet to try and avoid **circulatory** diseases.

Unit 17 Electricity and magnetism

Page 56

Static electricity is caused by **friction** between two dry, **non-conducting** materials. Electrons pass from one material (which becomes **positively** charged) to another (which becomes **negatively** charged). A sudden release of charge can cause sparks, electric shock and **lightning**.

Page 73

An electric current is usually a flow of **electrons**. Cells arranged in several pathways are called a **parallel** circuit. In a **series** circuit the current has the same value all round the **circuit**. Resistance is **voltage** divided by current. A **three**-pin plug can contain a **fuse**, which melts and breaks if excess current flows.

Page 79

Unlike poles **attract** and like poles **repel**. There is a **magnetic** field around a magnet and around an **electric** current in a **wire**. An **electromagnet** is made as an **electric** current flows in a coil around an iron core.

Unit 18 Chemical bonding, reactions and equations

Page 91

Metal atoms lose **electrons** to become **positively** charged **ions**. Non-metals can form **ionic** and **covalent** compounds. The valency of an atom depends on the number of **electrons** in the outer shell.

Page 99

Substances made in a chemical reaction are **products**. If energy is released in a reaction it is an **exothermic** reaction. Metals form **basic** oxides with oxygen. Heating of copper carbonate is a **decomposition** reaction. Magnesium is **more** reactive than copper.

Page 103

A superscript shows the **charge**. **Subscripts** are small numbers showing numbers of atoms. In equations, large numbers in front of molecules are **coefficients**. In equations (aq) means **aqueous** and (s) means **solid**.

Unit 19 Sensitivity and co-ordination

Page 121

Sensory cells in the sense organs respond to different **stimuli**. They send nervous **impulses** along nerves to the spinal cord or **brain**. Our eyes focus light waves; our ears respond to **sound** waves.

Page 125

The central nervous system consists of the **brain** and **spinal cord**, both protected inside **bone**. An automatic action is called **involuntary**, controlled by the **spinal cord** or the hind part of the **brain**. Actions we think about are called **voluntary**, controlled by the fore **brain**.

Page 129

The **pituitary** is the master gland. It produces **growth** hormone and controls several other organs, including the ovaries and **testes**. The adrenal glands make **adrenaline**. The thyroid makes **thyroxine** and the pancreas makes **insulin**.

Unit 20 Acids and alkalis

Page 137

Chemicals can be **acids**, **bases** or **neutral**. Litmus is an indicator that turns red in **acids** and blue in **alkalis**. The **dyes** in universal **indicator** change to different colours in weak and strong solutions of **acids** and **alkalis**.

Page 143

Acids ionise to make **hydrogen** ions and alkalis make **hydroxide** ions. Many metals produce **hydrogen** gas and carbonates produce **carbon dioxide** with acids. Metal salts make insoluble **hydroxides** and ammonium salts make **ammonia** with alkalis.

Page 149

The reaction of an acid and a base is called **neutralisation**: hydrogen ions balance with **hydroxide** ions. These reactions produce **salts** and **water** only. Other ways of making **salts** are to react acids with **carbonates** or **metals**.

Unit 21 Embryo development and birth control

Page 160

Fertilisation is the joining of egg and sperm. The zygote divides to make the **embryo**, which grows into the **foetus**. It gets oxygen and food from the **placenta** via the umbilical **vein**, and gets rid of carbon dioxide and other wastes through the umbilical **artery**.

Page 166

To help have a healthy pregnancy it is important for the mother to have a healthy **diet**, and not to **smoke** or to take **alcohol** or **drugs**. She should also avoid infections such as **HIV** and **German** measles. She will get helpful advice from the **prenatal** clinic.

Page 171

The Rhythm method is a **natural** method of birth control. Artificial methods use **barriers** such as **condoms**, and chemical hormones in **contraceptive** pills and patches. An **IUD** can be fitted in the uterus. A vasectomy and **tubal** ligation are sterilisation operations.

Glossary and Index

Here is a description of important terms, and the main places to find them in the book.

Abortion Generally means the artificial ending of a pregnancy before the 20th week, 162
Absorption To take in. Plants absorb water and mineral salts, 35, 37
Acceleration The change in velocity (m/s) with time (s); measured in m/s/s or ms^{-2}, 21
Acid-base indicator Indicates if a a solution is acidic or alkaline, 134, 135, 137, 145
Acids Turn blue litmus red; with metals, 99; properties and reactions, 135–6, 138–40, 144–5, 148
Acidic oxide Formed by burning a non-metal with oxygen, e.g. sulphur dioxide, 95; dissolves in water to make an acid, e.g. in acid rain, 95
Acid rain Formed when acidic oxides dissolve in water, 95; weathering of rocks by, 140
Adaptations Special characteristics, e.g. for dry or wet places, 31
Adhesion Force holding water molecules to a surface, such as a xylem vessel, 35
Adolescence The change from childhood to adulthood. It begins at puberty, 154
Adrenal glands Endocrine glands producing adrenaline; the fight or flight hormone, 127, 128
AIDS *see* **HIV**
Alcohol Affects the brain and can cause special problems during pregnancy, 164
Alkalis Bases that dissolve in water, e.g. sodium hydroxide; turn red litmus blue; properties and reactions, 103, 141–5, 146–7
Alkali metals Reactive metals with one electron in their outer shell, e.g. sodium. Lose one electron to form positive ions, 83, 84, 85
Alveoli Small air sacs in the lungs where gas exchange takes place, 45
Ammeter Used to measure the rate of flow of electric current (I) in amps (A), 60, 62, 64, 65
Ammonia Gas that turns red litmus blue, 89, 143
Amniotic fluid and sac Keep the embryo/foetus moist, at a steady temperature and protected, 156
Amoeba One-celled animal-like organism, 28, 39
Anions Negative ions formed from non-metal atoms gaining electrons, 85, 86
Antibodies Chemicals made by some white blood cells to kill particular micro-organisms, 39
Area Amount of surface of an object; measured, e.g. in cm^2, 14, 24, 27
Art Part of the design process for choice of materials, styles and colour, and drawings of models and advertising, 2, 9
Arteries Blood vessels that take blood away from the heart to the lungs and other body organs, 41, 42, 43–5; damage to, 47–8
Artificial birth control Methods using chemicals or artificial devices for birth control, 167, 169–71
Artificial fertilisers Synthetic mineral salts used to improve plant growth, 147
Astronomical unit The distance from the Sun to the Earth: 149.6 million km, 24
Atom A single neutral particle; structure of, 84
Atomic number Same as the number of protons or electrons in an atom, 86
Atria Top compartments of the heart, receiving blood from blood vessels, 42, 43, 45

Baby The young, e. g. of humans, 158, 159, 160
Bacteria Single-celled micro-organisms without a proper nucleus; and disease, 39
Balanced diet Contains a healthy mix of food nutrients in the right amounts, 162–3
Balanced equation The same numbers and kinds of atoms are shown in reactants and products, 101–2
Bar chart A way to show results by drawing bars to show the numbers of things, 18
Barrier contraceptives Physical barrier to stop egg and sperm meeting, e.g. condom; also offer some protection against transfer of STIs, 169
Bases Turn damp red litmus paper blue; properties and reactions, 135, 141–2, 144–5, 146
Basic oxide Formed by burning a metal with oxygen, e.g. magnesium oxide, 94; dissolves in water to make an alkali, 94
Battery Two or more dry cells working together to supply electricity, 68
Bimetallic strip Bar of two metals, one of which expands more when heated; a thermostat, 72

Binary code Using combinations of 0 and 1 to represent numbers, words and grammar symbols, 10–11

Birth The time when a foetus leaves the uterus as a baby, 158, 159; problems with, 159, 160

Birth control Methods reducing the likelihood that sexual intercourse will lead to pregnancy, 167–71

Blind spot Area in the eye without rods or cones where the optic nerve leaves the eye, 114–5

Blood Transport tissue in animals: structure and functions, 38–9; groups, 40; transfusions 40; circulation of, 41–5; doping, 38; and disease, 39

Blood vessels Arteries, capillaries and veins, in which blood travels, 41, 43–5, 47–8

Bone Hard part of the skeleton, protecting other organs, 122

Brain Controls thought, planning and some automatic actions; interprets impulses from the sense organs, 122–3

Cambium Layer of dividing cells important for plant growth. Found in the veins of the stem, 33

Capillaries Smallest blood vessels, with walls one-cell thick, close to all living cells, 41, 44, 45

Carbonates Compounds containing the carbonate radical, 97, 139, 140

Carbon dioxide Gas used in photosynthesis and produced by combustion, 95; it turns limewater milky, 97, 139; in cell respiration, 44; and exchanged in the alveoli, 45

Carbon monoxide A poisonous gas produced by incomplete combustion of carbon, 95

Cations Positive ions formed from metal atoms losing electrons, 84, 86

Cell The unit of living things, 28–9, 35, 109, 154–6; also *see* **dry cell**

Cell division Making more cells, e.g. from human zygote during development, 156, 157

Cell membrane Covering membrane around the cytoplasm in all cells, 28, 29

Cell respiration Respiration occurring in all living cells, 44

Cell wall Wall made of cellulose; outside the cell membrane in plant cells, 32, 33

Centi- A prefix meaning $1/100^{th}$ (10^{-2}), 12

Central nervous system Consists of the brain and spinal cord, 122–5

Cerebellum The midbrain that co-ordinates movement and balance, 122, 123

Cerebrum The forebrain that allows us to think, plan and remember, 122, 123

Charge Nature of particles: protons +ve and electrons –ve; atoms and ions, 86; static electricity, 54–6; current electricity, 57, 59, 68

Chemical change Produces new substances; cannot be easily reversed, 96

Chemical contraceptives Chemicals used to kill sperm or prevent egg development, 167, 169–70

Chemical energy Energy stored in chemicals; in dry cells and batteries, 68

Chemical equations Chemical formulae added to word equations, 100, 102, 143, 145

Chemical formulae Symbols and numbers of each kind of atom making up a molecule, 87, 90, 100, 102

Chemical reactions Reactions forming new compounds, 92–9

Chemical substances Stimuli to which the nose and tongue respond, 110–12

Chick A young chicken that can develop in an incubator from a fertile egg, 174

Chlorophyll Green pigment in chloroplasts in plant cells. Needed for photosynthesis, 34, 96

Chromosomes Inside the nucleus, they contain the genes, 155, 167

Circuit Complete pathway for flow of electricity, 57–65; series, 60–1; parallel, 62–3

Circuit breaker Safety device, containing an electromagnet, to protect a circuit, 73

Circuit diagram Diagram using circuit symbols, 57

Circuit symbols Simple way of showing the parts (components) in a circuit, 57

Circulatory system Pathway for blood to flow, pumped by the heart, 42–5

Coefficient Number in front of a molecule to show how many are present in a chemical reaction, 101, 102

Cohesion Force holding water molecules together, 36

Colour We see in colour using red, green and blue-sensitive cones in the eye, 115

Combining power Number of electrons lost, gained or shared in a chemical reaction, 88–9, 100

Combustion Combining of carbon-containing fuels, including food, with oxygen to release energy, 95

Communicate To share information by speech, writing or using ICT, 5, 6, 8, 11

Compass A freely moving magnet, 74, 75, 76

Components Parts, e.g. that make up an electrical circuit, 57

Composite shape An area or volume made up from two or more other shapes, 14–15

Compounds *see* **covalent** and **ionic bonding**

Computer Uses complex electronic circuits and binary code to perform particular tasks, 10–11

Concave lens A lens that is thin in the middle and spreads (diverges) light, 116–7

Concentrated Containing a lot of a certain substance, e.g. in a solution, 28, 29; acids, 136; alkalis, 142

Concentration The amount of a certain substance in a mixture, 27–9

Concentration gradient The direction of movement of particles from a region of high concentration to a region of lower concentration, 27–9

Conception Fertilisation of an egg by a sperm, 154, 156, 168

Conclusion What you learn from an activity, and whether you have solved your problem, 5, 6, 8

Condom Rubber or plastic sheath; forms a barrier to stop egg and sperm meeting; gives protection against transfer of STIs, 169

Conductor Material allowing passage of electricity, 58, 91

Contraceptive chemicals Pills, patches or injections used to prevent egg development, 170

Contraceptives Methods used to prevent fertilisation, e.g. barriers or chemicals, 169–71

Contractions Muscle movements in the wall of the uterus pushing when a baby is being born, 158

Controlling variables Setting up an experiment so that only one variable is changed, 7

Convex lens A lens that is thick in the middle and brings together (converges) light, 116–7

Coronary arteries They supply the heart with blood, 44; by-pass operation for, 48

Corrosive Chemicals that destroy equipment and can eat into living flesh, 140, 141

Covalent bonding Formed when electrons are shared between non-metals, 88, 89–90, 91

Current (I) Rate of flow of electrons; measured with an ammeter in amps (A). Current is voltage divided by resistance ($I = V/R$), 59, 60, 62, 64, 65

Cytoplasm Jelly-like substance in cells where many chemical reactions take place, 28

Data Can be numerical or words; with meaning it is called information, 18

Deci A prefix meaning $1/10^{th}$ (10^{-1}), 12

Decomposition Breakdown of a compound, 97

Deficiency diseases Caused by lack of important nutrients, e.g. anaemia, 49

Delivery End of the birth process, 158

Density The amount of mass in a given volume. Density = mass/volume; measured in kg/m^3 and g/cm^3, 20

De-oxygenated blood Has a low concentration of oxygen; in most veins and in pulmonary artery, 42, 43, 44, 45; in umbilical artery, 156

Dependent variable The results you observe or measure and that depend on the independent variable; plotted on the y-axis, 7, 18–21

Derived quantities Made up from fundamental quantities, e.g. cm^3, 12–13, 20–1

Design Work out, with drawings, how to solve a practical problem, 2, 8–9, 52, 106, 132, 152, 174

Development Becoming more complex with specialisation of organs: in humans, 156–7

Diaphragm Rubber dome that forms a barrier to stop egg and sperm meeting, and gives some protection against transfer of STIs, 169

Dicotyledons Flowering plants where there is one main root, 31

Diffusion Movement of particles from an area where they are in high concentration to an area of lower concentration, 26–9; in Amoeba, 28; in plants, 35, 36; in humans, 44, 45

Digestion Breaking down of food into small soluble particles that can pass into the blood, 45

Digits Used to write a numeral; in the decimal system 0 and 1 to 9 are the digits, 16

Dilute Not containing much of a certain substance, e.g. in a solution, 28, 29; acids, 136; alkalis, 142

Disease Upset in functioning of the body due to different causes, 39, 47–8; protection against, 39; reduction of, 49

Displacement A metal displaces hydrogen or a less reactive metal from another compound, 98

Displacement method Using a can and water to find the volume of an irregular object, 15
Distance-time graph When distance (m) is plotted against time (s), the gradient is speed (m/s or ms^{-1}), 20
DNA Makes up our genes and chromosomes that determine all our characteristics, 154
Down's syndrome A person with an extra copy of a chromosome, which can cause problems, 167
Double circulation Blood passes twice through the heart on its pathway around the body, 43
Drawing Making a picture that looks like the real thing, 5, 9
Drug abuse Use of dangerous drugs, which can cause special problems during pregnancy, 165
Dry cell Contains chemicals that can generate electricity when placed in a circuit, 57, 68
Ductless gland An endocrine gland that passes hormones directly in to the blood, 126
Duplet rule A few elements lose or gain electrons so the outer shell is stable with 2 electrons, 86
Dynamo Generates electricity when a magnet is turned within a coil of wire, 69, 77

Ear Sense organ for hearing, 121
Earth wire Wire (green-yellow) to the earth pin, which conducts electricity to Earth, 67
Echoes Reflection of sound from a surface; used to make ultrasound scans of developing foetus, 120
Egg Female gamete produced in the ovary, 154, 155; fertilisation to make zygote, 155, 156, 170
Electrical energy (electricity) Energy provided from batteries or the mains, 57–71; safety with, 67, 72–3
Electrical hazards Dangers associated with heat and electricity, 67, 72–3
Electricity meters Record energy usage in kWh; analogue (dial), 70–1; digital, 70–1
Electric shock Possible fatal effect of an electric current passing through the body, 55
Electromagnet Soft iron that becomes a magnet for as long as an electric current is passed in a wire around it, 76–9; uses of, 78–9
Electromagnetic induction Inducing an electric current by a conductor moving in a magnetic field, 77
Electrons Minute negatively-charged particles in shells around the nucleus of atoms, 84, 85, 86; and static electricity, 54–6; and current electricity, 57–9
Electrostatic forces Induction of charge due to static electricity; makes small objects move, 54
Elements Particles are of only one kind; contain atoms or molecules, 84–5
Embryo In humans, the young stage up to eight weeks growing in the uterus, 156
Endocrine system Produces hormones directly into the blood; ductless, 126–9
Endothermic reaction Reaction that takes in energy, 93
Energy The ability to do work; measured in joules (J): energy conversions, 64, 71
Energy unit This is one kilowatt-hour (kWh), 70–1
Engineering Engineers are technologists; making new structures and materials, 2, 8–9
Engineering design process (EDP) The process of trying out options and improving designs to make models or solve problems, 2–3, 8–9, 52, 82, 132, 174
Environment The surroundings in which plants and animals live, e.g. deserts, 31
Evaporating Removing water from a solution. The solute remains behind, 148
Exercise Action that makes us sweat, pant or make the heart beat more quickly, 46
Exothermic reaction Reaction that releases energy, 93
Eye Sense organ for sight, 114–7

Fair test An experiment where only one variable has been changed, so that its effect can be found, 5, 6–7
Family planning Using contraceptive methods to plan when babies are conceived, 167
Fertilisation Joining of sperm and egg, usually in the Fallopian tube (oviduct), 154, 155, 156
Flowering plants Plants that have flowers and make seeds; parts of, 30–1, 37
Foetus In humans, the developing stage from eight weeks until birth, 156–9
Food This is a fuel (energy source). Transported in the phloem, 37; and the blood, 45; importance in pregnancy, 162–3
Force A push or a pull; measured in newton, 1 newton (N) = 1 $kgms^{-2}$, 21

Ions Charged particles, formed when atoms lose electrons (metals) or gain electrons (non-metals), 83, 86

Irregular shape A shape whose area or volume cannot be found using a formula, 14–15

Isotonic Two solutions of the same concentration separated by a partially permeable membrane: there is no net movement of water, 28

IUD A device put into the uterus to prevent implantation, 115

Kidneys Main excretory organs; blood supply, 43

Kilo A prefix meaning × 1000 (10^3), 13

Kilojoule (kJ) The joule (J) is the unit in which we measure energy. 1 kilojoule (kJ) = 1000 J, 70

Kilowatt (kW) A thousand watts. Using 1 kW for one hour is one kilowatt-hour (kWh), 70

Kinetic energy Energy of movement. Characteristic of particles; and electrical energy, 69, 77

Labour Process by which a baby is born, 158

Law of conservation of mass Numbers of atoms in reactants equal those in the products, 92

Leaves The green parts of plants where photosynthesis and transpiration occur, 30–1, 34, 36–7

Length How long something is; measured, e.g. in m and cm, 12–13, 14–15

Lenses Transparent glass or plastic shapes that bend light and form images, 114–7

Light Stimulus to which the eye responds, 115; important for photosynthesis, 34

Lightning Sudden discharge of static electricity, 55

Light-year The distance that light can travel in a year: 9.5 million, million km, 24

Limewater Solution of calcium hydroxide; test for carbon dioxide: it goes milky, 97, 139

Line graph A display, using axes, that shows how two numerical variables are related, 18–21

Liver Important body organ for keeping blood composition constant, 43

Live wire Wire (brown) connected to the live pin in a plug, along which electricity is delivered, 67

Lungs Organs responsible for breathing and gas exchange of carbon dioxide and oxygen, 45

Magnet Usually made of iron or steel that can attract other pieces of iron or steel, 74–9

Magnetic field The area where a magnet or electric current flowing in a wire shows its effect, 75–9

Mains electricity Electricity supplied to the home and used by appliances, 68, 69

Mass The amount of substance in an object; measured, e.g. in kg and g, 12–13

Mass number Of an atom. also called the nucleon number. Number of protons and neutrons combined, 86

Mathematics Using numbers, measuring, calculating and graphical displays, etc., 2, 12–21

Measuring Using units to describe the size or amount of something, 13–15

Medulla oblongata The hindbrain that controls automatic responses in the body, e.g. heart rate, 122–3

Mega A prefix meaning × 1000 000 (10^6), 13

Membrane Structure, such as the cell membrane that controls what enters and leaves a cell, 29

Menstrual cycle Changes in the thickness of the uterus wall and release of an egg each month, which begins at puberty in females, 154

Metals Elements with only a few electrons in the outer shell; form positive ions, 84, 88; properties, 91, 94, 96, 98–9, 139, 140

Micro A prefix meaning 1/1000 000th (10^{-6}), 12

Micro-organisms Very small organisms only seen with a microscope, can cause disease, 39

Microscope Instrument for magnifying objects, 34

Milli A prefix meaning 1/1000th (10^{-3}), 12

Mineral salts Needed for health. Absorbed from the soil by plants, 35, 37; needed by animals, 162–3

Miscarriage Natural ending of a pregnancy before about twenty-fourth week, also called an abortion, 166

Model making Using the EDP to design and make models to solve problems, 52, 82, 90, 132, 174

Molecule Made of two or more atoms joined together. Can be elements or compounds, 88–9

Monocotyledons Flowering plants with many small roots, 31

Multicellular Organisms, e.g. plants and animals with many cells, 30, 38

Muscles Tissue that can contract; in arteries and veins, 41; during child-birth, 158

Power station Place where energy conversions occur to generate electricity, 69

Precision A measurement closest to the real measurement, 16–17

Prediction A suggestion about what might happen in the future, set up to test an hypothesis, 5, 6–7

Prefixes Descriptions with a certain value, that are added in front of a unit to make it bigger or smaller by powers of ten, 12–13

Pregnancy The time from fertilisation to birth, 154, 156–8; health during, 161–6; teenage, 161

Premature birth Birth of a baby before it is fully developed; baby needing special care, 160

Prenatal care Care provided before birth, 162, 166

Problem-based learning Working in groups, students solve problems often using ICT, 3, 6–9, 24, 52, 82, 106, 132, 152, 174

Problem statement Describing the specific problem to be solved, 6–9

Products Chemicals produced in a reaction; on the right-hand side of an equation, 92

Protons Particles in the nucleus of an atom; each has one positive charge, 86

Puberty The time when girls and boys begin to make eggs and sperm, 154

Pulse The spurts of blood in the arteries caused by the beating of the heart, 41, 42

Pupil reflex Automatic changes in the pupil with changes in light intensity, 114

Quantity *see* Physical quantity

Radicals Groups of atoms that stay together in chemical reactions, e.g. sulphate radical, 88, 90, 100

Reactants Chemicals that react together; on the left-hand side of an equation, 92

Receptor Sensory nerve endings in the skin or other sense organ, 109, 124–5

Record Make a display of results using tables, bar charts, line graphs etc., 4, 18–19, 20–1

Red blood cells Carry oxygen around the body, 38, 39, 40

Reflection The bouncing of waves from a surface; of light, 113; and sound, 120

Reflex arc The pathway of nerves involved in a reflex action, 124–5

Reflex action An automatic (involuntary) action involving the spinal cord or hind brain, 114, 124–5

Regular shape Shape with an area or volume that can be calculated, using a formula, 14–15

Report Make a written or oral presentation of an activity under certain headings, 5, 6, 8

Resistance (R) Force opposing flow of current; measured in ohms (Ω). $R = V/I$, 59, 64–5

Resistor A component that opposes flow of current; a variable resistor is called a rheostat, 64–5

Respiration Combustion of food with oxygen to release energy, carbon dioxide and water, 95; and gas exchange in cells and lungs, 44, 45

Response Reactions to stimuli, e.g. in a reflex action, 124–5

Responsible behaviour Behaving so that neither yourself nor others are harmed, 161, 164–6

Results What happens in an activity: observations, measurements, models, 6, 8

Rhesus factor A chemical that may (Rh+) or may not (Rh-) be present in the blood, 40, 165

Rhythm method A natural method of birth control, based on calculating 'safe' days, 168

Root push Water taken in by the root hair cells pushes more water up the xylem, 32, 35

Root hairs Small, elongated cells that take in water and mineral salts, 35, 37

Roots The underground parts of the plant that absorb water and mineral salts, 30–2, 35

Rounding Rules for making an approximation in value of a numeral, 16–17

Safety Taking due care of people, equipment and materials, so they are not harmed or damaged, 67, 72–3, 140, 141

Salts Compound formed, for example, by the neutralisation between an acid and base, 143, 144, 148–9; and *see* **mineral salts**

Scale Markings of lines and numbers on instruments; used for measuring, 12–13

Science Finding out about the natural world using systematic ways of thinking and working, 2, 4–5

Scientific method The systematic way of investigating, often involves fair tests, 6–7

Selectively (partially) permeable Membrane allowing water but not solutes through, 27–9

Sense organs Organs responsible for the senses: skin, tongue, nose, eye and ear, 108–21

Senses How we find out about our surroundings: touch, taste, smell, sight and hearing, 108–21

Sensory or receptor cells These sense the stimuli in the sense organs and pass on impulses, 109–112, 115, 121, 124–5

Series circuit Bulbs are one after another in a single circuit with the dry cell, 60–1

Sex chromosomes Determine whether a fertilised egg becomes a boy or a girl, 155

Sexual intercourse When the penis is placed in the vagina and sperm are transferred, 154; can also transfer micro-organisms, 164

Sexually transmitted infections (STIs) Infections transferred by sexual contact, 164

Shells Arrangement of electrons in atoms, 84

Sight The sense organ is the eye, using the sensory cells: rods and cones, 113–7; long and short sight, 116–7

Significant figures A digit that is important to determine the value of the numeral, 16–17

SI system International system of units used for measuring physical quantities, 12–13

Skills Thinking and practical skills, including ICT, needed for science and technology, 4–5

Skin The sense organ for touch, 108–9, 124–5

Smell The sense of smell is in the nose (nasal cavity), 111–2

Smoking Using cigarettes or cannabis etc., can cause special problems during pregnancy, 166

Solute The substance that dissolves in another, 28, 29

Solution A homogeneous mixture of substances, with one dissolved in the other, 28, 29

Solvent The substance that dissolves another, 28, 29

Sound Stimulus to which the ear responds, 118–21

Speed The distance an object moves (in metres) in a certain time (in seconds); measured in m/s or ms^{-1}, 20

Sperm Male gamete produced in the testes, 154, 155, 169, 171

Spermicide cream Chemical that kills sperm, 169

Spinal cord Part of the central nervous system concerned with most reflex actions, 122, 124, 125

Standard form A numeral between 1 and 10 multiplied by a power of ten, 16–17

Standardisation The use of standard units for measuring, e.g. in the SI system, 12

Static electricity Electricity at rest: the build-up of charge on a non-conductor, 54–6; uses of, 56

Stethoscope Instrument for listening to the heart beat, 42

STEAM Art and the making of detailed drawings is added to STEM, 9

STEM Using science, technology, engineering and mathematics together, 2–3, 8–9

Stem Upright part of a plant that supports other parts and contains veins and packing cells, 30, 33, 35, 37

Stimuli Changes in the environment that are sensed by living things and to which they respond, 108 *see* **light, sound, chemicals, temperature, touch**

Subscript Small number in a chemical formula showing how many atoms are present, 87, 100, 102

Sun Star at the centre of our solar system; we depend on it for life on Earth, for light and heat, 34

Surface area to volume ratio In diffusion, 27–9

Surgical methods Used to prevent pregnancy, e.g. vasectomy and tubal ligation, 171

Switch Device to open and close a circuit, 58

Symbols Letter(s) representing elements, 84–5; drawings representing parts of a circuit, 57

Synthesis Combining of simpler substances, 96

Taste The sense organ is the tongue with its taste buds containing sensory cells, 110–1, 112

Technology Design of new structures for specific purposes; includes ICT and engineering, 2, 8–11

Technological skills Designing and making skills: uses ICT and EDP, 4–5, 8–9, 52, 82, 106, 132, 152, 174

Teenage pregnancies Pregnancy of young teenagers who are not fully developed, 161

Temperature Average kinetic energy of a substance; stimulus to which the skin is sensitive, 108–9; measured in degrees Celsius (°C), 12, 13

Testes Male sex organ producing sperm, 127, 154

Thermometer Used to measure temperature in degrees Celsius (°C), 12, 13

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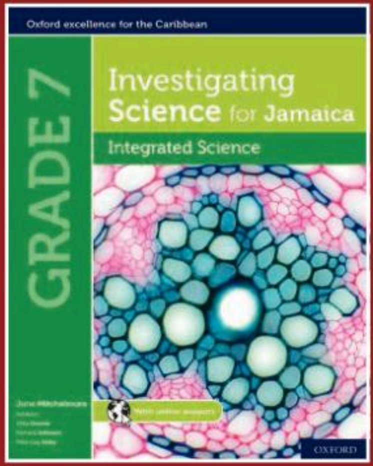

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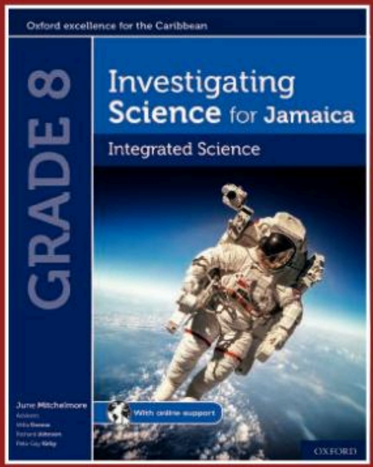

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