Oxford Secondary Science 2

Teaching Guide

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Introduction

Aims and content of the course

Learning science is fundamental to understanding the world in which we all live and work. Science helps people to ask questions, test explanations through measurement or experimentation, and assists people to clarify their ideas. Science is important to everyone—young or old, male or female, city or rural dweller. It is science that has brought our world to where it is today. Science has created the comforts we enjoy and the problems with which we must deal. Used wisely, science can make the world a better place; science used unwisely can lead to global disaster. An added reason for learning science is that we need more scientists, technicians, and engineers to run the complex world of the future.

Science involves mental discipline. As with so many other things, people must be exposed to that mental discipline when they are young. If children do not learn to think in a scientific, systematic way, they grow up blindly accepting all they are told, confusing science and superstition, and depending on hasty judgement rather than considered opinion. We have to learn to recognize that science is not something done to us, for us, or at us, by experts. We must do it. Each individual should be scientifically literate enough to keep abreast of developments throughout their lives. We must also learn to use scientific skills to make intelligent decisions. Life in an advanced technological society is driven by scientific decision-making. Should we build more nuclear power plants? Which diseases should receive research funding? Is it safe to use genetically engineered crops to increase food supplies? What is global warming and how do we deal with it?

Children and teenagers want to know everything about everything. The ***Oxford Secondary Science*** series of books is designed to provide a straightforward approach to the teaching of science in the first three years of secondary education. It develops and extends the learning acquired in the primary school from the use of such courses as ***New Oxford Primary*** Science by Nicholas Horsburgh and ***Science Success*** and ***Simply Science***, both by Terry Jennings.

Oxford Secondary Science covers the requirements of the Pakistani National Curriculum for General Science at Grades VI, VII, and VIII. The course aims to meet the needs of teachers and students by developing and building on the core scientific themes studied in primary school in carefully graded stages, thereby providing a comprehensive introduction to science for students aged 11 to 14 years.

The course is designed to do four main things:

1. To give students a solid body of knowledge in the natural, physical, and Earth and space sciences
2. To develop and extend their knowledge of the nature of scientific enquiry
3. To enable students to explore values and attitudes through science
4. To encourage them to think about how we can use science for the best

These four elements are developed side by side through the books which make up the complete Course. It is hoped that both students and teachers will find ***Oxford Secondary Science*** an exciting and stimulating learning experience. ***Oxford Secondary Science*** is aimed at the average student but is flexible enough to allow use by students of all abilities. It also promotes the development of independent learning by students.

The Course has been written specifically to help the teacher deliver science lessons in a stimulating and engaging way. Its flexibility allows the teacher to tailor the work to meet the known abilities and needs of the students, as well to make best use of what materials and resources are available. In addition, it allows the teacher to use his or her own strengths and to employ strategies that have proved effective in the past. To this end, it is hoped that the course will save the teacher time, money, and preparation.

Using this Teaching Guide

The Student's Books are intended to provide core material on the four broad themes of:

- life and living processes
- materials and their properties
- physical processes
- Earth and space science.

The themes chosen are based firmly on the student's own experience and cover areas affecting their everyday lives.

The overall objectives of the course are that the students should acquire:

A) Knowledge and understanding of science

i. knowledge of some facts and concepts concerning the environment
ii. knowledge of the use of appropriate instruments in scientific experiments
iii. an adequate scientific vocabulary
iv. an ability to communicate using this vocabulary
v. an understanding of some basic concepts in science so that they can be used in familiar situations
vi. an ability to select relevant knowledge and apply it to new situations
vii. an ability to analyze data and draw conclusion
viii. an ability to think and act creatively

The student should acquire:

B) Attitudes

ix. an awareness of the inter-relationship of the different scientific disciplines
x. an awareness of the relationship of science to other areas of the curriculum
xi. an awareness of the contribution of science to the economic and social life of the country
xii. an interest and enjoyment in science
xiii. an ability to become objective in observation and in assessing observations

The student should gain:

C) Practical skills

xiv. some simple science-based skills

xv. some experimental techniques involving several skills

The units within any one Students' Book can be taught in almost any order. If there are two or more teachers with classes of students of the same age, they could each choose different units. The teachers could acquire the materials for their particular unit and then, after the work is completed, they could exchange materials and ideas, and discuss any problems that arise.

Lesson planning

This Teaching Guide does not attempt to specify a rigid strategy for teaching the topics covered in the Students' Book. Schools vary greatly in the time and resources they have available for science work. Instead of detailed lesson plans, notes for possible lessons are included in each chapter. However, it is important to remember that these are just notes and observations which it is hoped will prove helpful in planning lessons and activities. No doubt you will want to develop lessons of your own, hopefully based on the materials in the Students' Book. Some of the suggested activities are spelt out in detail in the form of photocopiable worksheets. It is intended that these worksheets will extend students' knowledge and understanding of the topic, or prove useful when assessing students' basic skills in the laboratory. Some of the other suggested activities are short, fairly simple experiments, while others consist of more open-ended investigations which can be used to assess a student's ability to design scientific investigations and draw conclusions from the results. The use of these will depend upon the apparatus and equipment available and/or the particular characteristics of the teaching group. If equipment and materials are scarce, or if the students cannot be trusted to work without close supervision, then it may be necessary for the teacher to demonstrate some of the experiments rather than allow the students to work on them individually or in small groups.

Science practical work

Most teachers of science see practical work as an essential feature of their everyday teaching, believing that students learn better from doing than simply being told. However although it is in the doing of science that students learn best, this involves more than just practical work. As well as needing to observe, record, predict, measure, look for patterns, classify, ask questions and so on, students need time to discuss their work. Many teachers find that relatively short practical tasks, embedded in a lesson rather than taking up the entire lesson, are more effective in giving the teacher time to introduce students to, and fully discuss, new scientific terms and ideas. In this connection, the experimental worksheets should be discussed both before and after the completion of the activity. This is particularly important with those students who are not fluent readers. Such discussion also helps to clarify the main ideas and will help you to monitor progress and discover what interests the students, with a view to developing their interests in future sessions. Discussion will also reveal any misunderstandings which can then be corrected as soon as possible.

Organization

For practical activities, it may be necessary to divide the students into groups of a size you consider appropriate for each particular activity. The groups should be as small as possible but should have enough students to adequately handle the materials and to keep a record of the results. For most activities, two or three students is probably the optimum number for a group. Many of the activities can be done individually. Certainly the groups should never be so large that some students are merely spectators. In the case of activities which require a great deal of the teacher's attention, it is suggested that the class is divided into two, and while part of the class is engaged in the practical activity, the other part is kept busy with the 'desk-bound' written or other **Things to do** activities in the Students' Book.

Worksheets

The worksheets are designed to be photocopied and used within the purchasing institution. They are designed to allow the students to record their findings on the actual worksheets, but you should also encourage the students to use IT and other methods of recording, as appropriate.

Things to do

Each chapter of the Students' Book contains a number of suggestions for extension work or open-ended investigative work. The suggestions are designed to give students the opportunity to demonstrate creativity in their approach to tackling scientific problems rather than responding to detailed instructions.

There is no definitive answer to many of the tasks set and teachers will need to assess individually the quality of the students' responses. For example, many of the tasks involve the design of experiments, and these can be assessed by looking for examples of good scientific practice. Has the student understood the problem and identified relevant facts? Does the solution offered allow a degree of scientific control? Have appropriate safety factors been taken into account? Does the suggested investigation offer a reasonable chance of success?

Experimental design can be a pen and paper exercise. In many cases lack of resources or the complexity of the problem will make this a necessity. However, wherever possible, the students should be given the opportunity to put their design into practice. For this to be successful, it may be necessary for teachers to define the task much more closely than has been done here and to spell out any constraints which must be taken into account. Finally, it is not recommended that all the suggestions are used with any one group. Many of the open-ended tasks will place great demands on the teacher, so the emphasis placed on these activities is left to the teacher's discretion.

Notes for further investigation and extension work

Each chapter of this Teaching Guide contains a number of suggestions for further investigation and extension work. These are mainly practical or experimental activities and they are offered as suggestions to extend the 'core' practical investigations described in the lesson plans. Depending on the local circumstances and the availability of equipment, the teacher may find that they are more suitable alternatives to the experiments suggested in the outline lesson plans.

Equipment and materials

Essential materials and equipment are listed under 'Materials needed' on each worksheet. Nearly all the items are readily available in a fairly basic school laboratory. It may be necessary from time to time to call upon the school kitchen for access to a refrigerator or deep-freeze. The students themselves may be able to collect some of the materials if they are given sufficient notice.

Safety!

The activities described in this Teaching Guide and in the Students' Books mainly use standard items of equipment, and materials which are perfectly safe if used sensibly. All the activities have been checked for safety as part of the reviewing process. In particular, every attempt has been made to ensure that all recognized hazards have been identified, suitable safety precautions are suggested, and, wherever possible, the procedures are in accordance with commonly-used risk assessments.

However, it is important to be aware that mistakes can be made. Therefore, before beginning any practical activity, you should carry out your own risk assessment in relation to local circumstances. In particular, any local guidelines issued by your employer must be observed, whatever is recommended here. As a general principle if, on safety grounds, you are not completely sure about the ability of your students to carry out an experiment, then demonstrate it to them rather than risk an accident.

General safety precautions

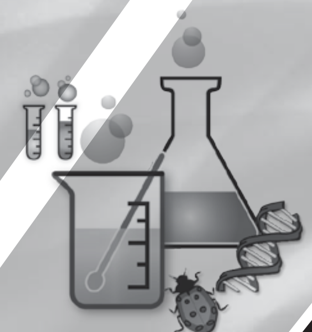
There are a number of general safety rules which you should observe

- If the students taste or handle food, ensure they wash their hands before doing so and that tables and utensils are clean and foods are fresh and uncontaminated. Be sensitive to different dietary requirements.
- Young students have little say or control over what they are given to eat at home. When discussing a healthy or balanced diet, for example, take care to ensure that students do not feel that you disapprove of their dietary habits. Similarly, when comparisons are made between the physical characteristics and intellectual abilities of students, it is important to emphasize that we are all different. Students are built differently, grow at different rates, and have different backgrounds and likes and dislikes and they are particularly sensitive to these differences during the often difficult years of adolescence.
- Visits beyond the school grounds must be carried out in accordance with the guidelines of your school or employing authority.
- Warn students never to look directly at the Sun. It could damage their eyesight or cause blindness. Warn them also of the dangers of inadvertently looking at the Sun through binoculars, telescopes and even microscopes.
- Some students are allergic to certain plants, e.g. some flower bulbs, and pollen (from flowers), and remember that some plants are poisonous. Many students are allergic to certain animals.

- Many seeds bought from garden centres will have been treated with pesticides and are not safe for students to handle unless they wear gloves. Seeds bought from health food shops are usually safe, although it is best to avoid red kidney beans.
- Whenever possible, use transparent plastic containers, rather than glass containers, particularly for collecting living things outside. Particular care is needed not to leave microscope slides or cover slips in sinks and on work surfaces.
- In the absence of Bunsen burners, night-lights and short, stubby candles are difficult to knock over. When using a naked flame always work in a metal tray, such as a baking tray, filled with sand.
- Use soils free from glass, nails, and other sharp objects, and collect soil samples from places that are unlikely to be contaminated with dog or cat faeces. Wash hands after handling soils.
- Wash hands after handling animals.
- Students should not touch ice immediately after it has been taken out of a freezer.
- Take great care with hot water or steam.
- Great care should be taken when using mercury thermometers (recognizable by the silver colour of the liquid inside them), because of the dangers from the toxic metal mercury if they are broken.
- Warn students of the dangers of mains electricity. However, assure them that the batteries they use in class are safe.
- Use plastic mirrors wherever possible. If you have to use glass mirrors, ensure that they do not have sharp edges; bind edges with masking tape or insulating tape.

Assessment

Teachers express considerable concern over assessment. The Students' Book contains questions to support the learning from the units and to build confidence. Many of these questions test factual recall for, without a knowledge of the basics of the topic, it is difficult or impossible for the student to later apply the learning. Answers to these questions are given in this Teaching Guide. In addition, each chapter of the Teaching Guide includes an Assessment section and a list of answers. The multiple choice questions are again primarily included to test the recall of facts, but the structured questions contain more subjective elements, allowing students to reveal a greater depth of understanding. A marking scheme has not been suggested for these assessment items. Again, the aim is to be as flexible as possible. The teacher may wish to set the whole test at the end of the topic, or he or she may want to use the shorter questions for short, sharp tests, or set one or more of the longer questions for homework.



The digestive system

CHAPTER 1

Teaching Objectives

- To examine the structure of the human digestive system
- To explain the process of digestion and its importance
- To explain how different kinds of food are digested.
- To review the causes of common disorders of the digestive system, such as constipation and diarrhoea and the measures that can be taken to prevent them

Learning Outcomes

After studying this chapter students should be able to:

- describe the various components of the human digestive system
- describe digestion and its importance
- describe how the digestive system helps in the digestion of various kinds of food
- identify common disorders of the digestive system
- list the factors that lead to constipation and diarrhoea and the measures that can be taken to prevent them

Introduction

Food and digestion, fortunately, are subjects which are of great interest to most young people, so this is an excellent topic with which to start the new school year. In simple terms, food is made up of large and complicated molecules that the body has to break down into smaller molecules that the blood can absorb. This is the process of digestion. It involves both physical and chemical processes. Some parts of the digestive system mash up food physically, just like a food processor. The teeth, for example, break food into chunks, while the stomach churns these around until they form a mushy liquid. Many digestive organs produce digestive juices that break down the chemicals in food into simpler substances. This work is actually carried out by enzymes, which turn large food molecules into smaller food molecules.

Experiments involving digestive enzymes are usually easy to carry out and the reagents can be obtained fairly cheaply. However, it is important for students to realize that the use of enzymes in the body is not just restricted to digestive processes. In fact, enzymes catalyse a wide variety of biochemical reactions. It has been estimated that in the human body there are over 7,000 different enzymes catalysing a whole range of biological changes.

Lesson suggestions

1. The digestive system

Refer to page 3 of the Students' Book

Starter suggestions

Ask the students to work in groups and write down the names of as many parts of the digestive system as they can think of.

Ask a volunteer to lie on a large sheet of paper. Draw around him or her to produce an outline of the human body. Ask the students to name the parts of the digestive system, write each of them on a small piece of paper and stick these on the appropriate place on the body outline.

Pose the questions: Why does the body need food? Where is it needed? How does it get there?

If the necessary skills and facilities are available, show the class the digestive system of a large earthworm. Stress to the students that even such a simple animal needs to grind up and digest its food.

Main lesson

Use a model of the human torso, PowerPoint diagrams, or a large poster, and point out to the students the main parts of the digestive system. You could, if you wish, give them all a copy of Worksheet 1 to label as the parts are pointed out and named.

Describe the role of the teeth in breaking down the food so that a larger surface area is exposed to the saliva. If a packet of dry bread or sugarless cream cracker biscuits are available, carry out the simple activity, described on page 4 on saliva and chewing.

Use a ping-pong ball or golf ball and a sock or the leg of a pair of tights to show how peristalsis occurs in the gullet or oesophagus. A volunteer student may be able to demonstrate that you can still swallow food even while standing on your head! The fact that vomiting is peristalsis working in reverse may be of interest.

Mention could be made of the presence of hydrochloric acid in the stomach and what we need to do when we produce too much of it. A model of one of the villi in the small intestine can be made from the finger of a rubber glove and some felt-tipped pens, while a cylinder of rolled up carpet will show how countless thousands of villi can increase the surface area of the small intestine so that absorption of dissolved food can occur.

The role of the large intestine in the absorption of water can be explained. The students could be asked what would happen if water was not absorbed, and also what would happen if too much water was absorbed.

This would also be a good place to stress that defecation or egestion is not an example of excretion. It is simply the removal of food that cannot be digested, whereas excretion is the removal of waste products formed as a result of biochemical reactions inside the body.

2. Digestion

Refer to page 4 of the Students' Book

Starter suggestions

Demonstrate the working model of the small intestine described on page 4 to illustrate how large molecules, in this case of starch, cannot pass through the walls of the intestine, whereas small molecules of glucose can.

Ask for two volunteer students. Give each a fork, to represent the teeth, and a large beaker of water. Ask one to mash up a piece of banana, the other a sugar cube, and then to put them into the water and stir them. Ask them to stop when the sugar cube has dissolved. Point out that the piece of banana has not dissolved, and ask how it can act as a food if it does not dissolve.

If you have access to a blender or liquidizer, place a small quantity of food in it and liquidize it. Pour the liquidized food into the leg of an old pair of tights and squeeze it. The liquid part will come through the tiny holes in the tights, while the solid parts are retained. Explain that this is a model of the way in which food is digested and absorbed. The digestive enzymes make the food particles small enough to go through the minute gaps into the small intestine.

Main lesson

Demonstrate the action of one of the digestive enzymes as described on page 4 of this book. If you have the materials and equipment, and are confident of the students' abilities to carry out the work safely, let them carry out one of these experiments working in small groups.

Conclude the lesson by explaining the role of each part of the digestive system in digesting food. At this stage, restrict yourself to calling the enzymes protease, lipase and amylase. On their labelled copies of Worksheet 1, or on new copies, ask the students to summarize the role of each organ in the digestive process. Alternatively you could assess their knowledge and understanding by asking them to complete Worksheet 2.

Ideas for investigation and extension work

Swallowing

Put some ice-cubes in a glass of cold water. Close your eyes as you drink the water. As you swallow, you should feel the coldness travel down your oesophagus or gullet, the tube leading to your stomach.

Saliva and chewing

Chew on a piece of dry bread or a sugarless cream cracker biscuit. Do not swallow but keep on chewing. How does the taste change as you chew? Bread or a cream cracker is made up mostly of starch. An enzyme in your saliva starts changing the starch into sugar. (The rest of it is changed in your small intestine.) Changing starch into sugar is one of the stages in digestion.

The action of saliva on starch

There are obvious health risks involved in using saliva in class experiments. You could, however, with suitable safety precautions, demonstrate the action of saliva on starch. Alternatively, the enzyme diastase can be used instead of saliva, and this does not involve any health risks.

If you decide to use saliva, then ask a volunteer to rinse his or her mouth out with water to remove all traces of food. Then collect his/her saliva in two clean test-tubes, labelled A and B, to a depth of about 15 mm. Heat the saliva in tube B over a small Bunsen flame until it boils for about 30 seconds. Then cool the tube under the tap. Add about 2cm^3 of a 2 per cent starch solution to each tube. Shake both tubes and leave them for at least five minutes.

Divide the contents of tube A between two clean test-tubes. To one add some iodine solution. To the other add some Benedict's solution and carefully bring it to the boil. Now test the contents of tube B in exactly the same way.

The contents of tube A will fail to give the blue-black colour with iodine, showing that the starch has gone. The other half of the contents will, however, produce a reddish precipitate with Benedict's solution, showing that glucose is present.

The contents of tube B, the control part of the experiment, will produce a blue-black colour with iodine, showing that starch is present, but they will not form a reddish precipitate with Benedict's solution.

As we know, the enzyme in saliva has converted starch into glucose in tube A. But because enzymes are proteins, they are destroyed by boiling, and so the starch in tube B remains unchanged.

The action of pepsin on egg-white protein

The albumen, or white, of an egg is largely protein and this is a convenient substance to use to demonstrate the action of the protease enzyme pepsin, which is found in the stomach.

Make a cloudy suspension by stirring the white of one egg into 500 cm^3 of tap water. Gently heat it to boiling point, and then filter it through a funnel containing glass wool (Careful!) to remove the larger particles. You need to have at hand a 1 per cent solution of pepsin and a bottle of dilute hydrochloric acid.

Label four test-tubes A, B, C, and D. Place 2 cm^3 of egg-white suspension in each of them. Now make the following additions to the four tubes:

Tube A: add 1 cm^3 of pepsin solution.

Tube B: add 3 drops of dilute hydrochloric acid.

Tube C: add 1 cm^3 of pepsin solution and 3 drops of dilute hydrochloric acid.

Tube D: add 1 cm^3 of pepsin solution **which has been boiled**, plus 3 drops of dilute hydrochloric acid.

Now place all four tubes in a beaker or water bath of warm water at about 35°C for fifteen minutes.

The result of the experiment will be that the contents of tube C will go clear, showing that the solid particles of protein have been digested to produce a soluble product. The contents of the other three tubes stay cloudy, showing that:

a) pepsin will only work in an acid solution.

b) it is the pepsin and not the hydrochloric acid which carries out the digestion.

c) pepsin is an enzyme because its activity is destroyed by boiling.

Make a model of the small intestine

It is in the small intestine that absorption of digested food into the bloodstream takes place. Use cellulose tubing (also called Visking tubing) to demonstrate how absorption occurs. The measurements given here are for student use. If you are demonstrating the experiment, then larger multiples of the quantities can be used.

Soak a 10 cm length of cellulose tubing in water for one minute. Rub one end between your fingers to open it up. Blow down the tube to open it out completely, and then tie one end.

Put 5 cm^3 of starch solution and 5 cm^3 of glucose solution in this tubing 'bag' and tie the top tightly with thin string. Check for leaks and then wash the sealed tubing under running water to remove any starch or glucose from the outside. Stand the model intestine in a 100 cm^3 beaker and cover it with distilled water. Leave it to stand for 10 or 15 minutes.

Add iodine solution to a little of the starch solution you used to show that it produces the characteristic blue-black colour. Heat a little of the glucose solution you used with Benedict's solution and show that it produces the characteristic orange or reddish-brown colour.

Then take samples of the water from around the model intestine. Test one sample for starch and another for glucose. You will be able to show that the small molecules of glucose have passed out of the intestine into the surrounding water, whereas the large molecules of starch are retained inside the intestine.

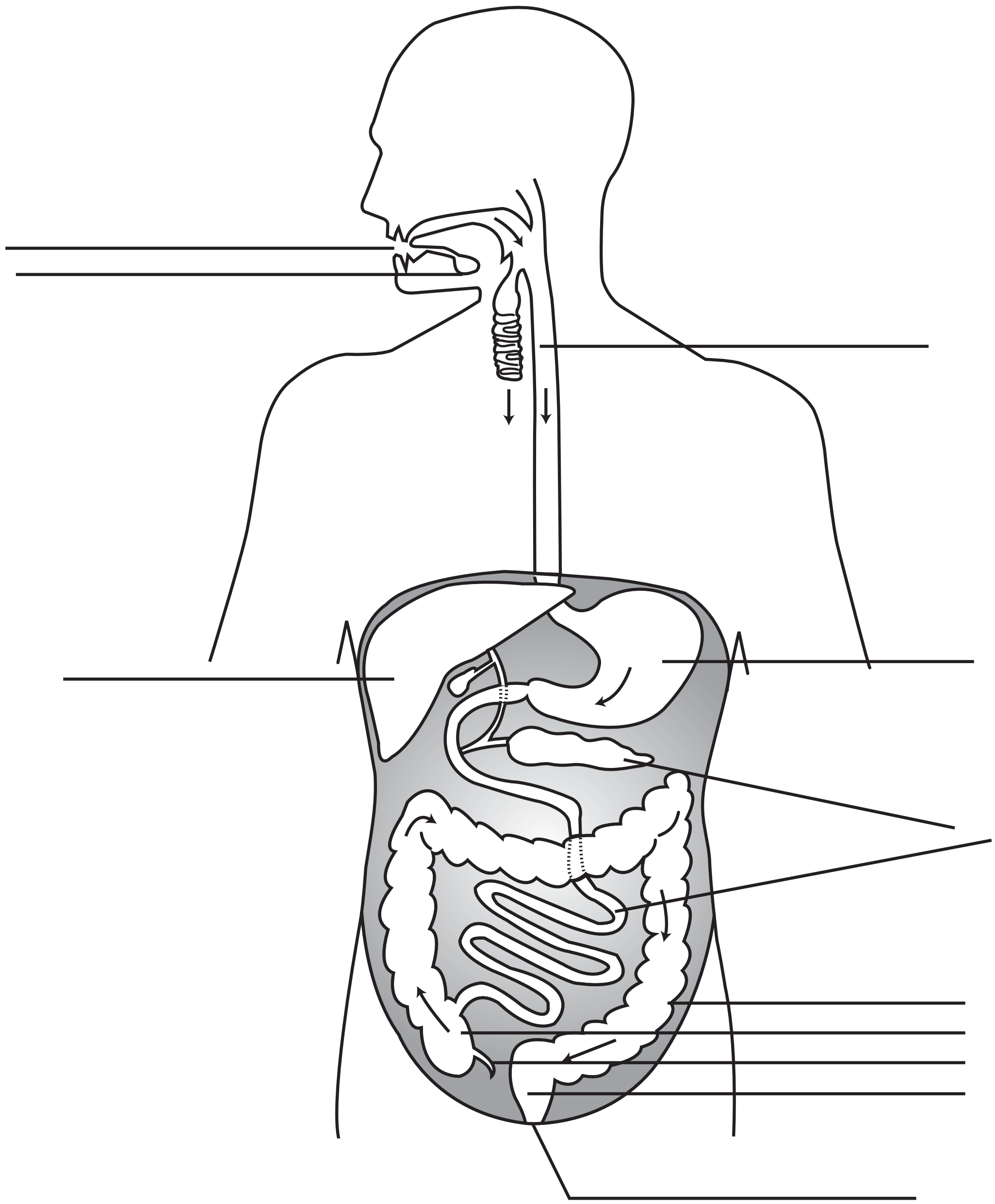
WORKSHEET 1

The human digestive system

Materials needed: pen or pencil

Label the diagram using the words from the box below.

small intestine	liver	gall bladder	stomach	salivary glands	pancreas
rectum	mouth	anus	oesophagus	intestine	



WORKSHEET 2

The functions of the parts of the digestive system

Materials needed: pen or pencil and ruler

Match the names of the parts of the digestive system to their functions.

1.	small intestine	where the faeces is stored
	appendix	produce saliva which contains an enzyme that begins the digestion of starch
	liver	food is chewed up by the teeth here and swallowed
2.	stomach	this is where bile is produced
	salivary glands	tube that connects the mouth to the stomach
	gall bladder	faeces leave the body here
3.	rectum	this organ produces enzymes that are released into the small intestine where they digest proteins, carbohydrates, and fats
	pancreas	this organ produces a protease enzyme and also hydrochloric acid to kill bacteria
4.	mouth	this is where the absorption of digested food into the bloodstream takes place
5.	oesophagus or gullet	this organ produces bile which is used to break down fats into small droplets
6.	anus	water from waste food is absorbed here
7.	large intestine	this part of the intestines has no use in humans and sometimes causes a lot of pain if it bursts

The parts that have numbers next to them are parts of the digestive system through which the food passes. Write the numbers in the correct places to show the journey the food takes:

Answers to questions in the Students' Book

1. The seven groups of food needed for a healthy and balanced diet are proteins carbohydrates, fats, mineral salts, vitamins, fibre (also called roughage), and water.
2. Digestion involves breaking down large food molecules into smaller food molecules that can be absorbed into the bloodstream. Digestion takes place in the digestive system, a coiled tube about 10 metres long. The breakdown of food involves acids and chemicals called enzymes.
3. The parts of the digestive system shown in the diagram are: a=gullet or oesophagus; b=stomach; c=liver; d=gall bladder; e=pancreas; f=small intestine; g=large intestine; h=rectum; i=anus.
4. We need to digest our food so that it can pass into the blood and be distributed to the muscles and other parts that require energy from the food. During digestion, food is broken down physically, e.g. by chewing it and the churning movements of the stomach and secondly, by the action of acids and enzymes.
5. The saliva moistens the food so that it is easy to swallow and an enzyme called amylase begins the work of breaking down starch into a simple sugar called maltose.
6. Glucose molecules do not have to be digested because they are small and soluble, and can pass through the wall of the small intestine into the blood. Starch molecules are large and insoluble and have to be broken down before they can be absorbed into the blood.
7. During digestion, starch is broken down into glucose and other simple sugars, proteins are broken down into amino acids, and fats are broken down into fatty acids and glycerol.
8. The villi in the small intestine are suited to the task of absorbing food because, a) they give the small intestine a large surface area where absorption can take place; b) they have a thin layer of cells on the outside; c) they are well supplied with blood capillaries. In addition, although most students will not know this, inside each villus is a dead-end tube containing lymph. Fatty acids and glycerol pass into the lymph and are carried round the body in lymph vessels.
9. The liver produces bile to break down fats.
10. The contraction of muscles in waves pushes food down the oesophagus or gullet in the process of swallowing. Similar contractions push the food along the intestines and eventually they push any undigested food from the anus. In the stomach, contraction of muscles in the stomach wall churn the food round and help to mix it with hydrochloric acid and enzymes. Rings of muscle, called sphincters, also relax to allow food into and out of the stomach and allow waste food to leave the body via the anus.
11. Although we cannot digest fibre, it is an important part of the diet because it contains cellulose from the cell walls of the fruit and vegetables we eat. This bulky material gives the muscles of the digestive system something to squeeze against, so preventing constipation and other diseases of the digestive system.
12. The starch in the cheese sandwich is broken down by the saliva in the mouth and then, later, by enzymes in the first part of the small intestine. It is digested into glucose and other simple sugars, such as maltose.

The fat in the butter is broken up into tiny droplets by the bile produced by the liver. The fat is then broken down into fatty acids and glycerol by enzymes produced in the first part of the small intestine. The digestion of the protein in the chicken meat begins in the stomach and is then completed by enzymes in the first part of the small intestine. Amino acids are the result of those chemical actions.

13. The most likely causes of constipation are not drinking enough water and other liquids, eating insufficient fibre, lack of exercise, and not going to the toilet at a time of the day when you have plenty of time.
14. The most likely causes of diarrhoea are eating infected food and poor hygiene when handling food. Both lead to germs which can irritate the gut. Diarrhoea, like vomiting, is the body's way of sweeping the germs out of the gut as quickly as possible.

Assessment

Question 1

Digestion is the breaking down of large food molecules into smaller ones. The main purpose of this is to:

(A) make the food soluble
(B) use up the digestive enzymes
(C) break down the fibres
(D) make the food slide along the intestine

Question 2

Digestion begins in the:

(A) stomach (B) small intestine (C) mouth (D) large intestine

Question 3

Digestion is completed in the:

(A) large intestine (B) small intestine (C) stomach (D) liver

Question 4

During digestion, food becomes soluble and passes from the digestive system into the blood. This mainly takes place in the:

(A) mouth (B) small intestine (C) large intestine (D) rectum

Question 5

Which of the following plays no part in digestion in humans?

(A) salivary glands (B) pancreas (C) liver (D) appendix

Question 6

Which one of the following is digested in the stomach?

(A) sugars (B) proteins (C) starches (D) fats

Question 7

The conditions in the stomach are:

(A) alkaline (B) acidic (C) basic (D) neutral

Question 8

Which of the following is the correct order of parts in the digestive system, starting with the mouth?

(A) gullet, small intestine, stomach, large intestine (B) gullet, stomach, small intestine, large intestine

(C) stomach, gullet, large intestine, small intestine (D) stomach, small intestine, large intestine, gullet

Question 9

While we eat, some digestive juice is passed into the mouth from the:

(A) gall bladder (B) small intestine (C) salivary glands (D) pancreas

Question 10

What are proteins broken down into during digestion?

(A) amino acids (B) starch (C) glucose (D) fatty acids

Question 11

What is starch broken down into during digestion?

(A) amino acids (B) fatty acids (C) glycerol (D) glucose

Question 12

What are fats broken down into during digestion?

(A) proteins and amino acids (B) starch and glucose

(C) fatty acids and glycerol (D) fatty acids and glucose

Question 13

The lining of the small intestine is covered in thousands of tiny finger-like villi. What job do the villi do?

(A) push food along (B) slow food down

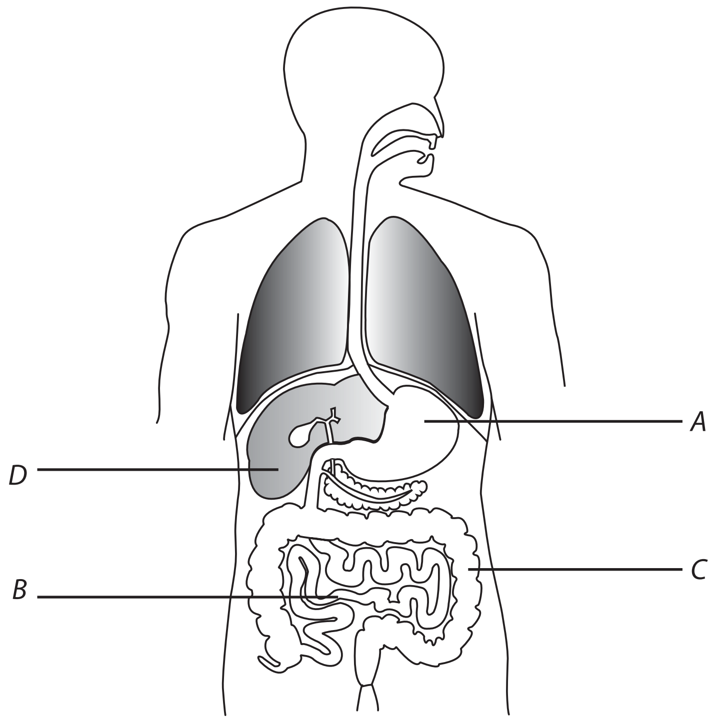
(C) increase the surface area (D) produce enzymes

Question 14

Faeces is stored temporarily in the:

(A) anus (B) large intestine (C) small intestine (D) rectum

Question 15



a) The picture above shows a diagram of the human digestive system.

What are the names of the organs A, B, C, and D?

____

____

____

____

b) Put the correct letter next to the job or function of each organ.

i) This organ has muscular walls to churn up the food. ______________

ii) This organ is where the last stage of digestion occurs and water is absorbed back into the body.

____

iii) This large organ produces bile which is stored in the gall bladder. ______________

iv) The digested food here is in the form of small molecules than can pass through the wall of this organ into the bloodstream. ______________

c) i) The body produces special chemicals to help digest the food. What are they called? ______________

____

ii) One of these chemicals is produced by glands in the mouth. What is the name of the liquid that contains this chemical? ______________________

iii) What does the chemical in this liquid do? ______________

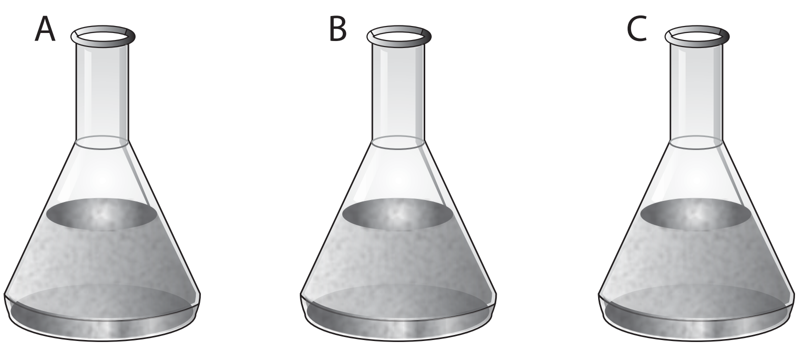
Question 16

How well do you know the parts of the digestive system and what they do? Match the names in column A with the correct functions in column B.

A	Part of digestive system	B	Function
a)	gullet or oesophagus	1)	mixes food with saliva
b)	tongue	2)	absorbs water
c)	stomach	3)	stores bile
d)	large intestine	4)	pushes food into the stomach
e)	liver	5)	produces insulin and enzymes
f)	pancreas	6)	produces hydrochloric acid
g)	salivary glands	7)	store faeces
h)	small intestine	8)	produces salivary amylase
i)	gall bladder	9)	absorbs digested food
j)	rectum	10)	produces bile

Question 17

A scientist wanted to know what are the best conditions for the digestion of proteins. He used three glass flasks, each containing some egg white to provide the protein. The egg white made the liquid in the flasks go cloudy. To each flask he added a chemical, called protease, obtained from the human stomach. The diagrams below show what was in each flask.



egg white and protease | *egg white, protease, and hydrochloric acid* | *egg white, boiled protease, and hydrochloric acid*

a) i) After six hours, the liquid in flask B was clear and not cloudy. What do you think had happened?

ii) What type of substance is protease?

iii) What effect does boiling have on the activity of the protease?

iv) All the flasks were kept at 37°C. Why was this?

v) What does this experiment tell you about the conditions needed to digest protein?

b) i) Where in the body would you find conditions like those in flask B?

ii) During digestion what are proteins broken down into?

Question 18

In an experiment to find out how the digestive system works, a student filled a cellulose or Visking tubing 'bag' with a mixture of glucose solution and starch solution. The bag was then sealed.

The outside of the bag was then washed under the tap and placed in a boiling tube containing distilled water. It was allowed to stand for an hour. At the end of this time, a sample was taken from the water in the boiling tube and tested for both glucose and starch solutions.

a) What would the student use to test for starch and what would happen if starch was present?

b) What would the student use to test for glucose and what would happen if glucose was present?

c) What do you think the student found in the boiling tube after one hour?

d) Explain the answer you have given in c) above.

e) Starch is changed to glucose in the human digestive system. What is the name of the substance which brings about this change?

Question 19

On the diagram below, write the names of the three different types of enzyme the body uses to help it to break down the large molecules of carbohydrates, proteins, and fats into smaller molecules like this:

starch ————————————→ glucose and other simple sugars

protein ————————————→ amino acids

fats ————————————→ fatty acids and glycerol

Answers to assessment questions

Question 1 (A)	**Question 2** (C)	**Question 3** (B)	**Question 4** (B)	**Question 5** (D)
Question 6 (B)	**Question 7** (B)	**Question 8** (B)	**Question 9** (C)	**Question 10** (A)
Question 11 (D)	**Question 12** (C)	**Question 13** (C)	**Question 14** (D)	

Question 15

1. a) The stomach is labelled A, the small intestine B, the large intestine C, and the liver D.
   b) i) stomach A ii) large intestine C iii) liver D iv) small intestine B
   c) i) enzymes ii) saliva (or spit) iii) The enzyme begins the digestion of starch into sugar.

Question 16

A	**Part of digestive system**	B	**Function**
a)	gullet or oesophagus	4)	pushes food into the stomach
b)	tongue	1)	mixes food with saliva
c)	stomach	6)	produces hydrochloric acid
d)	large intestine	2)	absorbs water
e)	liver	10)	produces bile
f)	pancreas	5)	produces insulin and enzymes
g)	salivary glands	8)	produces salivary amylase
h)	small intestine	9)	absorbs digested food
i)	gall bladder	3)	stores bile
j)	rectum	7)	stores faeces

Question 17

a. i) The liquid in flask B was clear and not cloudy because the protein/egg white had been broken down/digested.

ii) Protease is an enzyme.

iii) Boiling stops the protease from working/destroys or denatures the enzyme.

iv) All the flasks were kept at 37°C because this is the temperature of the human body.

v) The digestion of protein needs an enzyme, the correct temperature and acid/acidic conditions.

b. i) The stomach conditions in the stomach are like those in flask B.

ii) During digestion proteins are broken down into amino acids.

Question 18

a) The student would use iodine solution to test for starch. If starch was present a blue-black colour would be produced.

b) The student would test for glucose with Benedict's solution. A green, red, or brown colour would be there if glucose was present.

c) After one hour, glucose solution would be present in the boiling tube, but not starch solution.

d) Glucose particles are small enough to get through the Visking tubing, but starch particles are not.

e) The substance which changes starch to glucose in the human digestive system is the enzyme amylase (or carbohydrase).

Question 19

starch $\xrightarrow{\text{carbohydrase enzymes (or amylase)}}$ glucose and other simple sugars

protein $\xrightarrow{\text{protease enzymes}}$ amino acids

fats $\xrightarrow{\text{lipase enzymes}}$ fatty acids and glycerol

Respiration and energy from food

CHAPTER 2

Teaching Objectives

- To extend earlier learning on plant respiration to the mechanism of respiration in humans
- To examine and explain the differences between breathing and burning
- To examine the causes and prevention of common diseases of the respiratory system

Learning Outcomes

After studying this chapter students should be able to:

- describe the mechanism of respiration in humans
- differentiate between breathing and the burning processes
- identify some common diseases of the respiratory system and discuss their causes and preventive measures

Introduction

In order to perform their vital activities, the cells of the body require energy. One of the objectives of this unit is that the students should acquire knowledge of the fact that foods provide the energy necessary for life. At this stage we need to get across the point that in living organisms chemical energy (in food) is converted into kinetic energy and heat. The main energy-producing constituent of food is carbohydrates, and in this chapter we examine the processes of energy conversion during respiration in humans and its importance not only to the individual, but to humanity as a whole.

Students should already have some knowledge about the production of energy, especially heat and light, when fuels are burned in oxygen. Coal, oil and natural gas provide heat for our homes and factories; they are used to produce electricity in power stations. It therefore seems sensible to link these established concepts with the oxidation of glucose as an energy source in the cells of living organisms, including humans.

Lesson suggestions

1. Breathing

Refer to page 9 of the Students' Book

Starter suggestions

To recall earlier learning, ask the students why living things need energy.

Working in pairs of the same gender, ask the students to observe each other from the side as they breathe in and out. Notice in particular the movements made by the chest. Using a tape measure, or ruler and length of string, measure the change in the circumference of the chest when breathing normally and when breathing deeply. Ask the students why we breathe, and why we breathe harder and faster after exercise.

Observe a pet animal breathing, or fish in an aquarium breathing, and again ask why the animal needs to breathe and why it breathes harder and faster after exercise or when it is frightened or upset.

Main lesson

With the aid of a model of the human torso, PowerPoint diagrams, or a large poster, or the diagram in the Students' Book, explain the structure and function of the parts of the respiratory system.

Move on to demonstrate the classic bell jar and balloons model of the chest and lungs (page 16). Alternatively, let the students carry out the activity described on Worksheet 1. It is important to stress the similarities and differences between the working model and the real human body. In the human body, the volume of the chest cavity changes, thanks to the combined actions of the intercostal muscles and ribs, and the diaphragm. In the model, only the 'diaphragm' moves.

If there is time, carry out the activity of measuring 'lung capacity' described on Worksheet 4.

It is important to emphasize that is not really a measure of the volume of the lungs as some 'residual' air is always left in the lungs. To measure the volume of the bottle (and hence the volume of air breathed out), fill it from a measuring jug and mark the volume on the side of the bottle. If it is not possible to estimate lung capacity using this apparatus, you may be able to use a peak flow meter (often obtainable for low cost from a pharmacy or local doctor). As with the apparatus described on Worksheet 4, it is important to disinfect the mouthpiece between users.

2. Breathing and respiration

Refer to page 10 of the Students' Book

Starter suggestions

Ask the students to list in the correct order those parts of the breathing or respiratory system through which air passes.

Ask volunteers to demonstrate the activity of pouring a plastic bag of exhaled air over a lighted candle, as described on page 19.

Main lesson

Demonstrate, or allow the class to carry out, the other activities that show the differences between inhaled and exhaled air and the effect of exercise on the rate of breathing. Worksheet 2 requires minimal equipment. For Worksheet 3 you will need to have the apparatus prepared ready for the students and again, it is important that the mouthpiece of the apparatus is disinfected between users.

Discuss the structure of the lungs and thorax and how these relate to their function, in particular the lung's adaptations for gas exchange—thin walls so that gases can diffuse through quickly, a moist lining so that gases dissolve, a large surface area so that the gases can pass through easily, a rich blood supply to transport the gases.

Burn a small quantity of custard powder, which is rich in carbohydrates, in a deflagrating spoon to show the rapid release of energy. Alternatively plunge a deflagrating spoon of burning glucose into a jar of oxygen to show the rapid energy release. Explain that in the cells of the body glucose and other foods are oxidized in a slow and carefully controlled way.

Complete the lesson with an explanation of the word equation for respiration:

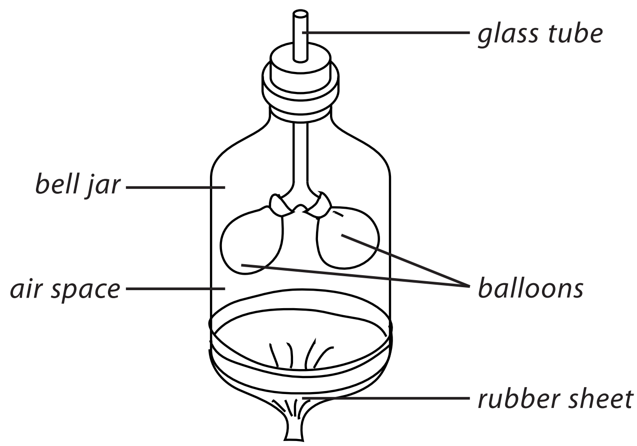
$$\text{glucose + oxygen} \longrightarrow \text{carbon dioxide + water} \longrightarrow \text{ENERGY}$$

Follow this with a discussion on the effects on the respiratory system of smoking tobacco. If possible, demonstrate the simple 'smoking machine' described on page 20.

Ideas for investigation and extension work

A model of the chest and lungs

If you have a bell jar, or a large transparent plastic bottle from which the base has been removed, make a model of the chest and lungs, as shown in the diagram.



Ask the students which parts of the human body the glass tube, bell jar, balloons, and rubber sheet represent. Ask them to describe what happens to the balloons when the rubber sheet is pulled down, and when it is pushed up. How is the model similar to, and different from, the way the lungs are inflated and deflated? What method of lung inflation is not represented by this apparatus?

Exhaled air

Under adult supervision, suggest the students breathe into a plastic bag before quickly sealing it. Look at the water vapour exhaled, then pour the air in the bag over a lighted candle to see the effects of the exhaled carbon dioxide on the flame.

Water vapour in inhaled and exhaled air

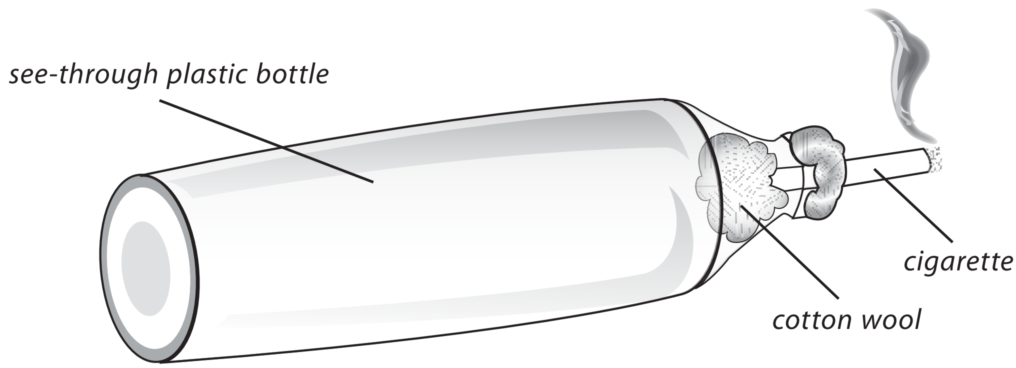
Compare the amounts of water vapour in inhaled and exhaled air. Using tweezers or forceps, take two pieces of dry cobalt chloride paper. They should be blue if they have not been exposed to water or water vapour. Place one piece of the paper on a dry spot on the bench. A volunteer student holds the other piece of dry cobalt chloride paper close to his or her mouth (again using tweezers of forceps) and breathes out onto it. Notice the change in colour of the paper from blue to pink as the student breathes out onto it. What do the class observe about the cobalt chloride paper that is left on the bench?

The temperatures of inhaled and exhaled air

Ask the students to devise an experiment to compare the temperatures of inhaled and exhaled air. Ask them to list the apparatus they will need and how they will measure the temperature of the inhaled and exhaled air. Try out the best of the suggestions.

Smoking

Use a transparent plastic bottle to demonstrate what happens to the lungs of someone who smokes. Set up the apparatus as shown in the diagram below and then light the cigarette. Keep squeezing the bottle gently so that air is sucked into the bottle. Ask the students to watch carefully to see what happens to the inside of the bottle.



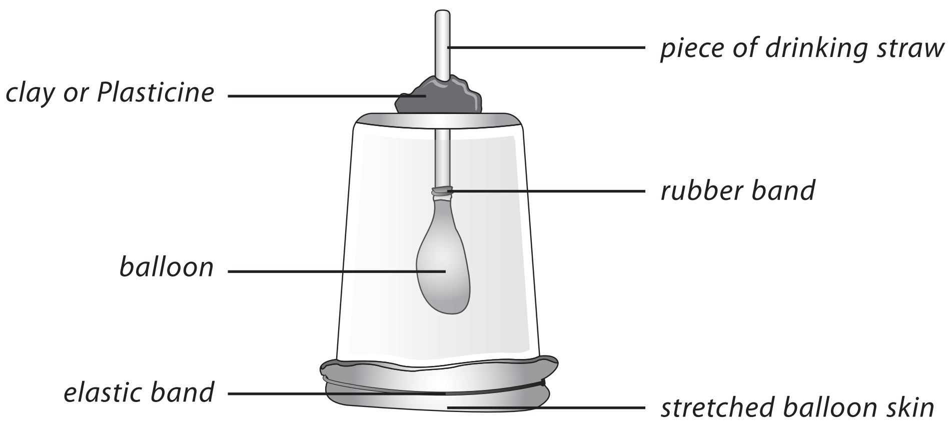
When the cigarette has burned down a little way, remove it and extinguish it. Examine the cotton wool and the inside of the bottle for signs of tar. Explain that more than 300 different chemicals have been found in cigarette smoke, including the drug called nicotine, which is addictive. At the end of the experiment, screw the top on the bottle and dispose of it safely.

WORKSHEET 1

Make a working model lung

Materials needed: clear plastic cup or beaker; piece of drinking straw approximately 5 cm long; 2 balloons; elastic band; sticky tape; clay or Plasticine

1. Make a hole in the middle of the bottom of the cup or beaker large enough for the drinking straw to pass through.
2. Fix one of the balloons to the end of the drinking straw and secure it with sticky tape. Make sure that the seal is airtight.
3. Pass the other end of the straw through the hole in the plastic cup or beaker, so that about half of the straw is inside the cup or beaker.
4. Fasten the straw into position using the clay or Plasticine, making sure that the opening is sealed but the straw is not pinched closed.
5. Cut a second balloon at the neck. Throw away the neck part and carefully stretch the rest of the balloon over the mouth of the cup to form a seal. Secure the balloon seal with sticky tape.



6. Push up on the piece of balloon. Now pull it down. How do these actions affect the appearance of the balloon inside the cup or beaker?

   How is this model like the human chest and lungs? ____________________

   ____

   How is it different? ____________________

   ____

WORKSHEET 2

Exercise and the rate of breathing

Materials needed: stopwatch, stopclock, or a watch with a second hand. Work with a friend.

Safety: If you suffer from asthma, bronchitis or any other breathing disorder, DO NOT over-exert yourself during this activity.

1. Sit quietly on a chair for a few minutes. Then ask your friend to count how many times you breathe in one minute. One breath means once in and out.
2. Do this three or four times and find the average.
3. Run around the playground or school hall until you are out of breath.
4. Sit down and ask your friend to count how many times you breathe in and out in a minute. Again find the average of three or four counts.
5. Now count your friend's rate of breathing before and after exercise.
6. Record your results in this table:

Name	Before exercise	After exercise

a) Whose rate of breathing is fastest a) when at rest ______________ ; b) after exercise? ______________

b) What happens to our rate of breathing when we have been exercising? ______________________

____

c) How long does it take for your rate of breathing to return to normal after you have been running?

____

Repeat this activity, but this time measure your rate of breathing every 30 seconds after exercise. Plot your results on a graph. How long does it take for your breathing to return to a normal 'resting' rate? How do you know? ____

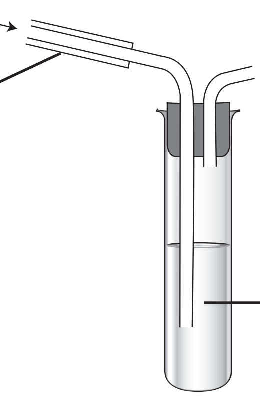
WORKSHEET 3

Exercise and carbon dioxide production

Materials needed: 2 large test-tubes; glass or plastic delivery tubes; rubber bungs each with two holes; lime water or universal indicator; clock or watch with a second hand; short lengths of rubber tubing; antiseptic solution

Safety: Ideally the apparatus should be set up ready for the students. They should NOT be allowed to push glass or plastic tubing through the rubber bungs themselves.

1. Prepare two sets of the apparatus shown below. The mouthpiece tubing must be dipped into antiseptic solution before and after use.



2. Sit quietly for a few minutes.
3. Note the time ____________ Then breathe out slowly through one set of apparatus until either the lime water turns milky or the universal indicator changes from red to yellow.
4. Note the time and record it. ____________
5. Begin some simple physical exercise, such as running on the spot or climbing on and off a stool until you begin to feel tired.
6. Note the time ____________ Then breathe out slowly through the other set of apparatus until the lime water or universal indicator changes its appearance.
7. Note the time and record it. ____________
   a) What does the change in the appearance of the lime water or universal indicator tell you?

   ____

   b) During which part of the experiment did the lime water or universal indicator change most quickly?

   ____

   c) What does this experiment tell you about exercise and carbon dioxide production?

   ____

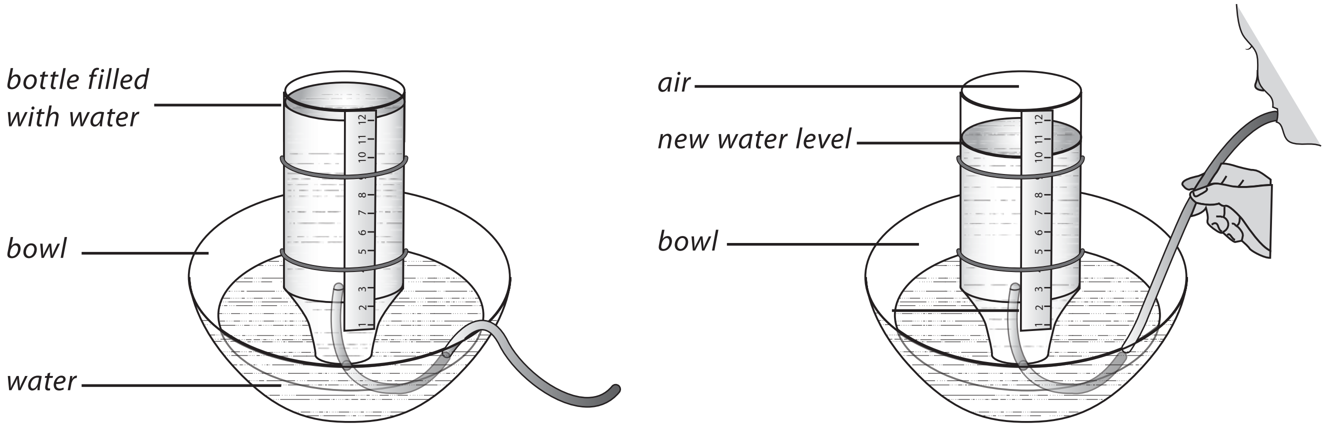
WORKSHEET 4

How much air do you breathe out?

Materials needed: large clear plastic bottle; bowl; rubber tubing; ruler, large elastic bands, beaker of weak antiseptic solution

Safety: If you suffer from asthma, bronchitis, or some other breathing disorder, DO NOT do this activity.

1. Half-fill the bowl with water.
2. Use elastic bands to fix a ruler to the side of the bottle. Make sure you can read it when the bottle is upside down!
3. Fill the bottle with water.
4. Put your hand over the top of the bottle and carefully turn it upside down. Put the top of the bottle under the water in the bowl.
5. Take your hand away and hold the bottle in an upright position.
6. Put one end of the tubing into the bottle. Rinse the other end of the tubing in the antiseptic solution.
7. Take a deep breath and blow down the tube into the bottle.



How much water did you blow out of the bottle? ____________________

Let your friends try. Who can breathe out the most air? ____________________

Try to find a way of measuring, in litres, how much air you breathed out. Describe what you did here.

____

____

Answers to questions in the Students' Book

1. Breathing is the movement of air into and out of the lungs in order to obtain oxygen and to remove the waste carbon dioxide and water vapour. Respiration is the process by which energy is released from food using the oxygen that has been breathed in.
2. Respiration takes places in the cells of living organisms.
3. Comparison of burning and respiration:

Burning	Respiration
▪ releases energy from a fuel	▪ releases energy from a fuel (food)
▪ uses oxygen and releases carbon dioxide	▪ uses oxygen and releases carbon dioxide
▪ releases energy rapidly and is difficult to control	▪ releases energy slowly and can be controlled
▪ involves heat and light (flames)	▪ heat produced, but not light

4. You breathe faster and your heart rate increases when you run because the body needs more energy for respiration. The faster rate of breathing gets oxygen into the lungs faster and releases carbon dioxide and water vapour to the air more quickly. The heart pumps faster to speed up the supply of oxygen and dissolved food to the muscle cells and to carry away the waste products of respiration.
5. The parts of the body the air flows through on its way to the lungs are: mouth/nose—nasal cavity—voice box or larynx— trachea or windpipe—bronchi-bronchioles—alveoli or air-sacs.
6. When we breathe, the chest changes shape. These changes are brought about by the ribs and diaphragm. Muscles work to move these. The intercostal muscles raise the rib cage, while muscles pull the diaphragm down. When breathing in, the diaphragm is pulled down and the intercostal muscles contract pulling the rib cage upwards. The space inside the chest gets bigger, and air rushes into the lungs to fill up the extra space. Breathing out occurs when the muscles relax. The diaphragm moves upwards and the rib cage is lowered. The space in the chest gets smaller and air is forced out of the lungs.
7. It is better to breathe in through the nose than the mouth, because hairs and mucus in the nose and nasal cavity filter dust and germs from the air while the numerous blood capillaries warm the air.
8. The parts of the chest and lungs are: a=larynx or voice box; b=trachea or windpipe; c=rib; d=left lung; e=right bronchus; f=bronchioles; g=diaphragm.
9. Model of the chest and lungs:
   i) The bell jar represents the chest and ribs, the Y-shaped tube is the trachea or windpipe and the bronchi, while the balloons represent the lungs, and the rubber sheet is the diaphragm.
   ii) When the rubber sheet is pulled down, the balloons inflate with air slightly. When the rubber sheet is pushed up, the balloons empty of air.
   iii) When the rubber sheet is pulled down, the same amount of air is in a larger space, therefore the air pressure is lower. When the rubber sheet is pushed up, there is the same amount of air in a smaller space, and its pressure is increased.

iv) This model is similar to the way we breathe in and out in that the diaphragm is also raised and lowered to change the air pressure in the chest cavity. The main difference is that in the human body, the ribs are raised and lowered by the intercostal muscles to make even larger changes to air pressure inside the chest.

10. A cough is a sudden involuntary or reflex action which helps to clear the large breathing passages of mucus and other secretions, as well as foreign particles and germs. Frequent coughing is often a sign of the presence of a disease. Coughing can also spread germs.

    Colds are caused by viruses which invade the cells lining the nose and throat, causing them to break down. This gives you a sore throat and runny nose. As yet there is no cure for a cold, although some medicines can relieve some of the effects of the cold.

    Influenza, or 'flu', is also caused by a virus, although it is a different virus from the one that causes colds, even though some of the symptoms are similar. The 'flu' virus enters the body through the eyes, nose or mouth and travels down towards the lungs. Once the virus is in the windpipe, bronchi, and bronchioles, it multiplies and multiplies. The first symptoms are a runny nose, sore throat, and cough. As the body tries to overcome the virus, it releases substances to try to fight it. These cause problems elsewhere in the body, including aching muscles, headaches, fever, and weakness. As with colds, there are medicines to relieve the symptoms of influenza, but no real cure. There are vaccines that can be injected to try to protect people against influenza, but the problem is that the virus keeps changing and it is impossible to produce vaccines quickly enough to fight each new form of the virus.

11. The main drug in tobacco smoke is nicotine, which is addictive, making it harder for the smoker to give up the habit. Nicotine also enters the blood from the lungs, affecting the blood system. Smokers get out of breath easily because carbon monoxide in the smoke joins on to the haemoglobin in red blood cells. This stops them from carrying oxygen. The tar in tobacco smoke collects in the lungs and irritates and damages the breathing tubes and air sacs or alveoli. Heavy smokers may develop bronchitis and emphysema, lung cancer, cancer of the voice box or larynx, and diseases of the arteries which supply the heart.

Assessment

Question 1

What is respiration?

(A) breathing in (B) breathing out

(C) a chemical reaction that produces energy (D) a plant's way of making food

Question 2

Respiration occurs in the:

(A) nasal cavity (B) lungs (C) red blood cells (D) cells of the body

Question 3

Which of the following word equations best summarizes tissue respiration?

(A) glucose + energy $\longrightarrow$ carbon dioxide + water

(B) glucose + water + oxygen $\longrightarrow$ carbon dioxide + energy

(C) glucose + oxygen $\longrightarrow$ carbon dioxide + water + energy

(D) carbon dioxide + water + energy $\longrightarrow$ glucose + oxygen

Question 4
Roughly what percentage of the air we breathe out is carbon dioxide?

(A) 4 per cent (B) 17 per cent (C) 78 per cent (D) 100 per cent

Question 5
The gas which passes into and out of the lungs unchanged is:

(A) oxygen (B) nitrogen (C) carbon dioxide (D) water vapour

Question 6
When the muscles of the diaphragm relax:

(A) air rushes into the lungs (B) the volume of the thorax increases

(C) the pressure in the thorax increases (D) the diaphragm is lowered

Question 7
When you breathe in your ribs move:

(A) down and in (B) up and out (C) up and in (D) down and out

Question 8
The body needs to use anaerobic respiration during:

(A) exercise (B) illness (C) sleep (D) walking

Question 9
Which of the following diseases is likely to be increased by air pollution?

(A) arthritis (B) influenza (C) deafness (D) bronchitis

Question 10
In the body, which of these structures is immediately below the diaphragm?

(A) trachea (B) lungs (C) bladder (D) liver

Question 11
Decide whether each of the following statements is TRUE or FALSE:

a) Air passes into the body through the trachea of windpipe.

b) The trachea divides into three branches, called bronchi, with one bronchus for each lung.

c) At the end of each bronchiole is a tiny group of air-sacs called alveoli.

d) Alveoli mean that there is less surface area for gas exchange to take place.

e) When we breathe out air we are said to exhale.

f) When we breathe out, the diaphragm moves up and the air is squeezed from the lungs.

g) When we breathe out air we are said to inhale.

h) When we breathe in the diaphragm moves up and, because there is more room, air rushes into the lungs.

i) During respiration, oxygen and glucose react together to produce carbon dioxide, water, and energy.

Question 12

Write the numbers 1 to 5 next to these sentences to show the correct sequence of events when we BREATHE OUT.

The volume inside the chest decreases. ______________

Air is forced out of the lungs. ______________

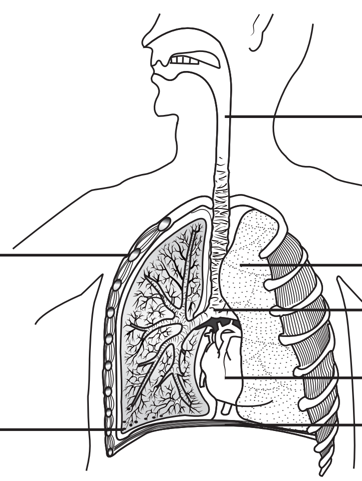
The intercostal muscles relax. ______________

The ribs move down and in. ______________

The diaphragm relaxes. ______________

Question 13

The diagram below shows the chest cavity. One of the lungs is cut away to show the air sacs or alveoli.



a) Which gas enters the blood from the alveoli or air sacs? ______________

b) Which gas leaves the blood and enters the air sacs or alveoli? ______________

c) Give two ways in which the lungs are adapted to absorb gases:

i) ______________

ii) ______________

d) Describe how the diaphragm moves when we breathe in and out.

____

e) State two ways in which the air we breathe out is different from the air we breathe in.

i) ______________________ ii) ______________________

f) The oxygen in the air we breathe in is used by the body's cells in a process which releases energy. What is this process called? ______________________

g) Write a word equation for the process you named in f) above.

____

Question 14

Doctors and scientists believe that smoking tobacco is bad for the health and damaging to the blood system and respiratory system. Three of the harmful substances present in cigarette smoke are:

nicotine	**carbon monoxide gas**	**tar**

In the table below, write the name of the substance next to its effects on the body.

Substance	Effect on the human body
	makes it very difficult for the red blood cells to carry oxygen around the body
	can cause cancer of the lungs and throat
	causes addiction to tobacco, speeds up the heart rate, narrows the arteries, and causes high blood pressure

Answers to assessment questions

Question 1 (C) **Question 2** (D) **Question 3** (C) **Question 4** (A) **Question 5** (B)

Question 6 (C) **Question 7** (B) **Question 8** (A) **Question 9** (D) **Question 10** (D)

Question 11

a) Air passes into the body through the trachea or windpipe. TRUE

b) The trachea divides into three branches, called bronchi, with one bronchus for each lung. FALSE

c) A the end of each bronchiole is a tiny group of air-sacs called alveoli. TRUE

d) Alveoli mean that there is less surface area for gas exchange to take place. FALSE

e) When we breathe out air we are said to exhale. TRUE

f) When we breathe out, the diaphragm moves up and the air is squeezed from the lungs. TRUE

g) When we breathe out air we are said to inhale. FALSE

h) When we breathe in, the diaphragm moves up and, because there is more room, air rushes into the lungs. FALSE

i) During respiration, oxygen and glucose react together to produce carbon dioxide, water, and energy. TRUE

Question 12

The correct sequence of events when we BREATHE OUT is:

- The volume inside the chest decreases. 4
- Air is forced out of the lungs. 5
- The intercostal muscles relax. 1
- The ribs move down and in. 2
- The diaphragm relaxes. 3

Note: the sequence 4, 5, 1, 3, and 2 is also acceptable.

Question 13

a) The gas which enters the blood from the alveoli or air sacs is oxygen.

b) The gas which leaves the blood and enters the air sacs or alveoli is carbon dioxide.

c) The ways in which the lungs are adapted to absorb gases are: i) large surface area ii) good blood supply iii) moist surfaces

d) The diaphragm moves down when we breathe in and up when we breathe out.

e) The air we breathe out is different from the air we breathe in because it is warmer, contains more water vapour/moisture, contains less oxygen, and more carbon dioxide.

f) The oxygen in the air we breathe in is used by the body's cells in the process of respiration.

g) A word equation for respiration is:

$$\text{glucose} + \text{oxygen} \longrightarrow \text{carbon dioxide} + \text{water} + \text{energy}$$

Question 14

Substance	**Effect on the human body**
carbon monoxide gas	makes it very difficult for the red blood cells to carry oxygen around the body
tar	can cause cancer of the lungs and throat
nicotine	causes addiction to tobacco, speeds up the heart rate, narrows the arteries, and causes high blood pressure

The human transport system

CHAPTER 3

Teaching Objectives

- To introduce the structure and function of the human blood system
- to examine the structure and functions of the heart and blood vessels
- to introduce simple ideas on the development of artificial tissues and replacement organs for dysfunctional body parts
- to explain the relationship between diet and some disorders of the blood system

Learning Outcomes

After studying this chapter students should be able to:

- explain the transport system in humans
- describe the structure and function of the heart and blood vessels
- explain the working of the circulatory system
- identify scientific developments that provide alternatives for dysfunctional body parts, such as artificial tissues and organs, and their transplantation.
- understand that some disorders of the human transport system can be affected by diet.

Introduction

A cell, whether in a one-celled organism or part of a large and complex organism such as the human body, requires food, water, and oxygen for its chemical activities. Waste products resulting from these activities must be removed.

In a unicellular organism, which has a large surface compared to its volume, these substances diffuse through the cell membrane. However, large multicellular organisms have a smaller surface area compared to their volume, and the diffusion of food and other substances into the body would be much too slow to maintain life. Certain regions of the body have become adapted for the absorption of one particular substance, for example, air is absorbed through the lungs and digested food is absorbed through the walls of the small intestine. The substances are then transported to all parts of the body, and this is the function of the heart and other parts of the blood system.

Blood travels around the body by means of a closed network of blood vessels that extends throughout the body. The blood delivers dissolved food and oxygen where needed, and carries away waste materials. The blood also helps to distribute heat, so that the body is kept at a uniform temperature, fights infections, heals wounds, and carries chemicals called hormones which affect growth and other important processes.

Blood leaves the heart through large arteries, then travels though smaller and smaller ones until it finally reaches networks of minute blood vessels, the capillaries, which have a diameter of only a fraction of a millimetre. Capillaries have extremely thin walls through which a two-way exchange takes place: food, oxygen and other chemical substances pass into the body cells, and waste products pass from them into the bloodstream.

On its return journey to the heart, the blood travels through veins, and as it has lost much of its oxygen, it appears bluish in colour. At different stages of its journey the blood collects necessary waste materials and unloads waste products. For instance, in the lungs carbon dioxide passes out of the blood and oxygen passes into it. In the small intestine glucose is picked up and carried to the liver, and waste proteins are transported by the blood from the liver to the kidneys.

The blood travels through the heart twice during one complete circulation: once on its way to the body and again on its way to the lungs. On average, a red cell would complete the circulation of the body in forty-five seconds.

Because of the risks of cross-infection, you may consider it undesirable for the students to make microscope slides of their own blood or the blood of an animal obtained from an abattoir. If this is the case, then the alternative would be to let the students examine prepared slides purchased from a scientific supplier.

Lesson suggestions

1. Blood

Refer to page 23 of the Students' Book

Starter suggestions

Ask the students to make a list of the jobs or functions of the blood, or alternatively, to write down five things they already know about blood.

Show the students a large clear-plastic or clear-glass bottle containing 5 litres of red liquid. Tell them: 'You have this amount of blood in your body. What does it do? How does it get around the body?'

Main lesson

Show the students a microscope slide or PowerPoint slide of the constituents of the blood. Remind them that blood is a tissue.

With the aid of the Students' Book, tell them about the relative numbers of red and white blood cells and the functions of the cells and other components of the blood:

Part of the blood	Function
red blood cells	carry oxygen
white blood cells	fight diseases/kill microbes or germs
platelets	clot the blood
plasma	carries dissolved nutrients, carbon dioxide, urea, antibodies, hormones

If you think it possible or desirable, obtain a supply of fresh blood from an abattoir. Put a little sodium citrate into the carrying flask to stop the blood from clotting. Using an oxygen cylinder or oxygen generator (adding hydrogen peroxide to manganese dioxide will work perfectly well), bubble some oxygen through the blood so that the students can see the difference in colour between oxygenated and deoxygenated blood.

An alternative is for the students to work in pairs (or to work on their own using a mirror) and examine inside each other's lower lip or under the tongue to see both oxygenated and deoxygenated blood within the arterioles and venules. Of course, it is essential that the students' hands are clean before they carry out this activity. You could also remind the students that when they cut a finger the blood is bright red, but when they have a sample of blood taken from a vein it is a purple or bluish colour.

If possible, show the class an animation of blood capillaries with red blood cells squeezing though them, or of white blood cells engulfing germs. It might also be useful for the students to make Plasticine models of red blood cells to demonstrate how their shape creates a large surface area over which oxygen can be absorbed.

If there is time you could also discuss the causes, symptoms and treatment of anaemia.

2. The heart and blood circulation

Refer to page 19 of the Students' Book

Starter suggestions

Show the students a blood pressure monitor. Ask them: 'What does the doctor use this for?'

Ask the students to research the work of the English physician William Harvey in the 1620s in discovering the circulation of the blood, or of the South African, Professor Christiaan Barnard, the first person to transplant a human heart.

Main lesson

Carry out the activity on exercise and rate of heartbeat, described on Worksheet 1, and also let the students measure their pulse rate.

Explain that, on average, the heart pumps 70 cm^3 of blood with each beat when they are at rest. Ask them to calculate how much blood the heart pumps in a minute, a) when they are at rest, and b) after exercise. Ask them to explain the figures they calculate because they only have about 5 litres of blood in their body. The explanation, of course, is that a drop of blood goes round the body more than once in a minute (on average in forty-five seconds).

Show the students either a model of the heart, or dissect an animal's heart from an abattoir in front of them. Point out the four main compartments, and the valves between the upper and lower chambers of the heart.

Ask them to notice the thick wall of the left ventricle of the heart. Show them that the heart receives blood from two places and pushes blood out to two different places.

Begin the explanation of the double circulation of the blood with a simple diagram, such as that on page 45 of the assessment section of this chapter, emphasising that this is a much simplified version of the real thing.

With the class, construct a chart which shows the main differences between arteries, veins and capillaries, and them go on to examine more detailed diagrams of the circulatory system. Listen to a heart with a real or model stethoscope (such as the one describe on Worksheet 5 on page 218).

Ask the students to label the blank diagram of the human heart shown on Worksheet 2 and to use coloured pencils or felt-tipped pens to colour the left side red and the right side purple. (Remind them that the diagram shows the heart viewed from the front of the body.)

A good final exercise would be to ask the students to imagine that they are red blood cells and ask them to describe how they are pumped around the body at speed, picking up oxygen and dissolved food and delivering it to the cells as they go.

Ideas for investigation and extension work

Model stethoscope

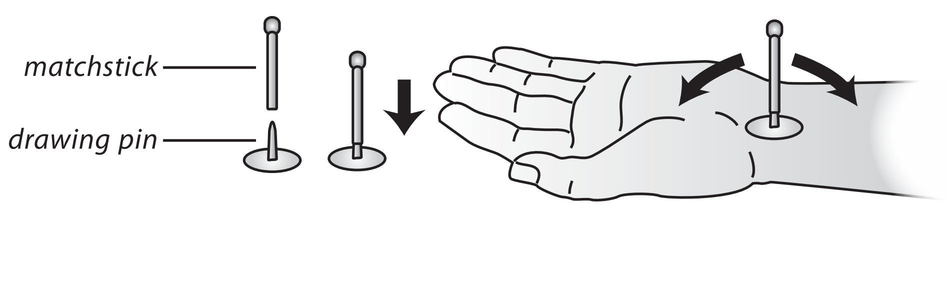
Make and use the model stethoscope described on Worksheet 6 on page 218 (Chapter 12). Listen to how the heart beat changes from the resting stage to when the body has been subjected to vigorous exercise.

Blood under the microscope

Let the students examine prepared microscope slides of blood smears and see for themselves the difference in size and number of red blood cells and white blood cells. These days it is not generally considered advisable to allow students to make their own blood smears because of the risk of cross-infection.

A pulse counter

It is often easier for students to count their own pulse if they make this simple counter. Carefully push a matchstick onto the point of a drawing pin. Rest the drawing pin on the left wrist behind the thumb. Watch the matchstick sway backwards and forwards each time there is a pulse beat. Look for pulse points elsewhere on the body.



William Harvey

William Harvey was the first scientist to explain how the blood is pumped around the body by the heart. Use the internet to research the life and work of William Harvey.

Blood pressure

Electronic blood pressure meters are now available quite cheaply. If one can be purchased or borrowed, demonstrate its use to the class.

Valves in the veins

If a *light* tourniquet is applied to the upper arm of a volunteer, the veins in the forearm can be made to stand out. The lower end of one of these can then be blocked off near the wrist by pressing it with one finger. The blood can be pushed out of that vein by running a finger with light pressure along the vein towards the elbow. When this has been done, the vein will remain collapsed up to a certain point. Above this point the vein will fill up with blood and swell once more. The boundary between the filled and collapsed region of the vein shows the position of one of the non-return valves.

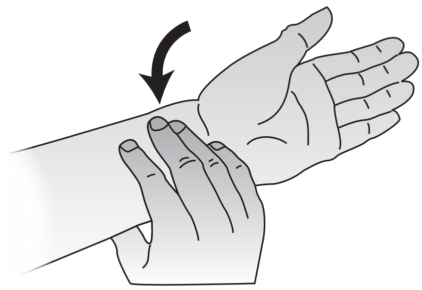
WORKSHEET 1

Exercise and the rate of heartbeat

Materials needed: stopwatch or watch with a second hand; chair or bench; use of the playground or school hall

Safety: If you have doubts about your physical fitness then do NOT carry out this activity.

1. Find the pulse in one of your wrists, as shown in the picture.



2. Count the number of beats in one minute.
3. Now stand still and swing both arms twenty times. Count your pulse as soon as you stop.
4. Ask a friend to hold a chair or bench steady while you step up and down from the seat forty times. Now count your pulse.
5. Finally run around the playground or school hall for two minutes. Count your pulse.
6. Ask two of your friends to do these tasks and to count their pulses.

Record your results in this table:

Name	Number of pulse beats per minute:			
	at rest	after 20 arm swings	after 40 step-ups	after running for 2 minutes

Compare your results with those of other groups in your class.

Why does your pulse rate change during and after exercise? ______________________________

____

How long does your pulse rate take to get back to the normal resting rate after your have been running for two minutes? Find out and plot a graph of your results.

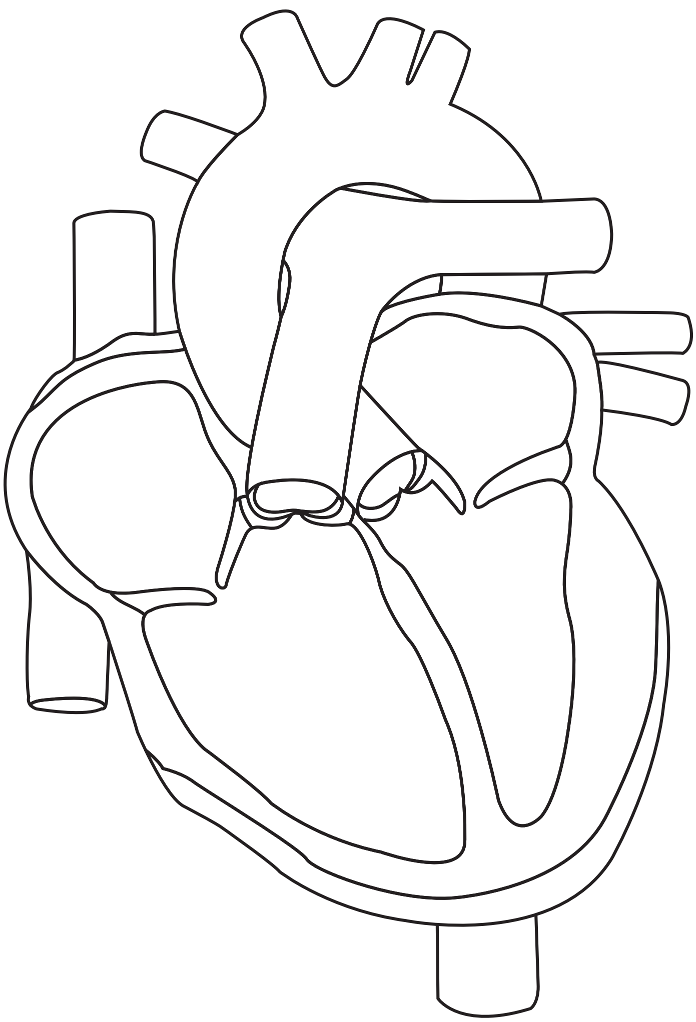
WORKSHEET 2

Inside the human heart

Materials needed: pen; pencil; coloured pencils, crayons, paints, or felt-tipped pens

The diagram below shows the human heart with the front cut away to show the inside.

Colour the diagram and label the parts.



Answers to questions in the Students' Book

1. The main job of the circulatory system is to transport, or carry, substances around the body.
2. The materials carried by the blood include dissolved food, water, oxygen, carbon dioxide, urea, and hormones.
3. The average human being has about 5 litres of blood.
4. The four main parts of the blood are: red blood cells which carry oxygen; white blood cells which help to kill germs and produce substances called antibodies. These kill germs and change the poisons produced by germs into harmless substances. Plasma is the liquid part of the blood. The red and white cells float in it and it contains many dissolved food substances, such as glucose, amino acids, vitamins, and mineral salts. The plasma also carries carbon dioxide and another waste product, urea, as well as hormones. Plasma also contains some blood proteins, including one called fibrinogen, which helps the blood to clot. Finally, there are platelets in the blood. These small cell fragments help to seal wounds by clotting the blood.
5. Haemoglobin is a protein combined with iron which enables the red blood cells to carry oxygen.
6. If the diet lacks iron, the body may not be able to make enough haemoglobin and so the blood will not be able to carry sufficient oxygen and the person will lack energy.
7. A drop of oxygenated blood leaving the lungs passes to the left atrium of the heart. From there it is pumped to the left ventricle which pumps it into the main artery, the aorta. The drop of blood eventually reaches the blood capillaries which carry the blood into the tissues. As the blood leaves the tissues, the capillaries join up to form veins. Veins carry the blood back to the right atrium of the heart. An artery called the pulmonary artery then pumps the deoxygenated blood back to the lungs.
8. Blood flowing from a cut vein is under very low pressure and so it is much easier to stop the flow of blood than it is from an artery.
9. Blood spurts from a damaged artery because it is under high pressure, and the spurts are caused by each beat, or pumping action, of the heart.
10. All arteries carry oxygenated blood, except for the pulmonary artery which carries deoxygenated blood from the heart to the lungs. All veins carry deoxygenated blood, except for the pulmonary vein which carries oxygenated blood from the lungs to the heart.
11. a = pulmonary vein; b = left atrium; c = valve; d = left ventricle; e = right ventricle; f = right atrium; g = aorta or main artery; h = vena cava or main vein; i = pulmonary artery
12. The table below shows the differences in structure and function of veins, capillaries, and arteries:

Arteries	Capillaries	Veins
They carry blood from the heart.	They link arteries to veins.	They carry blood to the heart.
They have thick walls of muscle and elastic fibres.	The walls are one cell thick.	They have fairly thick walls which contain some elastic fibres.

Valves are present only where arteries leave the heart.	They have no valves.	Valves are found in the long veins of the arms and legs.
Blood flows in pulses.	Blood flows steadily.	Blood flows steadily.
Blood is under high pressure.	Blood pressure changes.	Blood is under low pressure.
Blood is bright red and contains oxygen (except in the pulmonary artery).	Blood is losing oxygen and gaining carbon dioxide.	Blood is dull red and contains very little oxygen (except in the pulmonary vein).

13. Varicose veins are veins that have swollen because the valves in the legs do not work properly. Blood collects in them instead of making its way back to the heart.
14. The people who are prone to developing blood-related diseases include people who are overweight, who eat a fatty diet, who do not exercise enough or who smoke heavily. Some people have an inherited tendency to blood-related diseases.
15. A pacemaker is a device which produces a small but regular pulse of electricity to the heart to keep it beating steadily. It is needed by a person whose natural pacemaker is faulty.
16. A valve in the heart or a vein stops the blood from flowing backwards. If the valves of the heart do not shut properly, the heart cannot work efficiently. Sometimes a faulty valve can be replaced with an artificial valve.
17. The level of glucose in the blood is controlled by a hormone called insulin. People who do not produce enough insulin have a disease called diabetes. The person with diabetes may feel weak and sleepy as the level of glucose in his or her blood changes, Because fats and muscle proteins have to be used to supply the body with energy, the person loses weight. Diabetes can be controlled by injections or tablets of insulin, or by careful control of the diet.
18. A heart transplant is a life-saver for someone with heart failure. However, it is very difficult to find a replacement heart, usually from someone who has died in an accident, which the patient's own body will not reject. A major operation is needed to transplant a heart and special drugs have to be taken for the rest of the patient's life to reduce the risk of the body rejecting the new heart. Heart transplants lengthen the life of someone who would otherwise die from a seriously faulty heart.

Assessment

Question 1

Which part of the blood is mainly water?

(A) red blood cells (B) white blood cells (C) platelets (D) plasma

Question 2

Which cells of the body do not have a nucleus?

(A) red blood cells (B) white blood cells (C) skin cells (D) epithelial cells

Question 3

What is the work of the red blood cells?

(A) to carry oxygen (B) to prevent disease

(C) to clot the blood (D) to carry dissolved food

Question 4

What is the work of the platelets?

(A) to protect against disease (B) to clot the blood

(C) to carry hormones (D) to carry oxygen

Question 5

What is the work of the white blood cells?

(A) to clot the blood (B) to carry oxygen

(C) to carry dissolved food (D) to protect against germs

Question 6

What substance do blood capillaries take to the cells of the body?

(A) oxygen (B) dissolved food

(C) oxygen and dissolved food (D) carbon dioxide

Question 7

The main function of haemoglobin in the red blood cells is to:

(A) help the blood to clot (B) distribute heat

(C) destroy bacteria (D) carry oxygen round the body

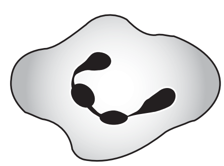
Question 8

The space inside a long bone contains:

(A) blood (B) marrow (C) nerves (D) nothing

Question 9

The diagram on the right shows:



(A) an antibody (B) a platelet

(C) a white blood cell (D) a red blood cell

Question 10

Why is the human blood circulation called a double circulation?

(A) The blood passes through the heart twice.

(B) The blood passes through each part of the body twice.

(C) The blood takes twice as long as in other circulations.

(D) The blood travels twice as fast as other circulations.

Question 11

How many blood vessels carry blood away from the heart?

(A) 1 (B) 2 (C) 3 (D) 4

Question 12

Which part of the heart has the thickest walls?

(A) left atrium (B) right atrium (C) left ventricle (D) right ventricle

Question 13

The pulse beat is measured in:

(A) a vein (B) an artery (C) a nerve (D) the heart

Question 14

To where does the aorta carry blood?

(A) the heart (B) the lungs (C) towards the body (D) the veins

Question 15

Which side of the heart carries oxygenated blood?

(A) the right (B) the left (C) neither side (D) both sides

Question 16

Blood passes from the heart to the lungs through the:

(A) pulmonary vein (B) pulmonary artery (C) aorta (D) renal artery

Question 17

Which two of these substances carried in the plasma are waste products produced by the body?

(A) carbon dioxide and urea (B) carbon dioxide and vitamins

(C) carbon dioxide and glucose (D) carbon dioxide and hormones

Question 18

The average pulse rate per minute for an adult at rest is:

(A) 98.4 (B) 37 (C) 58 (D) 70

Question 19

Fill in the gaps in the sentences below using the words in the box. You may need to use some words more than once.

plasma	carbon dioxide	red blood cells	white blood cells	tissue
haemoglobin	circulatory	platelets	heart	

Blood is a kind of ________________. It is made up of four main parts. They are the red blood cells, white blood cells, ________________, and plasma. The ________________ is a watery liquid that contains dissolved food, mineral salts, and ________________. The ________________ contain a pigment called ________________ which carries oxygen around the body. The ________________ fight infection and disease, while the ________________ clot the blood if you cut yourself. The ________________ pumps blood around the body and the whole system of blood vessels is called the blood system or ________________ system.

Question 20

Decide whether each of the following statements is TRUE or FALSE:

a) The right side of the heart receives oxygenated blood. ________________

b) The left side of the heart has thicker walls than the right. ________________

c) The valves in the heart prevent the blood from flowing backwards. ________________

d) The vena cava is the main artery of the body. ________________

e) The pulmonary vein collects oxygen from the lungs. ________________

f) The blood leaves the left side of the heart to go round the body. ________________

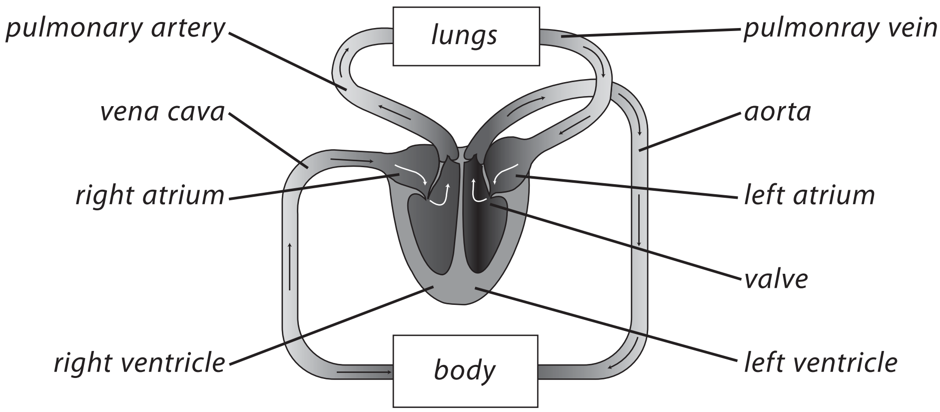
g) Varicose veins are caused when the valves in the veins do not work properly. ________________

h) Capillaries are the smallest blood vessels in the body. ________________

i) The disease called anaemia results from a lack of calcium in the diet. ________________

Question 21

The diagram below shows the heart and a much-simplified part of the blood system.



a) Describe the route taken by the blood from when it enters the heart in the vena cava (the main vein) to where it leaves through the aorta (main artery).

b) Which of the blood vessels shown contains most oxygen?

c) What is the job of the valves between the two atria and the two ventricles?

d) The heart receives its own blood supply through the coronary artery. Why is this blood supply important?

e) A major cause of death amongst adults is coronary heart disease. Give two causes of coronary heart disease and suggest how it might be avoided.

Answers to assessment questions

Question 1 (D) **Question 2** (A) **Question 3** (A) **Question 4** (B) **Question 5** (D)
Question 6 (C) **Question 7** (D) **Question 8** (B) **Question 9** (C) **Question 10** (A)
Question 11 (B) **Question 12** (C) **Question 13** (B) **Question 14** (C) **Question 15** (B)
Question 16 (B) **Question 17** (A) **Question 18** (D)

Question 19

Blood is a kind of **tissue**. It is made up of four main parts. They are the red blood cells, white blood cells, **platelets,** and plasma. The **plasma** is a watery liquid that contains dissolved food, mineral salts, and **carbon dioxide.** The **red blood cells** contain a pigment called **haemoglobin** which carries oxygen around the body. The **white blood cells** fight infection and disease, while the **platelets** clot the blood if you cut yourself. The **heart** pumps blood around the body and the whole system of blood vessels is called the blood system or **circulatory** system.

Question 20

a) The right side of the heart receives oxygenated blood. FALSE
b) The left side of the heart has thicker walls than the right. TRUE
c) The valves in the heart prevent the blood from flowing backwards. TRUE
d) The vena cava is the main artery of the body. FALSE
e) The pulmonary vein collects oxygen from the lungs. TRUE
f) The blood leaves the left side of the heart to go to the body. TRUE
g) Varicose veins are caused when the valves in the veins do not work properly. TRUE

h) Capillaries are the smallest blood vessels in the body. TRUE

i) The disease called anaemia results from a lack of calcium in the diet. FALSE

Question 21

a) The route taken by the blood from when it enters the heart in the vena cava (the main vein) to where it leaves through the aorta (main artery) is as follows: Blood flows into the right atrium, then into the right ventricle. From the right ventricle it flows to the lungs along the pulmonary artery and back to the heart along the pulmonary vein. Blood enters the left atrium, passes through the valve into the left ventricle and finally leaves the heart via the aorta.

b) The blood vessel which contains most oxygen is the pulmonary vein, which brings blood from the lungs to the heart.

c) The job of the valves between the two atria and the two ventricles is to stop the flow of blood backwards as the ventricles contract.

d) The coronary artery carries food and oxygen to the heart.

e) The causes of coronary heart disease include smoking, consuming alcohol, eating foods high in animal fat or cholesterol, and being grossly overweight. It might be avoided by avoiding any of the items mentioned previously, and also by exercising regularly and avoiding stress.

Transport in plants

CHAPTER 4

Teaching Objectives

- To explain the absorption of water by plant roots
- To illustrate how the roots, stems and leaves of plants are adapted to allow the movement of food, water and gases

Learning Outcomes

After studying this chapter students should be able to:

- describe the absorption of water by plants through the roots
- explain how the structure of the roots, stem and leaves of a plant permit the movement of food, water, and gases.

Introduction

As with multicellular animals, all but single-celled plants need a transport system to carry food, water and gases to the various cells and organs. However, because the movements made by plants are usually very slow, they have no need for a heart or similar pumping system. Instead of a continuous circulatory system, like that of the human body, plants have two sets of tubes, each consisting of elongated hollow cells; one set carries materials upwards and the other downwards. In almost all land plants the 'up' transport system consists of xylem vessels, which carry water from the soil, through the roots and up the stem The 'down' system is made of long thin-walled tubes called phloem cells. The phloem system transports food from the leaves where it is made to the parts of the plants where it is used or stored.

Water makes up over three-quarters of most living cells and is constantly used in cell processes. Small plants are kept upright by being distended with water, just as a car tyre is firm when filled with air. A tyre which is flat cannot support the car, and a plant short of water on a hot day wilts. Most of the water taken up by a plant is lost by evaporation from the leaves, a process called transpiration. A maize plant loses about two litres of water a day because, when the stomata are open to exchange gases during photosynthesis, water vapour is lost very rapidly. A large tree can lose 7 tonnes of water on a hot, sunny day. Transpiration actually helps to draw water up the plant in a way similar to sucking liquid up a straw.

Water and dissolved mineral salts are collected by thousands of minute hairs located just behind the growing tip of each root branch. It has been calculated that a rye plant one month old and 50 cm tall has 15,000,000,000 root hairs with a total length of 8000 km.

Roots are very strong and supple because the woody xylem vessels are concentrated at the centre. In young stems, however, xylem and phloem vessels are arranged in bundles, either in an outer ring or scattered throughout the stem, like reinforcing rods. This gives the stem strength to bear the weight of branches and to withstand the strain of the wind. The mass of any living tree is made up of dead xylem vessels (wood); new, living wood cells are produced each year. More and bigger xylem vessels are produced in spring, forming spring wood. Smaller xylem vessels are produced in summer. The difference between the light-coloured spring wood and the dark wood of the previous summer shows up as an 'annual ring', by which it is possible to tell the age of a tree.

Lesson suggestions

1. Osmosis and root hairs

Refer to page 33 of the Students' Book

Starter suggestions

Germinate some quick growing seeds, such as those of mustard, cress or mung beans. Examine the root hairs with a hand lens or magnifying glass. If a microscope is available, squash a root of one of the seedlings on a slide using the coverslip (wear gloves for this) and examine a root hair under the microscope.

Discuss why a plant needs a transport system. Ask the students why a plant does not have a heart and closed circulatory system like an animal.

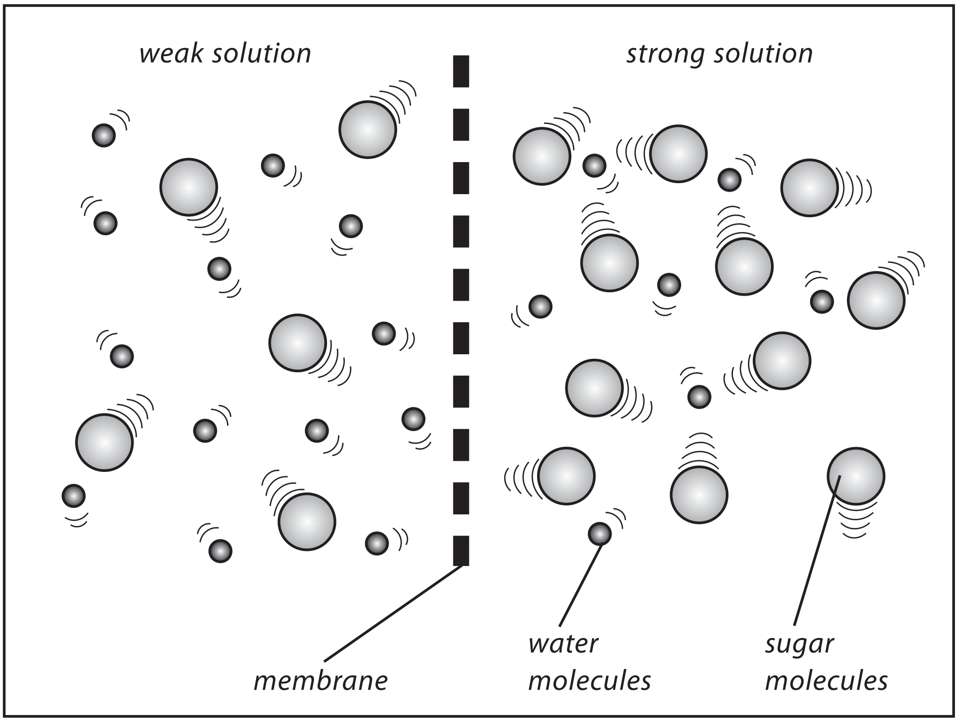
Main lesson

Revise the structure of a plant cell, mentioning in particular the cell membrane and the cell sap. Remind the students also that plant roots form a large network, underground in the case of a land plant, and that the tips of the many branches end in vast numbers of single-celled root hairs.

Without further explanation, either demonstrate the cellulose tubing experiment described on page 48 or let the students carry out the activity described on Worksheet 1. If time and materials are available, do both of these things. If carrots are not available for the activity on Worksheet 1, then potato tubers work just as well.

Explain that the cellulose tubing and the cell membranes are said to be semi-permeable or partially permeable. They act like a microscopic sieve, allowing tiny particles (molecules) through, but hold back larger particles (molecules). Osmosis is the special name used to describe the diffusion of water across a membrane from a weak solution to a stronger solution. Molecules of water will diffuse from a region where there are a lot of them to a region where they are fewer in number; that is, from a region of highly concentrated molecules to a region of lower concentration.

In the cellulose or Visking tubing experiment, sugar solution is separated from pure water by the thin membrane which acts as a microscopic sieve. The holes in it are big enough to allow tiny molecules of water through but not the larger molecules of sugar. Water molecules pass from the region where there are a lot of them, through the membrane to a region where there are fewer of them. The diagram below, which shows a dilute solution separated from a strong solution by a semi-permeable membrane, may help understanding. All the molecules are in constant motion and, since there are more of them, it is likely that some water molecules will diffuse through the membrane from the weak solution to the stronger one.



In a similar way, water passes from cell to cell of the carrot or potato to try to make the concentration of water inside the cavity equal to that outside the carrot or potato. The cell membrane of a root hair is also a semi-permeable or partially permeable membrane and water molecules pass through it to dilute the cell sap. The cell sap of the root hair then has a higher concentration of water molecules than the cell next to it, so water passes through to that cell, and so on right through to the xylem vessels in the middle of the root.

It is important to stress that if osmosis or diffusion were the only method by which a cell could take in substances, the cell would have no control over what went in or out. Any substance that was more concentrated outside a cell would diffuse into the cell whether it was harmful or not. Substances which the cell needed would diffuse out as soon as their concentration inside became higher than the concentration of that substance outside of the cell. In fact the cell membrane seems to control what substances enter and leave the cell. This explains why essential mineral salts can enter the root hair. The processes are not properly understood and may be different for different substances. They are all called active transport because, for active transport to occur, it is known that the cell needs to provide energy from respiration and, of course, enzymes.

2. Transpiration

Refer to page 35 of the Students' Book

Starter suggestions

Show the students a wilted house plant and a well-watered plant of the same species. Ask them if they can account for the differences they observe.

Ask the students why plants need water. Why is it important for plants to be watered regularly? The students should begin to realize that plants need water for the following reasons:

- to transport materials to all the cells in the plant
- to keep the cells rigid and the plant upright
- to provide aqueous conditions for cell reactions to take place
- to provide one of the raw materials necessary for photosynthesis

Main lesson

There are a number of simple experiments and activities that can be used to increase the students' knowledge and understanding of transpiration. They include the experiments described on Worksheets 2 and 3, and also the smaller ideas for investigation and extension work described below.

During the course of the lesson it will be necessary to remind the students about the microscopic structure of a plant leaf, perhaps with the aid of a PowerPoint slide, colour slide or prepared microscope slide. In particular, stress the importance of the stomata in controlling water loss from the leaf. The factors affecting water loss are:

- light intensity
- temperature
- humidity
- air movement

The last three of these factors are fairly obvious and are the same factors that affect the rate of drying of washing on a clothes line. The effect of light intensity is less obvious. What happens is this: at high light levels the rate of photosynthesis increases. This uses up the carbon dioxide in the air spaces within the leaves. The guard cells of the stomata open to allow in more carbon dioxide, and at the same time more water vapour diffuses out.

Ideas for investigation and extension work

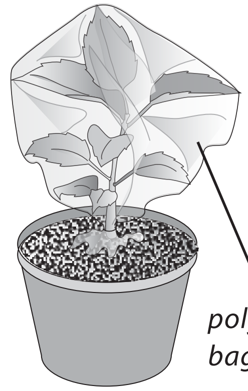
Osmosis

Demonstrate osmosis with cellulose tubing (also called Visking tubing). Cellulose or Visking tubing is selectively permeable. This means that, like a microscopic sieve, it lets some molecules through but not others. It lets small water molecules through but keeps larger sugar molecules out.

Cut a piece of Visking tubing about 15 cm long and securely knot one end. Wet the tubing and rub it between the thumb and forefinger to open it up. Fill the tubing with strong sugar solution or syrup, and securely knot the other end. It does not matter if a small amount of air remains in the tube.

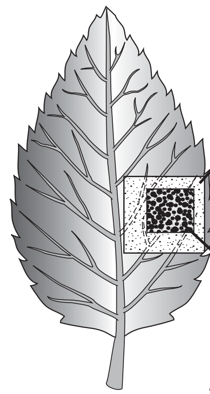
Explain that the Visking 'sausage' is a model cell and place it in a beaker of water. Leave it for about ten minutes. Remove the model cell and look at it closely. How has the model cell changed during this activity? Ask the students to explain how this change has occurred. In what way would a cell in this condition help a plant to support itself?

Demonstrate that water vapour is given off during transpiration



Completely enclose the shoot of a recently watered pot plant, or a garden plant in the garden, in a transparent, polythene bag which is tied round the base of the stem. Make sure that the polythene bag has no perforations. Leave the plant for an hour or two in direct sunlight. The water vapour transpired by the plant will soon saturate the atmosphere inside the bag and drops of water will condense on the inside. Remove the bag and shake all the condensed water into one corner. Show that it is water by adding a few drops to a little anhydrous copper sulphate (which will turn blue). A control experiment can be set up using a shoot in a similar situation, but from which all the leaves and flowers have been removed.

Which surface of a leaf loses more water vapour?



Remove small squares of cobalt chloride paper from a desiccator and stick them as quickly as possible to the upper and lower surfaces of a leaf using Sticky tape. Avoid prominent veins to make sure you have an air-tight seal. In damp conditions, cobalt chloride paper changes from blue to pink. Compare the time taken for this change in both squares to see which surface gives off most water vapour.

Safety: cobalt chloride paper should be handled as little as possible and ideally only with forceps or tweezers. Wash the hands afterwards and avoid skin contact.

Stomata

Well before the lesson, paint transparent nail varnish on the underside of leaves of Tradescantia plants. During the lesson, ask the students to carefully peel off the hardened nail varnish and examine it, first under the low power of a microscope, and then under a higher power. Explain that the little pores they see are called stomata (singular: stoma). The two sausage-shaped cells either side of the pore are called guard cells. They bend to allow oxygen and surplus water out of the leaf, and air into it. Explain that some leaves have very large numbers of stomata, more than a thousand per square millimetre in some cases.

Transport in vascular bundles

Demonstrate how food colouring travels up the stem of a flower. You need some fresh white flowers, carnations or tube roses are best, some food colouring, warm water and several small vases or clean bottles

First fill the vases with warm water, not too much if the vases are large. Add 15-20 drops of food colouring to each vase (put different colours into each vase to see if some colours work better than others, brighter colours are probably best).

Cut the stem of the flower at a slant, this helps the flower take up the water. Then put a flower into each of the vases and wait…

Let the flowers stand in the water, and keep checking to see when the colour starts to change. It should take about six hours, but it could take longer.

Which colours worked best or quickest? Try moving the flower to a different vase with a different colour, what happens then?

After you have finished the experiment, try cutting the stem down the middle and look inside. You will notice that the xylem vessels that the plant uses to move water have been dyed too.

Transport in celery

As an alternative to the above experiment, place a stick of celery, complete with leaves, in water which has been dyed red or blue. After about thirty minutes note the colour of the leaf veins. Cut across the stem and note where the dye appears in the tissues. Slice the stem lengthwise to trace these xylem vessels up and down the stem.

Water intake in small mammals

Design an experiment to investigate how much water a pet mammal, such as a mouse, rat or hamster, drinks in a day. What factors might affect this water intake?

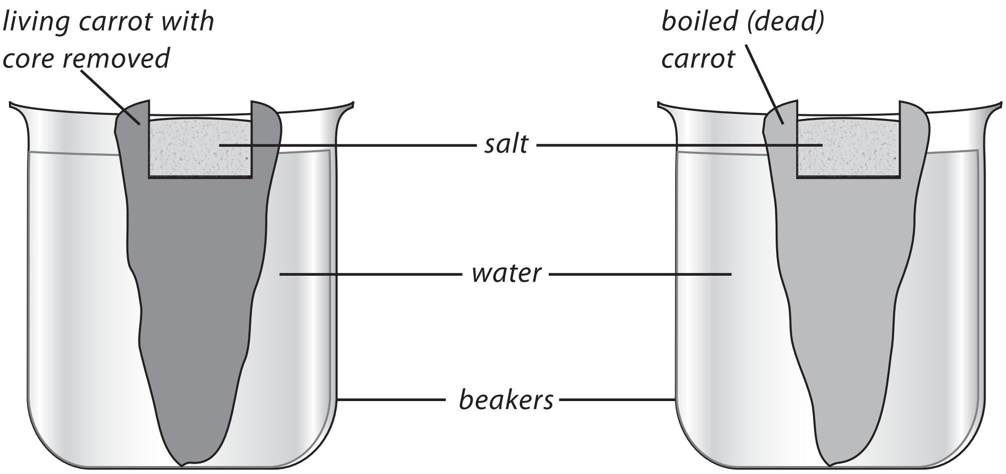
WORKSHEET 1

Studying osmosis in a living root

Materials needed: two carrots, as near equal in size as possible; two identical beakers; salt; an apple corer or small knife; boiling water; tissues

A carrot is a large root that is swollen with stored food. If you cannot obtain two carrots, carry out this experiment with two potatoes, which are stems swollen with stored food.

1. Take two carrots and boil one in water for about five minutes to kill the cell membranes.
2. Using an apple corer or small knife, carefully cut a hollow in the centre of each carrot. Dry the hollows with a tissue.
3. Half-fill both hollows with salt.
4. Stand the carrots in a beaker of water and leave them overnight.



The next day, look at the hollows closely.

What do you see? ______________________________

In which carrot has osmosis occurred? ______________________________

How does this experiment show that osmosis only occurs in living roots? ______________________________

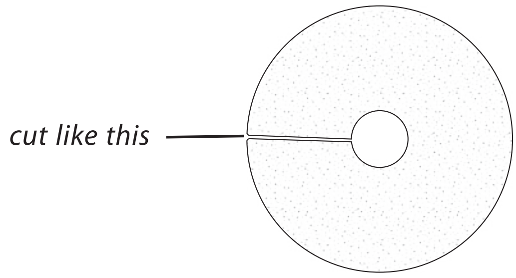
____

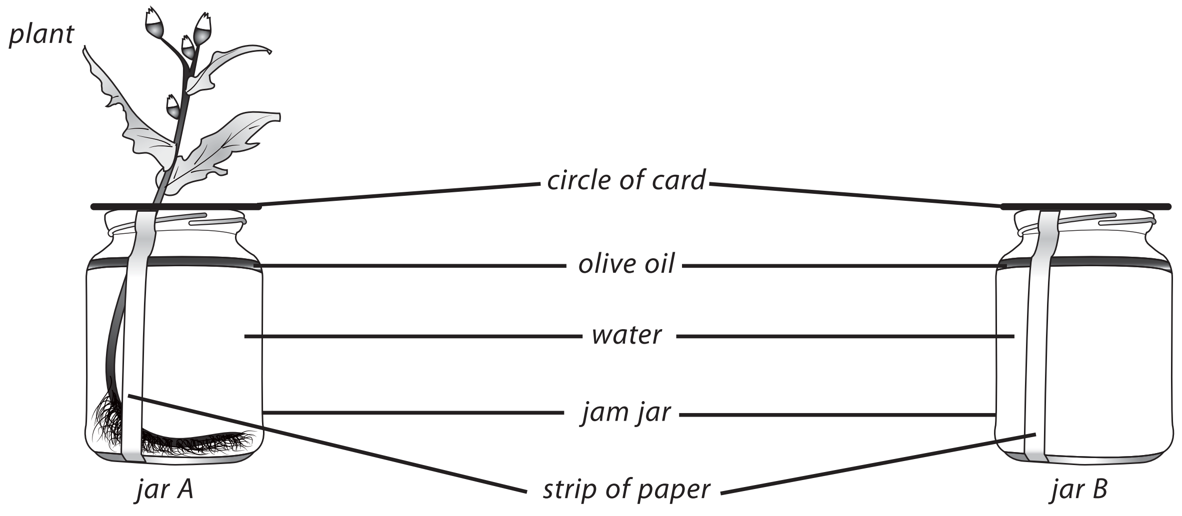
WORKSHEET 2

How much water does a plant absorb?

Materials needed: two clean, transparent jars (both the same size); water; small plant such as a garden weed; two strips of sticky paper; two circles of thin card to cover the jars; olive oil, corn oil or other vegetable oil; scissors

1. Fill both jars to exactly the same level with water.
2. Stick a strip of sticky paper up the side of each jar.
3. Make a hole and a slit in one card circle, as shown.
4. Slip the plant through the card circle. Put it in jar A so that its roots are in water.
5. Carefully lift the circle of card and pour a layer of oil on the surface of the water.
6. Pour a layer of oil onto the water in jar B. cover the jar with a circle of card.
7. Mark the water levels on the strips of sticky paper.
8. Stand the jars side-by-side on a windowsill.
9. Mark the water level in each jar every day for a week.





By how much does the water level go down in each jar? A ______________ B ______________

Where has the water gone? ______________

What was the purpose of the jar without the plant? ______________

____

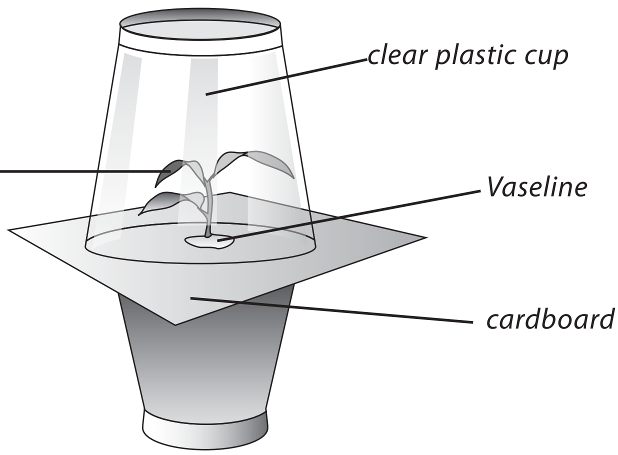
What does the oil do? ______________

WORKSHEET 3

How much water does a plant transpire?

Materials needed: 2 transparent plastic cups; square piece of card to fit between the two cups; small cutting of a house plant or twig from a tree; Vaseline or petroleum jelly; lamp or sunny windowsill; water; scissors

1. Use the scissors to cut a small hole in the centre of the card, just big enough for the plant stem to pass through.
2. Pull the plant stem through the hole and seal around the hole with Vaseline or petroleum jelly.
3. Fill the bottom cup with water and place the plant stem with its cardboard cover into the cup. Cover the plant with a second cup, as shown below.
4. Put the apparatus on a sunny windowsill or near a lamp.



5. After about fifteen minutes look at the inverted plastic cup. You should see droplets of water on the inside of it.
6. Leave the apparatus for several days and measure the total amount of water transpired by the plant.
7. Calculate the loss per square centimetre of leaf. You can estimate the surface area of each leaf by tracing it onto a piece of graph paper and then counting the number of squares the leaf covers. ____________

____

Where does the water that collects along the sides of the top cup come from? ____________

____

How do you know that the water has come from the plant and is not just evaporating from the plastic cup?

____

____

Answers to questions in the Students' Book

1. Large, many-celled plants need a transport system because it would take a long time for gases and other materials to diffuse into and out of the plant.
2. The two sets of tubes which make up the transport system of the plant are called phloem and xylem.
3. In a leaf, phloem and xylem tubes are found in the veins.
4. Water enters root hairs by a process called osmosis.
5. Xylem moves water and mineral salts from the roots to the leaves of the plant. Water enters the root hairs by osmosis, while some mineral salts enter the roots by diffusion. Other mineral salts enter the roots by what is called active transport. The main force which draws water up the plant is transpiration—the evaporation of water from the plant leaves.
6. The phloem cells carry dissolved food to storage areas, growing points, and other places where it is needed.
7. Most plants would die if they were watered with a strong salt solution. This is because the concentration of salts outside the root hairs would be higher than the concentration inside the root hairs. As a result, water would leave the root hairs by osmosis, and the plants would wilt and die.
8. A transpiration stream is the flow of water and dissolved mineral salts from the roots to the leaves. The water and mineral salts are pulled up the xylem tubes and water evaporates from the plant leaves.
9. The highest rates of transpiration would occur in hot, dry, or windy conditions in bright sunshine.
10. A potted plant on a sunny windowsill will soon start to wilt because water is evaporating from the leaves faster than it is being taken up by the plant roots.
11. The rate of transpiration is greatly reduced at night because light levels are lower, the stomata are closed, water is not needed for photosynthesis and the temperature is usually lower.
12. The leafy shoot lost 25 grams in weight. The beaker of water lost 4 grams. The water lost by the leafy shoot due to transpiration was, therefore, $25 - 4 = 21$ grams in four hours or 5.25 grams in one hour.
13. In summer it is better to water potted plants in the evening when the rate of transpiration is lower. The water has time to soak into the soil or compost and the plant roots can take up enough water to make up for that lost by transpiration during the day.

Assessment

Question 1

The process by which water is lost from the leaves of a plant is called:

(A) condensation (B) decomposition (C) diffusion (D) transpiration

Question 2

The process by which foods made by photosynthesis are moved in a plant is called:

(A) transpiration (B) translocation (C) transference (D) transmission

Question 3

Transpiration takes place from:

(A) all parts of a plant
(B) the leaves
(C) the stem
(D) the above-ground parts of a plant

Question 4

The plant tissue which allows water and mineral salts to pass from the roots to the leaves is:

(A) phloem (B) xylem (C) epidermis (D) cuticle

Question 5

The plant tissue which moves sugars and other foods from the leaves to the growing points and storage places is:

(A) epidermis (B) cuticle (C) xylem (D) phloem

Question 6

On which surface of leaves are stomata present?

(A) upper only (B) lower only (C) mostly upper (D) mostly lower

Question 7

Cells which are full of water and rigid are said to be:

(A) support cells (B) flaccid (C) turgid (D) none of these

Question 8

Much of the transpiration from a plant takes place through the:

(A) stomata (B) lenticels (C) epidermis (D) cuticle

Question 9

Roots absorb water through:

(A) epidermal hairs (B) root hairs (C) root xylem (D) root phloem

Question 10

Sap rises in a plant because of:

(A) root pressure (B) transpiration pull (C) both (A) and (B) (D) osmosis

Question 11

Stomata open and close because of:

(A) the presence of valves
(B) hormones

(C) water pressure of the guard cells (D) concentration of gases

Question 12

Mineral salts are absorbed into cells by:

(A) osmosis (B) diffusion (C) active transport (D) air pressure

Question 13

Food is transported in the phloem as:

(A) glucose (B) sucrose (C) fats (D) amino acids

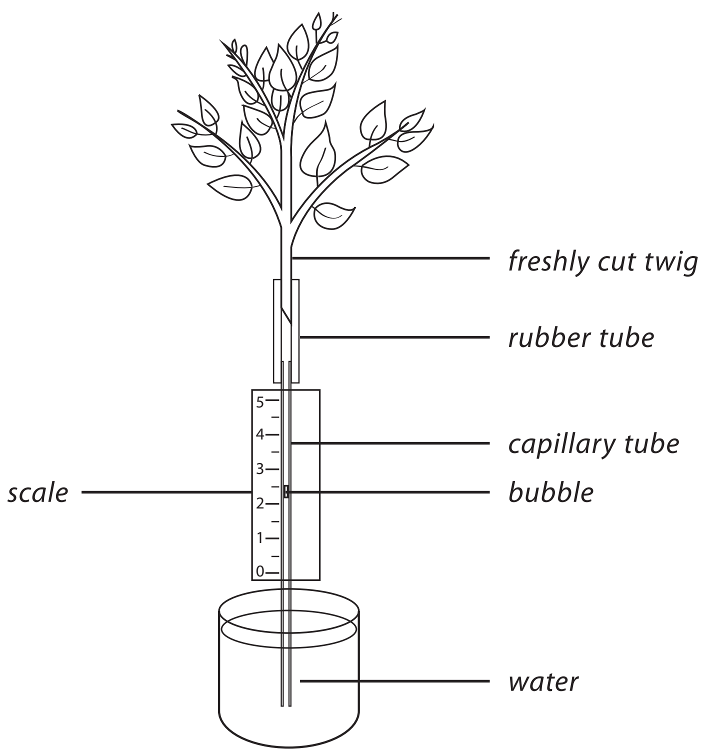
Question 14

The movement of particles from a region of higher concentration to a region of lower concentration is called:

(A) osmosis (B) diffusion (C) active transport (D) sap flow

Question 15

The picture below shows a piece of apparatus used to measure the rate of transpiration in plants. It is called a potometer.



a) Look at the picture carefully and then describe how the potometer works.

b) What is the purpose of the air bubble in the capillary tube?

c) What do you think would happen to the rate of transpiration if the potometer was moved from a cold room to a warm room?

d) What would happen to the rate of transpiration if the potometer was placed near a fan?

e) What would happen if the photometer was put in a warm, humid atmosphere?

Question 16

A potted plant was watered and then the pot was enclosed in a plastic bag tied securely around the base of the plant stem. The plant, pot, and plastic bag were weighed at 9 a.m. and then again at 4 p.m. During this time there was a loss in weight of 35 g.

a) From these results, what was the plant's rate of transpiration?

b) Why might this rate be slightly inaccurate if it was calculated in daylight?

c) Why might this rate be slightly inaccurate if it was calculated in darkness?

d) What was the purpose of watering the plant at the start of the experiment?

e) Why was the plant pot enclosed in a plastic bag?

Answers to assessment questions

Question 1 (D) **Question 2** (B) **Question 3** (D) **Question 4** (B) **Question 5** (D)

Question 6 (D) **Question 7** (C) **Question 8** (A) **Question 9** (B) **Question 10** (C)

Question 11 (C) **Question 12** (C) **Question 13** (B) **Question 14** (B)

Question 15

a) As water evaporates from the plant, the plant takes up more water from the capillary tube. The movement of the air bubble upwards shows the rate at which transpiration is occurring and can be measured on the scale.

b) The movement of the air bubble in the capillary tube shows the rate at which the plant is taking up water from the capillary tube.

c) If the potometer was moved from a cold room to a warm room the rate of transpiration would increase because evaporation occurs faster at higher temperatures.

d) If the potometer was placed near a fan the rate of transpiration would increase because the moving air would sweep water vapour away from the vicinity of the leaf.

e) If the potometer was put in a warm, humid atmosphere the rate of transpiration would decrease as evaporation slows or stops under humid conditions when the air is already full of water vapour.

Question 16

a) The plant lost 35 g in weight in seven hours. Therefore its rate of transpiration was 5 g per hour.

b) The calculated rate might be slightly inaccurate if it was calculated in daylight because the plant would be using some of the water it took up in photosynthesis. The rate of transpiration would, therefore, be slightly lower.

c) The calculated rate might be slightly inaccurate if it was calculated in darkness because the plant would be producing some water as it respired. The real rate of transpiration would, therefore, be slightly higher.

d) The purpose of watering the plant at the start of the experiment was to make sure that all the plant cells were full of water (or turgid), so ensuring that all the weight loss was due to transpiration.

e) The plant pot was enclosed in a plastic bag to make sure that the weight loss was due to transpiration and not the evaporation of water from the soil or the pot.

Reproduction in plants

CHAPTER 5

Teaching Objectives

- To explain the importance of pollination and to compare and contrast self- and cross-pollination
- To introduce simple ideas on the differences between sexual and asexual reproduction in plants
- To examine the processes of fertilization, and seed and fruit formation in plants

Learning Outcomes

After studying this chapter students should be able to:

- define pollination
- compare self- and cross-pollination
- list various factors involved in cross-pollination
- differentiate between sexual and asexual reproduction
- describe fertilization
- describe seed and fruit formation

Introduction

A flower cannot produce seeds until it is pollinated and its ovules are fertilized. Pollination is the transfer of pollen from the male parts (stamens) of a flower to the female parts (stigmas). If pollen is carried to the stigma of the same flower, it is called self-pollination. More often, pollen is carried to a flower of another plant of the same species. This is called cross-pollination. The advantage of cross-pollination is that characteristics from two plants combine in the seeds, producing great variety in the offspring that develop from them. Many plants, including some varieties of apple and pear, are self-sterile, which means that self-pollination cannot take place.

Pollen is usually carried from one plant to another by small animals, mainly insects, or the wind, and the structure of the flower is adapted to its method of pollination. After a flower has been pollinated, fertilization can take place. When a pollen grain lands on a suitable ripe stigma, it quickly grows a tube down through the style and into the ovary to the ovule or egg-cell. A male nucleus then passes through the pollen tube and fertilizes the egg-cell. After fertilization has taken place the ovule develops into a seed, which consists of an embryo plant together with a food store inside a protective coat. At the same time the ovary develops into a fruit and its wall either dries out or becomes fleshy and juicy.

Because plants stay rooted in one place, their fruits are almost always adapted in some way for dispersing, or spreading, the seeds. This ensures that the new plants do not take up valuable soil space that is needed by the parents. The main methods of seed dispersal are by wind, water, animals and explosive mechanisms.

A seed will remain dormant until conditions are suitable for its germination. The first part to emerge is the young root (radicle) which grows down into the soil. The young shot (plumule) then begins to grow upwards, drawing on the food store in the seed until the first leaves are formed.

Many flowering plants can reproduce without seeds. This is called vegetative reproduction. It is often used by gardeners because the plants develop faster, are less delicate, and thus not easily damaged while growing. The new plant has exactly the same qualities as its parent. There are many forms of vegetative reproduction, such as rhizomes, corms, bulbs, runners, tubers, and cuttings.

Lesson suggestions

1. Flowers and pollination

Refer to page 42 of the Students' Book

Starter suggestions

Make a collection of flowers—wild and cultivated—and ask the students what the purpose or function of flowers is. Conclude the discussion by summarising the job of flowers as being to 'make seeds.'

Main lesson

Using PowerPoint, a wall chart or the pictures in the Students' Book, explain the structure of a typical flower. Then, with the aid of Worksheet 1, let the students dissect and compare a selection of flowers. If possible, include insect- and wind-pollinated flowers in the selection available.

Explain the functions of the parts of the flower and the adaptations to the two main methods of pollination.

Conclude by showing the students a series of photographs or slides of different flowers. Give each picture a number and ask the students to write down against each number whether they think the flower is pollinated by wind or by insects. Show them the pictures again and discuss why they came to those particular conclusions.

2. Fertilization in plants

Refer to page 45 of the Students' Book

Starter suggestions

Ask the students to recall the structure of a flower and to explain what happens during pollination. It is important that they understand that when pollination has occurred satisfactorily, there are pollen grains stuck to the stigma of the flower.

Main lesson

If microscopes are available, let the students examine and draw the pollen grains from different plants.

Pollen grains can be grown in several ways. The easiest and quickest way is to put a drop of 10 per cent sucrose (cane sugar) solution in a cavity slide and then to sprinkle a few pollen grains over the surface of the liquid. Carefully lower a coverslip over the cavity in the slide and put the slide in a warm, dark place for a few hours. A certain amount of trial-and-improvement is involved, because some kinds of pollen grains will produce pollen tubes in less than an hour at room temperature. Examine the slide under the low power of a microscope.

Alternatively, peel a small piece of the epidermal tissue from between the overlapping layers of an onion. Carefully lay a piece of this on a microscope slide with the side that was towards the outside of the onion uppermost. Dust the surface of the onion epidermis with a little ripe pollen and place it in a closed petri dish on top of a piece of moist paper towel. After a few hours, examine the slide with the low power of a microscope.

Using PowerPoint, show the students the stages in the process of fertilization, beginning with the pollen grain having landed on the stigma and sticking to it. Continue with the pollen tube growing down the style and into the ovary, and then the pollen nucleus moving down the pollen tube and eventually fusing with the nucleus of the ovule or egg-cell. If PowerPoint is not available, use diagrams, including those from the Students' Book.

Finish the lesson with a description of how the fertilized ovule divides many times and develops into a seed, while the ovary becomes the fruit.

3. Seed dispersal

Refer to page 46 of the Students' Book

Starter suggestions

Make a display of different types of fruits (or photographs of different types of fruits), including some of those, such as bean or pea pods, cucumbers, marrows, and squashes, which are often described as vegetables. Ask the students to point out the fruits in the collection. Explain that they are all fruits, because the definition of a 'fruit' is that it develops from the ovary wall after fertilization and contains seeds. Ask the students to examine each of the fruits and to write down how they think the seeds are dispersed or scattered.

Main lesson

Discuss why seeds need to be dispersed and explain the various methods by which this is achieved. If wind-dispersed fruits are available, including those of trees such as pine and sycamore or maple, and those of herbaceous plants such as dandelion and thistles, ask the students to devise and carry out experiments to find out how far the seeds will travel under different conditions, including when they are wet and when they are dry. Discuss what are the best conditions for a wind-dispersed seed to be released from the parent plant.

4. Germination

Refer to page 48 of the Students' Book

Starter suggestions

Discuss the importance of seeds in our diet. Mention, in particular, the members of the grasses family. Arguably these are the most important plants in the world, since they include the cereals such as wheat, rice and maize, bamboos, and the plants on which cattle, sheep, and other grazing animals feed.

Show the students a germinating seed (either a specimen or a picture) and ask them what a seed needs to germinate.

Main lesson

Since this is a topic which lends itself to safe and inexpensive practical work, encourage the students to observe the germination of as many different kinds of seed as possible. Use Worksheet 2 to help if you wish. The students may notice that seeds fall into two main groups: seeds such as the cereals and grasses which have only one seed leaf (technically called monocotyledons), and the majority of seeds, including those of beans, peas and sunflowers, which have two seed leaves (called dicotyledons). However, these technical terms are not important at this stage.

Go on to investigate the conditions necessary for seeds to germinate, as described on Worksheet 3. The students should discover that seeds need air or oxygen, warmth and water if they are to germinate. It may be worth mentioning that a very few seeds also need exposure to light before they will germinate, while some tree seeds have to be exposed to a period of cold (simulating winter) before they will germinate in warm conditions.

Ideas for investigation and extension work

Flower colours

Investigate what the most common flower colours are at any one season of the year. Do insects such as bees or butterflies have a preference for any one particular colour flower?

Pollen grains

Dust or squash the ripe anthers of a flower on a microscope slide and examine it under low magnification to see the pollen grains. Examine and draw the pollen from several different flowers and notice how the pollen grains differ. This is the basis of the technique of pollen analysis, in which samples of pollen from different layers of soil, marsh or bog are examined and identified to give an indication what the vegetation was like in that area in ancient times.

Pollen grains and stigmas

Examine the stigmas of several flowers using reflected light and the low power of a microscope. Look for pollen grains sticking to the stigmas. If one of these stigmas is put in a drop of water and squashed between two microscope slides, it may be possible to see pollen tubes growing between the cells of the stigma and style.

A model of plant fertilization

Use Plasticine, plaster of Paris, or some other modelling material, to make a scale model of the stigma, style and ovary of a flower, with the pollen tube, containing a nucleus, growing down to fuse with an ovule or egg-cell.

Beans and other seeds

Split open a bean or pea pod and notice the row of beans or peas inside. The beans or peas are the seeds, while the pod is the fruit.

Examine the pea and bean seeds and the seeds of various other plants. Can the students explain their similarities and differences?

Broad bean seeds

Take a broad bean seed which has been soaked in water and look for the testa or seed coat, the micropyle (a tiny hole through which water is taken up) and the black scar which shows where the bean was attached inside the pod. Cut the bean in two, lengthwise. Look for the radicle and plumule of the embryo and the cotyledon. Pipette a drop of iodine onto one of the cotyledons inside the seed. Notice the blue-black colour which shows the presence of starch.

WORKSHEET 1

What is in a flower?

Materials needed: a collection of simple flowers; forceps; hand lens or magnifying glass; sticky tape; paper.

1. Look carefully at one of the flowers with a hand lens or magnifying glass. Draw it.
2. Use the forceps to carefully pull off the sepals. How many are there? ______
3. Now remove the petals. How many are there? ______
4. Next gently pull off the stamens. How many are there? ______
5. Find the carpels in the centre of the flower. How many are there? ______
6. Stick the different parts of the flower to a sheet of paper using sticky tape. Label them.
7. Now examine other flowers of the same species and different species like this. Do they all have the same number of parts?

Prepare a table of your findings like this:

Plant species	Colour of flower	Number of sepals	Number of petals	Number of stamens	Number of carpels

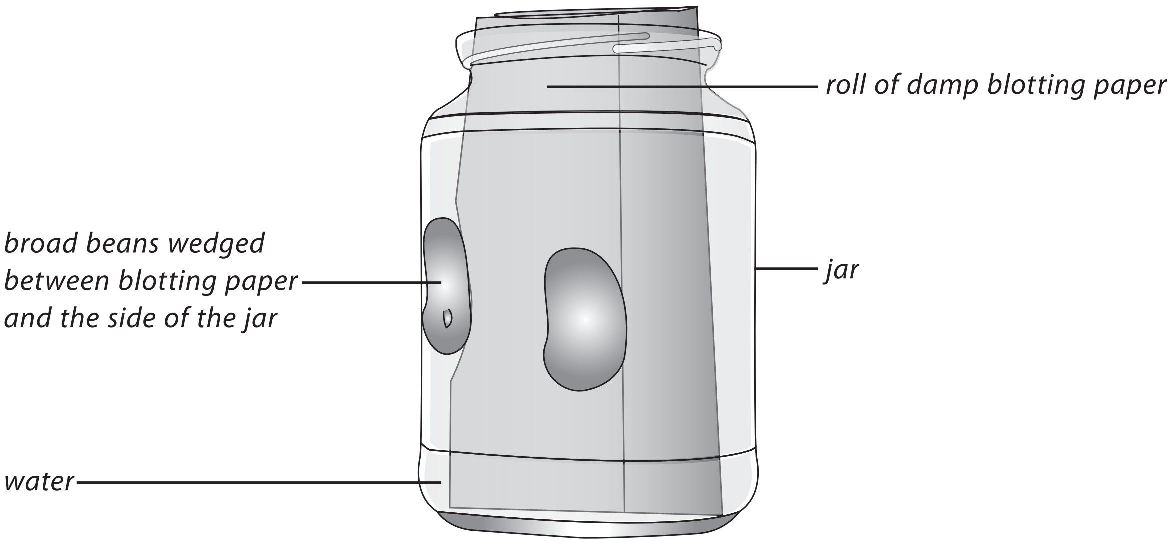
Would it be possible to recognize a plant species just by the numbers of sepals, petals, stamens and carpels in one of the flowers? ______

WORKSHEET 2

Watching seeds germinate

Materials needed: clear glass or plastic jars; blotting paper or filter paper; broad bean seeds or seeds of some other kind of bean plant.

1. Put some water in the bottom of the jar.
2. Roll up a piece of blotting paper or filter paper and put it in the jar as shown in the diagram.



3. Tilt the jar so that the blotting paper is thoroughly wetted and sticks to the sides of the jar.
4. Carefully push several broad bean seeds between the blotting paper and the sides of the jar. Put at least one seed the right way up, one on its side and one upside down. Make sure the seeds do not fall to the bottom of the jar.
5. Observe the bean seeds at intervals over the next ten days or so and watch the stages of germination.

Which part of the embryo emerges from the seed first? ____________________

Why is the shoot hook-shaped to begin with? ____________________

____

Where does the seedling get its food from? ____________________

Does it matter which way up the seed is planted? ____________________

____

What do you think makes the shoot grow upwards and the root downwards? ____________________

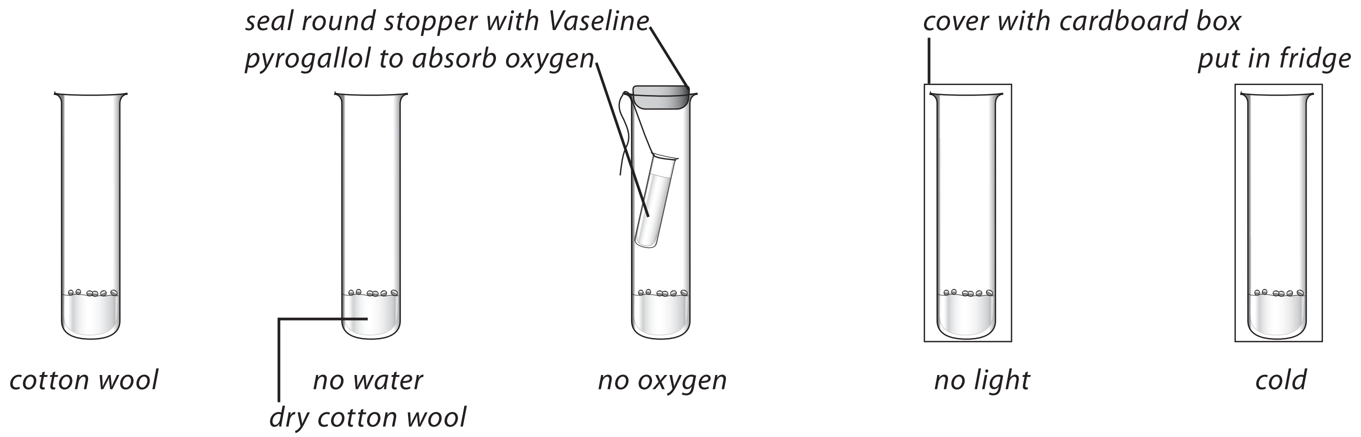
____

WORKSHEET 3

What conditions are necessary for a seed to germinate?

Materials needed: cotton wool; five large test-tubes; cress seeds, mustard seeds or grass seeds; pyrogallol, or water which has been boiled and then allowed to cool to room temperature in a sealed container; access to a refrigerator; a small cardboard box

1. Push a plug of cotton wool into the bottom of five large test-tubes.
2. Pour a little tap water into four of the tubes so as to moisten the cotton wool. Leave the cotton wool in the other tube dry.
3. Sprinkle some cress seeds (or mustard seeds or grass seeds) onto the cotton wool in each test-tube.
4. Set up the test-tubes as shown in the diagram below. If you do not have any pyrogallol to absorb the oxygen from the tube, then fill the tube to the top with tap water which has been boiled, to drive off the dissolved oxygen, and then left to cool to room temperature in a sealed container.



5. Leave four of the tubes on a sunny windowsill. Put the fifth one in a refrigerator.
6. Observe the test-tubes at intervals during the next few days.

In which test-tubes do the seeds germinate? ______________________________

____

What conditions are needed for seeds to begin to germinate? ______________________________

____

What other condition is necessary if the seedlings are to grow healthily? ______________________________

____

Why do you think seeds begin to grow in the ground in spring? ______________________________

____

Which tube acted as the control in this investigation? ______________________________

____

Answers to questions in the Students' Book

1. There are too many endangered plants to be able to list them here. In fact, a report produced by scientists in 2010 claimed that one-fifth of the world's plants are in danger of extinction. The main causes of the extinction of plants are loss of habitat—the clearance of vegetation for farmland, houses, roads, factories, etc.—and the use of chemical pesticides and fertilizers on farmland. Pollution of the air or water is another cause of pollution.
2. Working from the outside inwards, the four main parts of a flower are: sepals, which protected the flower at the bud stage; petals, which are often brightly coloured to attract insects; stamens which are the male reproductive organs and which produce pollen; carpels which are the female reproductive organs.
3. Insect-pollinated flowers have fewer and larger pollen grains because, once an insect has been attracted to the flower and eaten some of the pollen grains or nectar, there is quite a high chance that it will accidentally carry some of the pollen grains to another flower of the same species. By contrast, wind-pollinated plants have to rely on the wind carrying pollen to another plant of the same species. The pollen grains have to be small so that they blow along easily. There have to be very many of them because most will be wasted.
4. In a greenhouse, where there are no insects, cucumber or melon plants often have to be pollinated by hand. A stamen, or a small paint brush bearing pollen, is rubbed against the stigmas of the flowers so that fertilization can occur.
5. Pollination is the transfer of pollen from one flower to the stigma of another flower of the same species. Fertilization occurs after pollination. A tiny tube grows from the pollen grain down towards the ovary. A male nucleus from the pollen grain moves down the pollen tube and joins with the nucleus of the female sex cell, the ovule. When the two nuclei have fused together, the ovule is said to have been fertilized.
6. The nucleus in a pollen grain passes down the pollen tube inside the stigma of the flower to reach the ovary of the flower.
7. A fruit is formed from an ovary after fertilization. A seed develops from a fertilized ovule. When a seed starts to grow it is said to germinate. A cotyledon is another name for a seed leaf inside a seed. It contains stored food for the developing seedling. The embryo is the miniature plant inside a seed. The plumule is the first shoot or stem which grows from a seed as it starts to germinate. Dormancy is the resting or sleeping stage of a seed. A root hair is a single-celled structure, found near the tip of a root, which absorbs water and dissolved mineral salts from the soil.
8. The main ways in which seeds are dispersed is by the wind, by animals, by water, and by explosive mechanisms.
9. Seeds formed in the autumn will not grow during the winter because the temperatures are too low for germination to occur. Seeds formed in dry weather will not grow because they need water to germinate.
10. i) The wall of the ovary grows to form the tomato fruit after fertilization; ii) The petals fall off after fertilization; iii) The sepals remain at the base of the fruit after fertilization.

11. Gardeners sometimes cut a potato tuber in half before they plant the two pieces, but they have to make sure that there is a bud, or 'eye', in each part.
12. Vegetable reproduction produces young plants that grow quickly and which are identical to the parent plants. Sexual reproduction produces seeds which are often slow to germinate. The seeds, however, contain characteristics of the plant from which the pollen grain came and characteristics of the plant on which the ovule was fertilized. Sexual reproduction can, therefore, be used to produce new types of plants.

Assessment

Question 1

The most important part of a plant for the continuation of the species is the:

A) root B) stem C) leaf D) flower

Question 2

In flowering plants, sexual reproduction involves the formation of:

A) pollen B) seeds C) spores D) conifers

Question 3

The order of the parts of a flower, from the outside inwards is:

(A) sepals carpels, stamens petals (B) sepals, petals, stamens, carpels

(C) carpels, sepals, stamens, petals (D) petals, carpels, stamens, sepals

Question 4

Where is the male sex cell in a plant?

(A) pollen grain (B) ovule or egg-cell (C) anther (D) filament

Question 5

Which of these is the female sex cell?

(A) ovary (B) pollen grain (C) anther (D) ovule or egg-cell

Question 6

The part of a flower to which pollen grains carried by insects stick is called the:

(A) anther (B) stigma (C) ovary (D) moss

Question 7

Hay fever is caused by the male cells of certain plants. These males cells are contained in the:

(A) ovules (B) pollen (C) anther (D) stigma

Question 8

Which of these stages is the beginning of fertilization?

(A) A pollen tube begins to grow.
(B) The ovary turns into a fruit.
(C) Pollen lands on the stigma.
(D) The ovule grows into a seed.

Question 9

Because a watermelon fruit contains many seeds, we know that the normal flower of the watermelon contains large numbers of:

(A) sepals and petals
(B) very large anthers
(C) ovules
(D) stamens

Question 10

Which of these conditions is NOT suitable for germination to occur?

(A) warmth
(B) cold
(C) moisture
(D) oxygen

Question 11

Which of these is NOT a method of seed dispersal?

(A) wind
(B) animals
(C) explosive mechanisms
(D) fog

Question 12

You find a new fruit with a thin, flattened piece sticking out from it. How it is most likely to be dispersed?

(A) wind
(B) animals
(C) water
(D) explosively

Question 13

What is the first part to emerge when a seed germinates?

(A) embryo
(B) cotyledon
(C) plumule
(D) radicle

Question 14

Sexual reproduction is a big advantage to a species because it provides lots of:

(A) identical organisms
(B) variation in the species
(C) energy for the species to survive
(D) similar copies of the parent

Question 15

When a strawberry plant produces a new plant without the formation of seeds, this type of asexual reproduction is called:

(A) budding
(B) binary fission
(C) spore formation
(D) vegetative reproduction

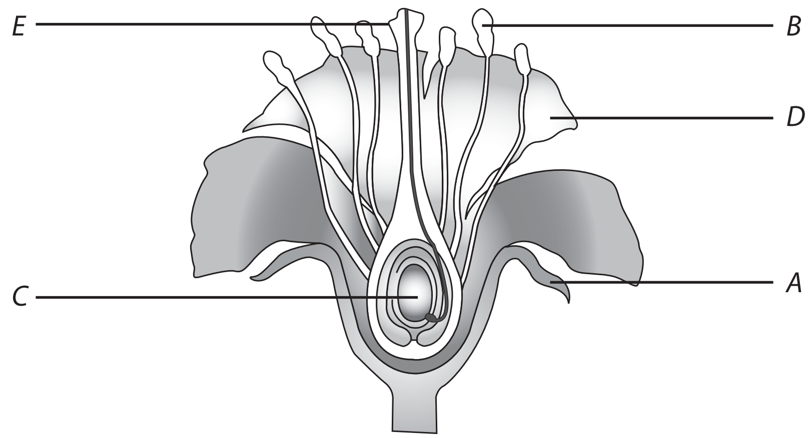
Question 16

The type of vegetative reproduction seen in potatoes is by the formation of:

(A) runners (B) suckers (C) bulbs (D) tubers

Question 17

The diagram below shows a flower that has been cut in half to show its reproductive organs.



a) In the table below write the correct letter next to the name of the part of the flower.

Flower part	Letter
sepal	
petal	
stamen	
stigma	
ovary	

b) Write the letter of the flower part next to its job or function.

Job or function	Letter
i) attracts insects to the flower ii) protects the flower when it is a bud iii) makes the seeds iv) makes and stores pollen v) has a sticky surface for the pollen to land on	

c) A honey bee with pollen on it from another flower lands on the stigma of this flower. What is this process called?

d) Name another way that pollen may be transferred from flower to flower.

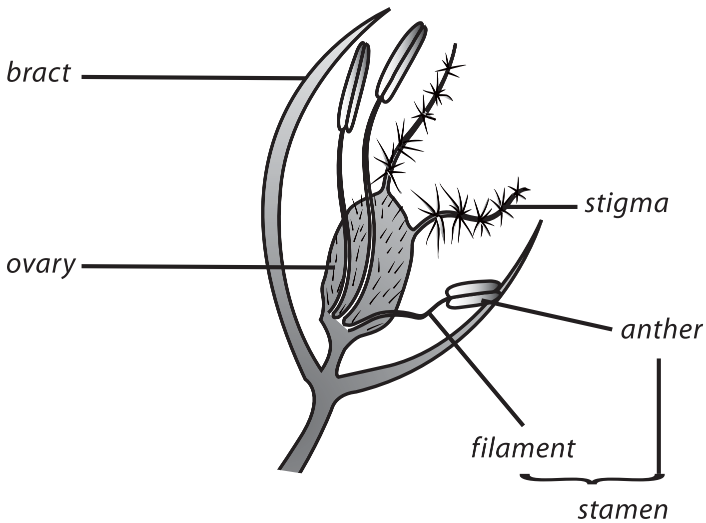
e) Once the pollen lands on the stigma, a tiny tube grows down towards the ovule in the ovary. The pollen nucleus travels down the tube to join with the egg-cell or ovule nucleus. What is this process called?

f) The seeds produced by the flower need to be scattered over a large area in order to grow into new plants. What are two ways in which this can happen?

g) The seeds need oxygen and warmth so that they can germinate. What other substance is needed?

Question 18

The diagram below shows a typical grass flower. It is pollinated by the wind blowing pollen from the stamens of one grass flower to the stigma of another.



a) How is the stamen adapted for wind pollination?

b) How is the stigma adapted for wind pollination?

c) The stamens and stigma of the flower are not ripe at the same time. How is this an advantage?

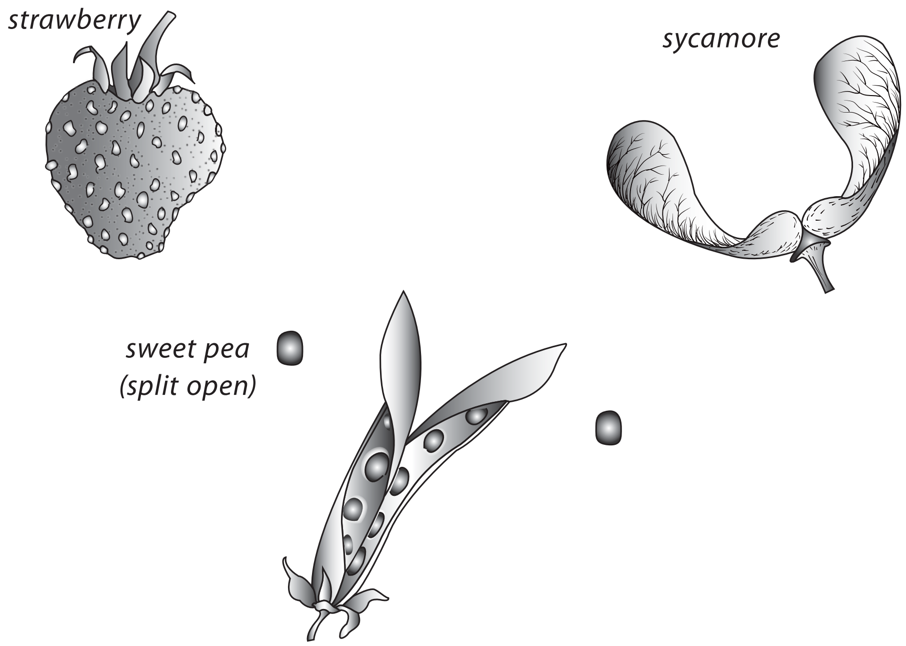
d) Flowers like those of the apple tree are pollinated by insects such as bees. Why do these flowers have brightly coloured petals, unlike grass?

e) Name another part which is often present in insect-pollinated flowers but not in wind-pollinated flowers

____

Question 19

The diagrams below show three different kinds of fruit.



a) Name the fruit whose seed is dispersed by wind. ______________________

b) Explain the reason for your choice. ______________________

____

c) When strawberries are eaten by birds, the seeds are dropped in the faeces. Suggest why birds are attracted to the strawberry as food. ______________________

____

d) Explain why the seeds can still germinate after passing through the digestive system of a bird.

____

____

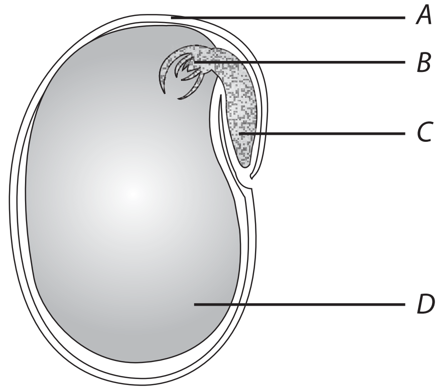
e) Give TWO reasons why seed dispersal is necessary:

i) ______________________

ii) ______________________

Question 20

a) The diagram shows a section through a bean seed.



(i) Name the parts labelled A, B, C and D.

A ____________________

B ____________________

C ____________________

D ____________________

(ii) Together, the parts labelled B and C make up a miniature plant. What is the correct name for this miniature plant? ____________________

(iii) What is the job or function of part D?

____

b) Explain how runners increase the number of strawberry plants.

____

____

____

c) What are the advantages of runners as a way of increasing the number of strawberry plants?

____

____

d) What are the disadvantages of runners as a way of increasing the number of strawberry plants?

____

____

Answers to assessment questions

Question 1 (D) **Question 2** (B) **Question 3** (B) **Question 4** (A) **Question 5** (D)

Question 6 (B) **Question 7** (B) **Question 8** (A) **Question 9** (C) **Question 10** (B)

Question 11 (D) **Question 12** (A) **Question 13** (D) **Question 14** (B) **Question 15** (D)
Question 16 (D)

Question 17

Parts of flower

a)

Flower part	Letter
sepal	A
petal	D
stamen	B
stigma	E
ovary	C

b)

Job or function	Letter
i) attracts insects to the flower	D
ii) protects the flower when it is a bud	A
iii) makes the seeds	C
iv) makes and stores pollen	B
v) has a sticky surface for the pollen to land on	E

c) The process whereby a honey bee with pollen on it from one flower lands on the stigma of another flower is called cross-pollination.

d) Pollen may also be transferred from flower to flower by the wind, by water and by animals such as bats.

e) The process whereby the pollen nucleus travels down the tube to join with the egg-cell or ovule nucleus is called fertilization.

f) The seeds produced by the flower need to be scattered over a large area in order to grow into new plants. This can be brought about by wind, water, animals or explosive means.

g) As well as oxygen and warmth, seeds also need water in order to germinate.

Question 18

a) The stamen is adapted for wind pollination because it sticks out from the flower to catch the wind; the anther is loose to blow around in the wind.

b) The stigma is adapted for wind pollination because it is large and feathery to act as a net to catch wind-blown pollen.

c) The fact that the stamens and stigma of the flower are not ripe at the same time is an advantage because it stops the flower from pollinating itself (self-pollination).

d) Flowers like those of the apple tree have brightly coloured petals to attract insects. Grass flowers do not need to attract insects.

e) Insect-pollinated flowers often have a nectary containing nectar to attract insects. This is not present in wind-pollinated flowers. Insect-pollinated flowers also often produce scent, which wind-pollinated flowers do not.

Question 19

a) The fruit whose seed is dispersed by wind is the sycamore.

b) The surface area of the sycamore fruit is increased by the wing, which enables the wind to carry it along.

c) Birds are attracted to the strawberry as food because of the bright colour of the fruit, its scent and also its sweet taste.

d) Strawberry seeds can still germinate after passing through the digestive system of a bird because the seeds are small and have a hard coat which is resistant to the bird's digestive juices.

e) Seed dispersal is necessary to avoid overcrowding, or competition for space, light and nutrients, and also to enable the plants to spread into new and different environments.

Question 20

a) i) The parts of the bean seed labelled A, B, C, and D are:

A = testa or seed coat

B = plumule

C = radicle

D = cotyledon or seed leaf

ii) The correct name for the miniature plant made up of B and C is embryo or embryo plant.

iii) The job or function of part D, the cotyledon, is that it is a seed leaf swollen with stored food. When some seeds germinate, the cotyledons grow above the soil surface and carry out photosynthesis until the first true leaves have opened.

b) Runners are modified stems which grow out horizontally from the parent strawberry plant, and form new plants at intervals. When the new plants are well established, the stems connecting them with the parent plant die away.

c) The advantages of runners as a way of increasing the number of strawberry plants are that they form new, quite large plants quickly, compared with the many weeks it would take to grow new plants from seeds. In addition, the new plants are identical to the parent plants.

d) The disadvantage of runners as a way of increasing the number of strawberry plants is that the young plants are genetically identical to the parent plants. They are clones. In agriculture and horticulture this is an advantage, although if one of the parent plants contains a disease, this will probably be passed on to the offspring. However, in the wild, an asexual population cannot adapt to changes in the environment and evolve defences against a new disease, and so faces extinction.

Environment and feeding relationships

CHAPTER 6

Teaching Objectives

- To extend earlier learning on habitats and ecosystems and to compare different habitats
- To investigate the adaptations that allow plants and animals to live in a particular habitat
- To explain the ways in which living organisms respond to daily and yearly changes in their environmental conditions
- To demonstrate that food chains start with green plants as primary food producers
- To explain the role of producers and consumers in an ecosystem
- To describe the energy transfer process in a food chain
- To show how a food web is constructed by interconnecting several food chains

Learning Outcomes

After studying this chapter students should be able to:

- explain the term 'ecosystem'
- define the term habitat
- compare the different kinds of habitat
- investigate the various features that allow animals and plants to live in a particular habitat
- identify the factors that cause daily and yearly changes in a habitat
- explain how living things adapt to daily and yearly changes in their habitat
- explain the ways in which living things respond to changes in daily environmental conditions such as light intensity, temperature and rainfall
- explain why food chains always begin with a producer
- illustrate the relationship between producers and consumers
- describe two food chains in the environment around them
- explain a food web

Introduction

Living things are found almost everywhere on Earth: on land and in the air, in water and underground. You will find them in the most unlikely places, such as hot, dry deserts and the freezing cold polar regions. There are living organisms in salt lakes and in hot springs where the water is almost at boiling point. Many organisms live in or on the bodies of other organisms.

Habitats

The place where an organism lives is called its habitat. Every organism is suited, or adapted, to live in its particular habitat. For example, some animals are wonderfully camouflaged so that they cannot easily be seen by their predators. Organisms can survive only if they are suitably adapted. But not only are organisms adapted to their environment, they are also dependent on one another for food, shelter and protection.

Ecosystems

The plant and animal life, as well as the non-living surroundings where they are found, make up an ecosystem. This is a balanced system, not relying on any other for its survival. It is self-sufficient in food, although sometimes animals may come from elsewhere to feed, for example, a heron visiting a pond to take fish or frogs. An ecosystem can be large or small. Small ones can be found within larger ones, such as a rotting log within a wood or forest.

All ecosystems work in the same way. The plants take carbon dioxide from the atmosphere, and the energy from the Sun enables them to make food. These primary producers (of food) are eaten by herbivores (plant-eaters), which are then consumed, and some of the energy absorbed, by carnivores (meat-eaters). These may then be eaten by tertiary (third) consumers. This pattern is called a food chain, and a number of food chains link together to form a food web. Finally, decomposers break down dead organisms into humus and mineral salts, from which they get their energy, but then they in turn are eaten by animals further up the food chain or food web.

Field-work

Ideally students need first-hand experience of habitats and the populations of living things they support. But of course, not all schools are located in areas where there are opportunities for extensive field-work. School grounds are probably the most likely choice, especially if time is limited. Many urban schools may have access to a park or public garden, or an area of waste ground, however small. However, there is no denying the advantage of taking students away from their immediate environment and into a 'natural' community if time and finance permit. For these reasons, the lesson suggestions given here are rather brief and generalized, dealing with preparation and techniques, rather than giving detailed suggestions for work to be carried out.

Preparation

Before embarking on any field-work activity, it is also important that the teacher consults his or her employing authority to obtain the appropriate guidelines for school visits, particularly those relating to the health, safety and number of supervising adults needed for a group of students working away from school.

It is also very important that the teacher is familiar with the area to be studied. It is a big advantage if he or she can visit the site several times before taking students. In that way, any health or safety issues can be identified and a basic knowledge of the plants and animals living on the site can be gained.

It is essential that the students are appropriately dressed for field work. It is inevitable that at least some students will get dirty, so informal clothing is best. It should, however, be sensible enough to provide protection from the heat, cold, wind or rain, and from abrasions. Strong shoes or boots are essential if serious walking is to be included in the work. Each student should also have a shoulder bag, such as a small rucksack or haversack, in which notebooks, identification guides, pencils, plastic bags, labels, and the all-important packed lunch can be carried.

Woodland habitats are ideal for investigative work and to demonstrate the complexities of a natural or semi-natural community. It is relatively easy to observe and record the distribution of individual species within it and to compare the effects of light and shade on plant distribution. There are, however, many other suitable habitats where comparisons can be made, including waste ground, coastal habitats and marshy areas **(Take care here.)** Teachers will no doubt think of many more suitable habitats. Provided students are given the opportunity to count populations and relate the distribution of populations to each other, then almost any area will do, even the school playing field.

However, if all else fails, it is important to remember that there are many suitable films, television programmes and DVDs which demonstrate the plant and animal life and important differences in physical conditions between ecosystems, including deserts and tropical rainforests. These same films, TV programmes and DVDs will also provide many examples of food chains and food webs and of what happens when humans upset the natural balance of an ecosystem.

Lesson suggestions

1. Food chains and food webs

Refer to page 65 of the Students' Book

Starter suggestions

Remind the class of the work they did on food chains and food webs in the primary school, and on producers, consumers and decomposers in the last school year. To test their knowledge and understanding, give them a number of incorrectly-written food chains (e.g. with no producer, with the tertiary consumer coming first, or the arrows pointing the wrong way). Ask them to point out the errors and to correct them.

Main lesson

Discuss with the students the ways in which animals and plants are adapted to their habitats. You could use Worksheets 1 and 2 for this purpose.

Move on to show the class a series of pictures of different organisms. Ask which ones make or produce their own food, and which are consumers. Draw out the key words, such as producer, consumer, carnivore, herbivore, omnivore, decomposer, predator, prey, scavenger, parasite, food chain, and food web. Ask the students to write these words down and put the correct definitions against them.

Let the students carry out the activity on Worksheet 3, from which they can construct a simple food chain. Alternatively, ask them to write down, or construct using pictures, a number of simple food chains, and then try to link some of these together into food webs.

2. Food pyramids and energy flow

Refer to page 66 of the Students' Book

Starter suggestions

Ask the students why they think big, fierce animals are so rare.

Show them a photograph of, say, a blue whale, the world's largest animal. Ask them how such a huge animal can survive by eating microscopic organisms.

Main lesson

Collect animals from a freshwater habitat and sort them into herbivores, carnivores, and detritivores. Count (or weigh) the animals in each group and help the students to construct a pyramid of numbers and/or a pyramid of biomass for that habitat.

Alternatively, collect the leaf litter from a 1 square metre of woodland floor (or some other suitable land habitat). Again, sort the animals into herbivores, carnivores and detritivores. Count or weigh the animals in each group and help the students to construct a pyramid of numbers or pyramid of biomass for that habitat.

Safety: Whichever habitat is investigated, all the animals should be returned safely to their original habitat at the end of the investigation.

Explain the shape and structure of the pyramid and make sure that the students understand that it represents the number (or weight in the case of a pyramid of biomass) of organisms at each level of a food chain. Emphasize that energy is lost at each stage of a food chain or food web (through respiration, excretion, movement, heat, reproduction, etc.) and that only about 10 per cent of the energy present in the bodies of the organisms at one stage of the food chain is passed on to the organisms at the next stage.

This might be the point to mention the concentration of pesticides and other poisons along a food chain. In the 1960s, scientists discovered that mice and small birds were eating chemically treated seeds. The individual mice and small birds did not consume enough of the poison to kill them, but they were preyed on by owls and hawks which ate a lot of the poison-carrying mice and small birds. The chemicals weakened the eggshells of the predator birds so that fewer of their chicks survived. This led to a decline in their species. Some of these chemicals, such as DDT, are now banned in many countries.

Finish by explaining that the reason big, fierce animals are rare is because they are predators or consumers, and in order to obtain enough food energy they have to range over huge distances to obtain food.

3. Ecology in the school grounds

Refer to page 63 of the Students' Book

Starter suggestions

Ask the students to write down the names of five animals and plants that live in a given habitat.

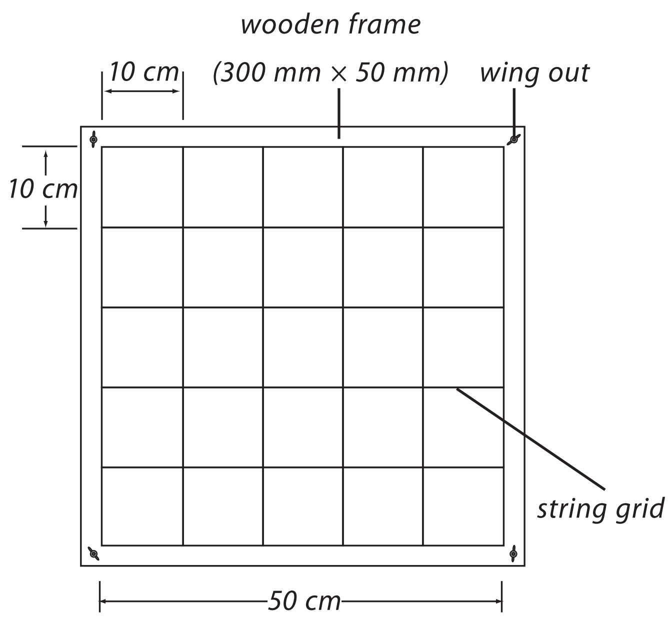
Ask the students to find the words 'habitat' and 'ecosystem' in the Students' Book and to write down the definitions of these words.

Ask the students to name an artificial ecosystem and say what they might find living in it.

Main lesson

Although the title of the lesson suggestion refers to the 'school grounds', this lesson could be conducted in a local park (with permission of the authorities), a piece of waste ground, or any other site which is occupied by a variety of plants and animals.

Divide the class into four groups and, using quadrats or line transects, let them investigate and record the plants and animals living in the given habitat. A diagram of a suitable quadrat is shown below. At the end of the session, the four habitats can be compared.



At the end of the session, the students could discuss how the methods they used to collect the data could be improved. Help them to think, in particular, about sample size. The students can also write a summary linking the abiotic factors of the habitats with the plants and animals living there.

As alternatives to the fieldwork outlined above, the students could identify the living organisms in leaf litter collected from two different woods or forests. They could then compare the numbers of species and relate their findings to the plant life and physical conditions in the two areas of woodland. If there is space in the school grounds, the longer-term activity described on Worksheet 4 could also be carried out.

Ideas for investigation and extension work

IMPORTANT: With all investigations where small animals are caught or trapped, it is important that they are released back into their natural habitat, or a closely similar one, as soon as possible after your work is finished.

Area of plant leaves

You know that leaves are the main organs of photosynthesis and therefore the starting point for food chains. Are leaves bigger in the shade where light levels are lower? Ask the students to investigate by collecting, say, twenty leaves from a plant growing in full sunlight, and twenty leaves from plants of the same species growing in the shade. Ivy plants are good ones to start with. Devise a way of measuring the surface area of the leaves. Find the average surface area of the leaves from the plants growing in the shade and compare that figure with the average for the leaves from plants growing in full sunlight. Is there a difference?

Food chains

Observe and draw some food chains involving birds in the school grounds or a local park or public garden.

Animal life of leaf litter

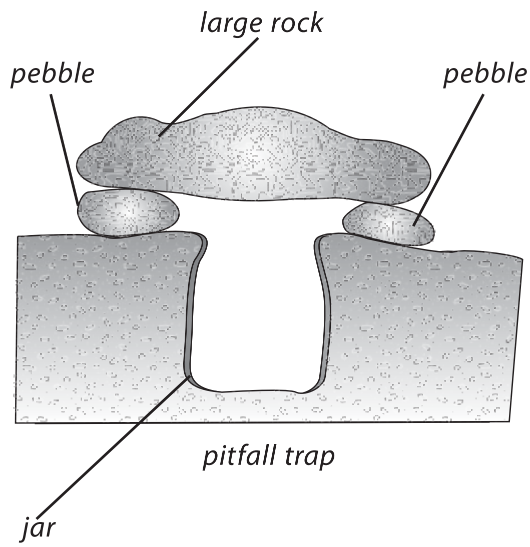
The leaf litter which accumulates under trees often contains a large variety of invertebrate animals. These can be extracted by standing a large funnel over a jar or bottle. Put a handful of the leaf litter in the funnel and shine the light from a desk lamp about 20 cm above the litter. The heat and light from the lamp will make the small invertebrate animals move down deeper into the funnel, until they eventually fall through into the jar below. Compare the invertebrate animals living in the leaf litter from different species of trees.

Animal life in long grass

Use a strong net to sweep through long grass or other herbaceous plants. Examine and count the different invertebrate species caught. How many of them are camouflaged?

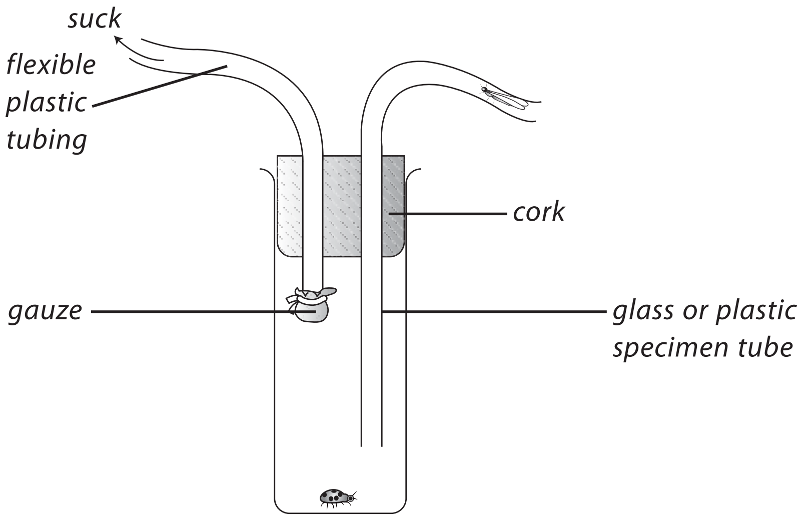
Using a pitfall trap

Make a series of pitfall traps like the one shown to catch the insects and other small animals that crawl across the ground at night. Investigate the animals that live under different types of trees or in grasses of different heights. It is important to check the traps several times each day. Remember to immobilise the traps, or dig them up, immediately after you have finished using them.



Make a pooter

A pooter is very useful for picking up tiny animals which are too small to handle.



A pooter

Using a line transect

You may have noticed that the plants growing in one place differ from those in another. The vegetation growing where a playing field is regularly trampled may be different from the vegetation either side of this path. You can map the changes by using a line transect. A length of string or plastic clothes line is stretched across the area you want to examine. You then record all the plants (and animals too, if you wish) that grow along the line. If the distances involved are too great, then map the plants which occur every 10 cm or 20 cm.

Fleas

Look at a prepared microscope slide of a flea under the low power of a microscope. Look at the shape of the body. Notice in particular how flat the body is. Study the mouth parts and legs closely.

a) Why do you think the body of the flea is flat?
b) What can you see at the end of each leg? Suggest reasons for these.
c) In what ways are the mouth parts of the flea adapted for sucking blood?
d) Briefly describe how a flea could carry a disease from one person to another.

Slugs and snails

Design and carry out an investigation to find out how much food a slug or snail eats in a day.

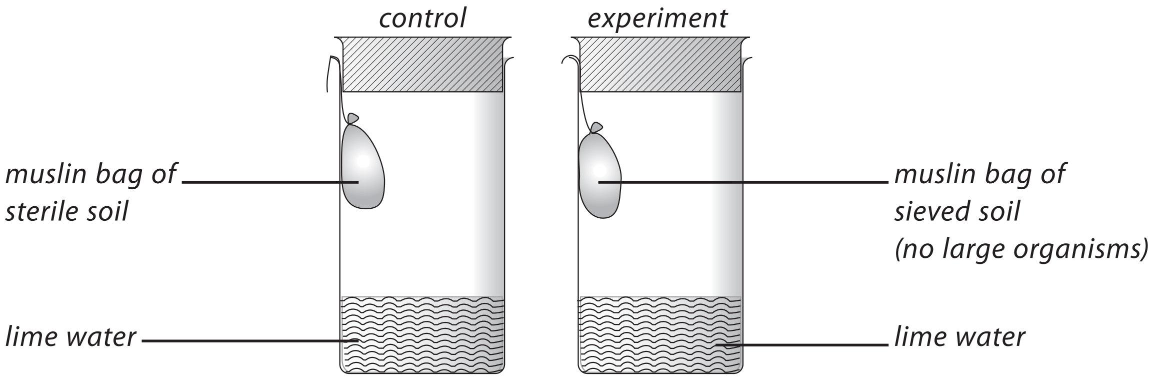
Decomposition

Investigate the rate at which a fruit, such as an apple, banana, or tomato, decomposes when placed in different parts of a garden. Do different fruits decompose in different ways?

Micro-organisms in the soil

Micro-organisms in the soil include bacteria, fungi, and single-celled animals—protozoa. They live in the water film around the soil particles. Most bacteria and fungi are decomposers. The protozoa feed on the bacteria and fungi.

You can show the presence of micro-organisms by the experiment shown in the diagrams below.



The sterile soil needs to be heated to 100°C for a few minutes, while the experimental vessel contains ordinary garden soil that has been sieved to remove any stones and larger organisms. Once the tubes have been set up, leave them for a few days. The lime water in the experimental vessel should turn milky, as a result of the carbon dioxide produced by the micro-organisms when they respire. The lime water in the control tube should remain unchanged.

WORKSHEET 1

Animal adaptations

Materials needed: pen or pencil; the use of the Internet or reference books and encyclopedias

All animals have adaptations that enable them to live in their own habitat. These adaptations allow the animal to feed, respire, move, and find a mate, and also protect it from predators.

Find out all you can about some endangered animals and how they are adapted to live in their particular habitat. Complete the table below. The first has been started for you.

Animal species	Habitat	Adaptation	Forest
tiger	forest	vertical stripes	camouflage protection against enemies; hides animal from its prey.

WORKSHEET 2

Plant adaptations

Materials needed: pen or pencil; the use of the internet or reference books and encyclopedia

All plants have adaptations that enable them to live in their own habitat. These adaptations allow the plant to receive light for photosynthesis, to respire, to produce and disperse seeds, and sometimes also protect it from grazing animals.

Find out all you can about some plants, either wild or cultivated, and research how they are adapted to live in their particular habitat. Complete the table below. The first has been started for you.

Plant species	Habitat	Adaptation	Forest
cactus	desert	spines which are modified leaves	reduce evaporation of water and protect the plant from grazing animals

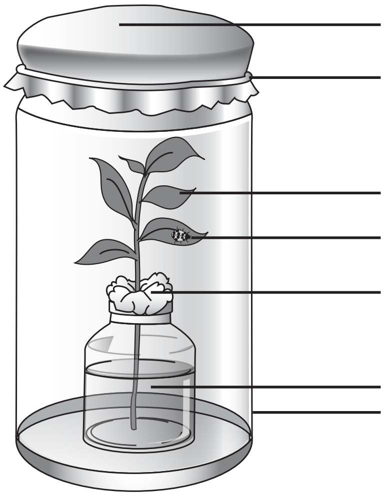
WORKSHEET 3

Studying a food chain

Materials needed: a large plastic sweet jar; piece of muslin or tights; elastic band; small plastic bottle; cotton wool; plastic spoon and small paintbrush; hand lens or magnifying glass; a ladybird; a leafy shoot with aphids on it

Ladybirds are predators or consumers that feed on aphids called greenfly and blackfly.

1. Find a plant which has aphids on it, such as a rose bush, broad bean plant or sycamore tree.
2. Carefully pick a shoot of the plant with aphids on it. Stand it in a small bottle of water. Plug the top of the bottle with cotton wool to stop the insects falling into the water.
3. Stand the small bottle and leafy shoot in the bottom of a large jar.
4. Use the plastic spoon and small paintbrush to carefully put a ladybird on the leafy shoot.
5. Put the cover made of muslin or tights on the large jar.



Watch carefully to see how the aphids eat the plant shoots. You may need to use a hand lens or magnifying glass for this. Record your observations here. ______________________

____

How does the ladybird catch and eat the aphids? ______________________

____

Does the ladybird eat all of each aphid? If not, what parts of the aphids does it leave? ______________________

____

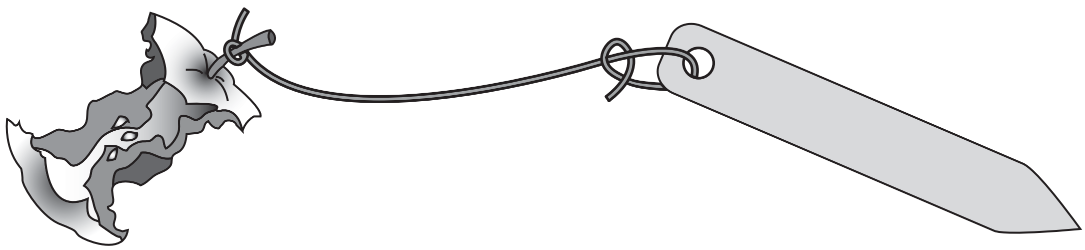
Draw and label the food chain you have just been studying.

WORKSHEET 4

Investigate the decomposition of litter

Materials needed: four or five pieces of waste organic materials (e.g. apple core, orange peel, banana skin; cabbage leaf; dead tree-leaf); small wooden pegs or plant labels; gardening gloves; string; garden trowel or hand fork; large sheet of paper

1. Tie each of the waste materials to a wooden peg or plant label, like this:



2. Write on each peg or label what the waste material is.
3. Bury each material in a flowerbed next to its label.
4. After about a month, look carefully at each of the materials. Wear gloves for this. How have the materials changed?
5. Bury the materials again for another month. Then, wearing gloves, look at them again.

Record on a wall chart how the materials have changed, after one month and after two months.

Try this experiment with other materials.

Which organic (once living) materials are the slowest to rot? ______________________________

____

Was your experiment fair? If not, how could you make it fairer? ______________________________

____

Answers to questions in the Students' Book

1. A habitat is the place where an organism lives and reproduces.
2. A habitat is the place where an organism lives and reproduces. The conditions in the organism's habitat, such as how hot, cold or wet it is, make up the organism's environment.
3. An ecosystem is all the plants and animals in a particular habitat and the way they interact with each other and their non-living environment. Examples of ecosystems include a pond, a rotting log, a forest, a desert, or even a large tree.
4. In order to survive, all animals need food, water, air or oxygen, shelter and protection, and somewhere to breed.
5. Adaptation is the way in which a plant or animal is suited to living in its particular habitat. If an animal is adapted to its environment then its body shape, colour, type of food, and method of catching its food, are all suited to the place in which it lives.
6. A land animal's environment can change from one part of the day to another as the position of the Sun overhead changes, as the temperature rises and falls, and if it rains. A sea animal's environment might change with the tide. If the animals lived in a rock pool the water would become more and more salty as the Sun evaporated the water. The temperature of the water in the rock pool would also rise. If there was sudden heavy rain, the salt water in the pool would be diluted and its temperature would fall.
7. The main changes to a plant's environment from season to season would be in the amount of daylight and the temperature. In winter, there might be so little daylight with such low temperatures that the plant would become dormant until the spring.
8. The number of species that can survive in a habitat depends on how well each species is adapted to its environment, how much competition there is between the species for light, mineral salts and water in the case of plants, and for food, water and breeding sites in the case of animals. The number of species also depends on how much predation there is in the habitat. In other words, a species will survive if it can avoid being eaten by another species.
9. Some animals sleep or hibernate to survive cold winter weather. In hot, dry weather some animals undergo a special kind of rest or sleep called aestivation. Other animals avoid severe weather by migrating to places where food is more plentiful and the weather is better.
10. The flowers which close during the day and open at night are mainly those which are pollinated by night-flying moths and other insects, or by certain kinds of bats.
11. The two main groups of decomposers are bacteria and fungi. Like animals, they obtain their energy and nutrients by breaking down ready-made food (in this case dead living organisms) into simpler substances.
12. Life on Earth could not continue if there were no decomposers, because there are only limited amounts of mineral salts available for plants and animals, and bacteria and fungi recycle these nutrients. In addition, without decomposers the surface of the Earth would quickly become covered with the bodies of dead plants and animals.

13. The arrows in a food chain or food web show which animal feeds on which other animal or plant. More importantly, the arrows show the direction in which energy flows in a food chain or food web.
14. Most food chains have only two, three, or four consumers after the green plant producer because a great deal of energy is lost at each stage of a food chain.
15. i) If the top predator in a food chain increased in number, the animals that predator fed on would be severely reduced in number. With no herbivores to feed on the plants, they would increase in number. ii) If the plant producers increased in number, then there would be more food for the herbivores, and they would increase in number. With more herbivores, the number of carnivores would also soon increase.
16. It is likely that the weed-killer killed all the plants, except for the wheat plants, as it was intended to. If the mice and other small mammals fed on these weeds, or obtained an important nutrient from them, then the number of mice and other small mammals would decrease. This would cause the owls to begin to die of starvation. Alternatively, the mice and other small mammals could have been poisoned by eating the weeds that had been sprayed with weed-killer. If the owls ate large numbers of the poisoned mice and other small mammals they would accumulate the poison in their bodies and die.

Assessment

Question 1

Which of the following is a producer?

(A) green alga (B) water spider (C) minnow (D) perch

Question 2

A student saw a sparrow eating a caterpillar. Later she noticed that the mango tree in her garden was covered in caterpillars. A food chain linking these organisms is:

(A) caterpillar → mango tree → sparrow
(B) mango tree → caterpillar → sparrow
(C) mango tree → sparrow → caterpillar
(D) sparrow → caterpillar → mango tree

Question 3

A crow eating a dead rat is an example of a:

(A) decomposer (B) herbivore (C) producer (D) scavenger

Question 4

Why is an apple tree called a producer?

(A) Its leaves fall off in autumn.
(B) It makes food by photosynthesis.
(C) It has fruits we can eat.
(D) Its leaves do not rot in the soil.

Question 5

When energy is transferred between the links in a food chain, a great deal of it is lost at:

(A) every stage (B) the first stage (C) the last stage (D) the middle stage

Question 6

It is better for animals to eat plants because:

(A) there is not enough meat to go round
(B) there is a lot of land to grow plants on
(C) there is a greater variety of food
(D) there is a more efficient transfer of energy

Question 7

Rice is a good source of food because:

(A) lots of things can be made from it
(B) pests do not like it
(C) it does not need fertilizer
(D) it contains lots of energy

Question 8

Two organisms living together so that they both benefit from the relationship is called:

(A) commensalism (B) mutualism (C) parasitism (D) saprophytism

Question 9

A community is a collection of:

(A) different organisms living in different places
(B) different organisms living in the same place
(C) similar organisms living in different places
(D) similar organisms living in the same place

Question 10

A population is:

(A) a group of organisms of the same species
(B) a collection of habitats
(C) a group of different species
(D) the number of different species

Question 11

A farmer ploughed up 100 hectares of his land. What would happen if the land was left alone for 200 years?

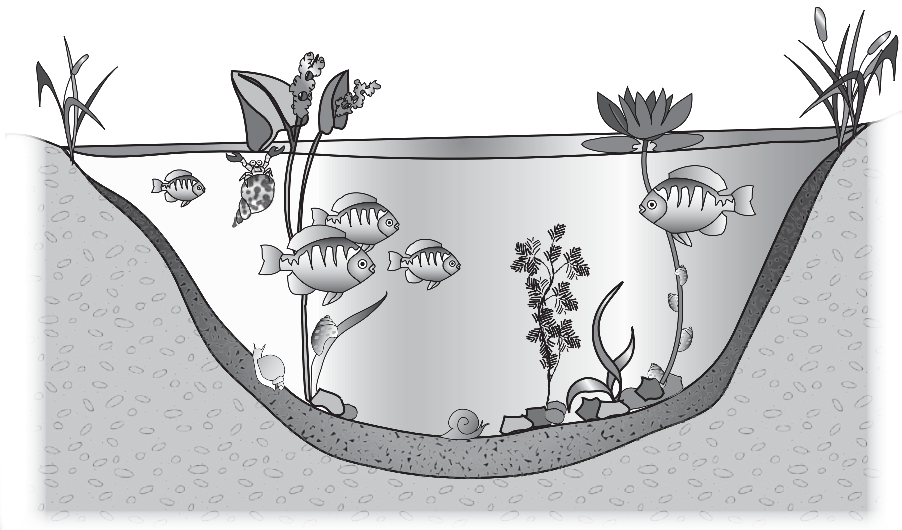
(A) It would stay bare soil.
(B) It would be covered in grass and weeds only.
(C) It would be covered in grass and shrubs only.
(D) It would be covered in grass, shrubs, and trees.

Question 12

Complete the passage below using words from the list. You may need to use some words more than once.

compete	food chain	habitat	oxygen	photosynthesis
primary consumers	producer	respiration	top consumers	community

The diagram shows a section through a small pond.



pond

A number of different organisms live in a pond. A place where organisms live is called a ________________. The organisms that live in the pond make up a ________________. The pond weed can produce its own food by ________________. Because of this it is called a ________________. The snails eat the pond weed and so they are called ________________. The fish eat the snails and so they are called the ________________ in this pond. Listing the organisms in this way, to show the passage of food and energy, is called a ____________. The organisms in this pond habitat rely on each other for more reasons than just food. The pond weed produces ________________ gas by ________________. The animals then use this gas for ____________. If a different type of fish is introduced into this pond, these fish may also eat pond snails. Then they may ________________ with the original fish for food.

Question 13

Draw lines to connect the words on the left with their correct meanings:

carnivores	animals that can eat both plants and animals
parasites	animals that eat plants
omnivores	animals that eat other animals
herbivores	organisms that obtain their food from another living organism
consumers	organisms that can make their own food
producers	organisms, such as bacteria and fungi, that feed on dead plants and animals
decomposers	organisms that rely on other organisms for their food

Question 14

Place the words and phrases in the box into the most appropriate column of the table below.

eats plants	rabbit	fungi	secondary consumer
makes its own food	eats meat	primary consumer	photosynthesis
plants	vegetarian	breaks down dead organic matter	

Producers	**Herbivores**	**Carnivores**	**Decomposers**

Question 15

Which of these statements is TRUE and which are FALSE?

a) Most of the energy that an animal eats is lost to its surroundings as heat. ____________

b) Food chains are never more than three or four organisms long because most animals are very fussy about what they eat. ____________

c) Food chains are usually only three or four organisms long because of the amount of energy lost at each stage. ____________

d) About 10 per cent of the energy an animal takes in is transferred to movement energy. ____________

e) About 50 per cent of the energy that an animal takes in is passed on to the next animal in the food chain. ____________

f) Energy enters a food chain as sunlight. ____________

g) The features that make organisms well suited to their habitat are called adoptions. ____________

h) When two or more organisms of different species work together so that both benefit, this is called mutualism. ____________

i) The most common resource that animals compete for is food. ____________

j) Because plants can make their own food they are called consumers. ____________

Question 16

a) There are ten lettuce plants, five slugs, and two starlings in a food chain. Show this information as a pyramid of numbers diagram.

b) Look at this food chain.

rose bush ⟶ greenfly or aphids ⟶ ladybirds ⟶ thrushes

(i) Which is the producer in this food chain? ____________

(ii) Which are the predators in this food chain? ____________

(iii) What is another name for a predator? ______

(iv) Why do rose bushes grow better if there are lots of ladybirds in the garden? ______

______

(v) One year the rose bushes became infected by a disease and there were fewer of them. What were the effects on the rest of the food chain? ______

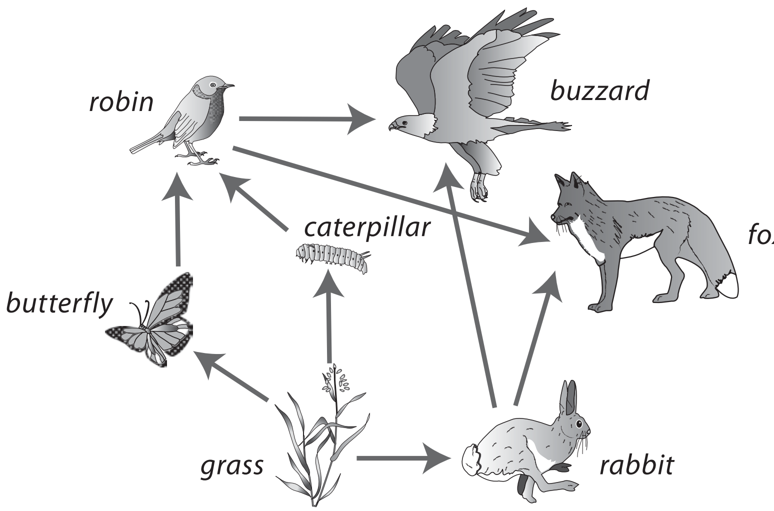
______

(vi) Where does the energy in a food chain come from? ______

(vii) Many food chains linked together make a more accurate picture of what eats what. What are linked food chains called? ______

Question 17

The diagram below shows part of a food web for grassland.



a) Name the producer in the food web. ______

b) Name a secondary consumer. ______

c) Explain the importance of producers in the food web. ______

______

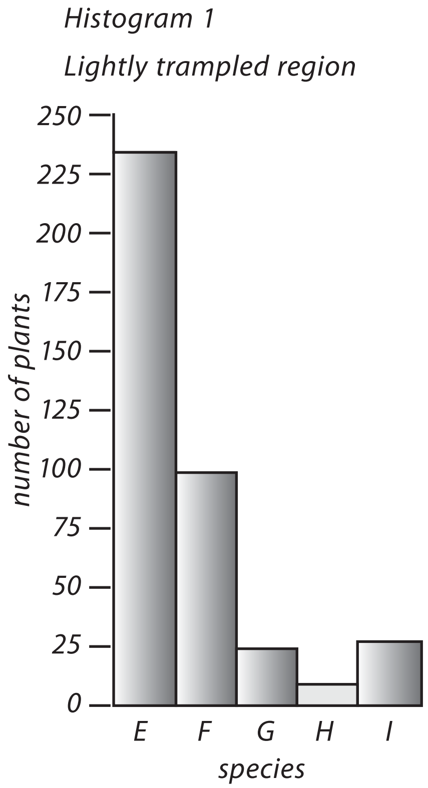
d) Only a small part of the energy in the rabbit is available to the fox. Suggest two reasons for this.

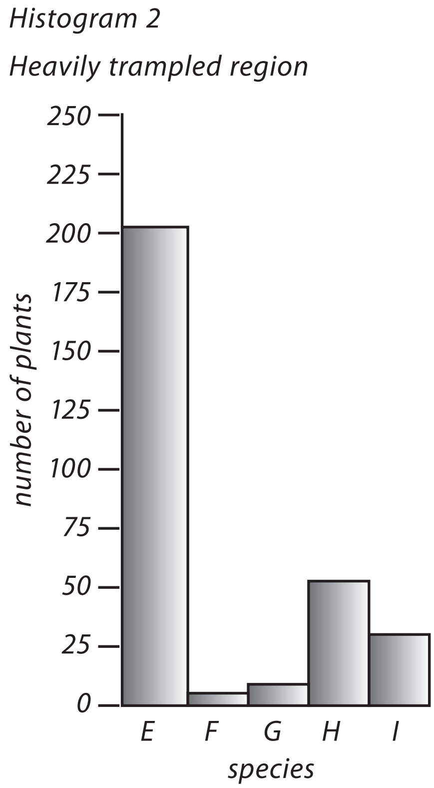
i) ______

ii) ______

Question 18

A group of students studied two areas of grassland, one lightly trampled and the other heavily trampled. The histograms below show the numbers of plants of five different species they found in random samples taken within each of the two regions.





a) How many of species E were found in each region?

i) lightly trampled region ______________ ii) heavily trampled region ______________

b) How many of species G were found in each region?

i) lightly trampled region ______________ ii) heavily trampled region ______________

c) What is the effect of increased trampling on species G and H?

____

____

d) Which species is most affected by trampling? ______________

e) Which species is least affected by trampling?

f) How would the students have obtained random samples of the plants in the two areas?

____

____

Answers to assessment questions

Question 1 (A) **Question 2** (B) **Question 3** (D) **Question 4** (B) **Question 5** (A)
Question 6 (D) **Question 7** (D) **Question 8** (B) **Question 9** (B) **Question 10** (A)
Question 11 (D)

Question 12

A number of different organisms live in a pond. A place where organisms live is called a **habitat**. The organisms that live in the pond make up a **community**. The pond weed can produce its own food by **photosynthesis**. Because of this it is called a **producer**. The snails eat the pond weed and so are called **primary consumers**. The fish eat the snails and so they are called the **top consumers** in this pond. Listing the organisms in this way, to show the passage of food and energy, is called a **food chain**. The organisms in this pond habitat rely on each other for more reasons than just food. The pond weed produces **oxygen** gas by **photosynthesis**. The animals then use this gas for **respiration**. If a different type of fish is introduced into this pond, these fish may also eat pond snails. Then they may **compete** with the original fish for food.

Question 13

carnivores	animals that eat other animals
parasites	organisms that obtain their food from another living organism
omnivores	animals that can eat both plants and animals
herbivores	animals that eat plants
consumers	organisms that rely on other organisms for their food
producers	organisms that can make their own food
decomposers	organisms, such as bacteria and fungi, that feed on dead plants and animals

Question 14

Producers	Herbivores	Carnivores	Decomposers
makes it own food plants photosynthesis	primary consumer eats plants rabbit	eats meat secondary consumer tiger	fungi bacteria breaks down dead organic matter

Question 15

a) Most of the energy that an animal eats is lost to its surroundings as heat. TRUE

b) Food chains are never more than three or four organisms long because most animals are very fussy about what they eat. FALSE

c) Food chains are usually only three or four organisms long because of the amount of energy lost at each stage. TRUE

d) About 10 per cent of the energy an animal takes in is transferred to movement energy. TRUE

e) About 50 per cent of the energy that an animal takes in is passed on to the next animal in the food chain. FALSE

f) Energy enters a food chain as sunlight. TRUE

g) The features that make organisms well suited to their habitat are called adoptions. FALSE (the correct word is adaptations)

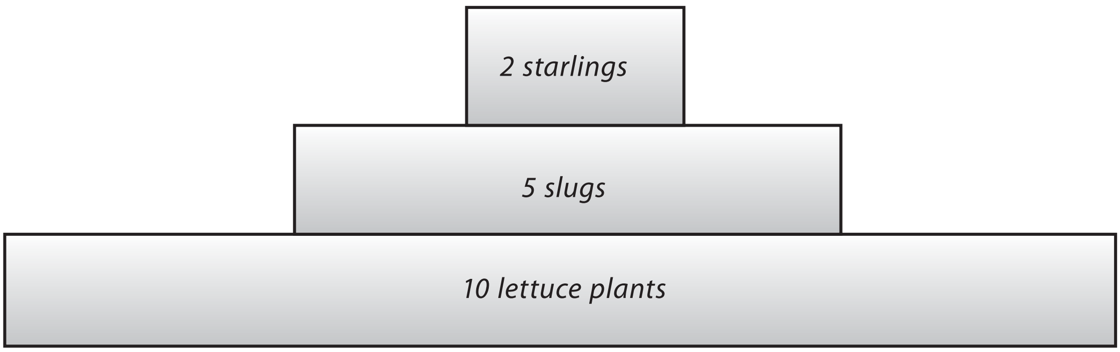
h) When two or more organisms of different species work together so that both benefit, this is called mutualism. TRUE

i) The most common resource that animals compete for is food. TRUE

j) Because plants can make their own food they are called consumers.FALSE

Question 16

a)



b) Look at this food chain.

rose bush	greenfly or aphids	ladybirds	thrushes

(i) The producer in the food chain is the rose bush.

(ii) The predators in this food chain are the ladybirds and thrushes.

(iii) Another name for a predator is a carnivore or consumer.

(iv) Rose bushes grow better if there are lots of ladybirds in the garden because the laydbirds eat the greenfly or aphids and so the rose bush does not get eaten.

(v) If the rose bushes became infected by a disease and there were fewer of them, then there would be fewer animals as there would be less food for them to eat.

(vi) The energy in a food chain comes from the Sun (or sunlight).

(vii) Linked food chains are called food webs.

Question 17

a) The producer in the food web is the grass plants.

b) The robin, fox, and buzzard are secondary consumers.

c) Green plants are the only organisms that can make their own food using sunlight energy (by photosynthesis), and they provide the energy for all the other organisms in a food web.

d) Only a small part of the energy in the rabbit is available to the fox because the rabbit uses energy when it feeds, moves, grows, reproduces, excretes and it also uses energy to keep itself warm. Much of the energy the rabbit acquires is lost as heat. If the fox catches the rabbit, it is unlikely to eat all of it, and the bones and fur will be discarded, or some of the rabbit is passed out in the fox's droppings.

Question 18

a) Number of species E that were found in each region:

i) lightly trampled region—approximately 228 ii) heavily trampled region—approximately 202.

b) Number of species G that were found in each region:

i) lightly trampled region—approximately 25 ii) heavily trampled region—approximately 3.

c) Increased trampling decreases the number of species G, but increases the number of species H.

d) Species F is most affected by trampling.

e) Species I is least affected by trampling.

f) The students could have obtained random samples of the plants in the two areas either by throwing quadrat frames at random and recording the numbers of each species within each frame, or by making a line transect across the two areas and recording the plant species which occurred at pre-determined intervals.

Water, water everywhere

CHAPTER 7

Teaching Objectives

- To explain the vital importance of clean water for humans and other living organisms
- To identify the main sources of fresh water
- To recognize that water contains many dissolved substances
- To outline the processes involved in the purification of water
- To examine the many uses of water in our country and to emphasize the necessity for water conservation

Learning Outcomes

After studying this chapter students should be able to:

- describe the ways in which clean water is vital for meeting the needs of humans and other living things
- identify the sources of water
- recognize the substances present in water that make the water impure
- suggest different ways to clean impure water
- describe the various uses of water in our country
- investigate the consumption of water in daily life and suggest ways to reduce wastage of water

Introduction

Water is a common everyday substance and most students probably consider that they are already very familiar with it. The work contained within this chapter covers a very wide range, but the way in which water affects our lives is a common theme throughout.

The basic problem is that, although there is an abundance of water on Earth, most of it is not available for us to use. In fact only about 2 per cent of the world's water is fresh, but more than three-quarters of that is locked up as ice in the polar ice caps and glaciers. As a result, only a tiny proportion of the world's water is accessible to us because it is part of the water cycle. At one time, humans made little impact on the water cycle, but in the past 100 years or so this has changed. We now use so much fresh water in our homes, power stations and factories, and on our farms, that in some places supplies are running out.

Water shortages

People in many parts of the world are desperately short of water, and the problem is getting worse. According to the United Nations Environment Programme, about 20 per cent of the world's population lacks access to safe drinking water. Wasteful use of water and poorly planned irrigation systems are having a devastating effect on communities and the environment they depend upon. People need clean, fresh water to drink. They need water for sanitation, and for their crops and livestock. Droughts cannot be prevented, but even small amounts of rainfall can go a long way if they are carefully collected and stored

Problems with irrigation projects

The Aral Sea in western Asia was one of the world's largest lakes. But large-scale desert irrigation projects built by Russia in the 1960s diverted the rivers that used to feed it. Today, the lake has lost two-thirds of its water. The surrounding farmland has returned to desert. Salt flats cover the dried-up lake bed, and the local fisheries have been ruined.

Closer to home, for more than forty years, billions of litres of water have been drawn from Pakistan's Indus River to feed farm irrigation schemes. Now an ecological disaster threatens. Much of the farmland has been turned into infertile salt flats. These are formed when mineral salts in the soil are drawn up to the surface as irrigation water evaporates. This rock-hard layer is toxic to plants and too hard to plough.

Science to the rescue

Fortunately science is coming to the rescue. It is possible to build low earth or stone-wall dams on sloping ground to hold back precious rainwater and help it to soak into the ground. Crops can draw on the stored water even through dry periods. New cultivation methods, such as hydroponics, allow farmers to feed and water their greenhouse crops with much less waste. Tomato plants, for example, are grown without soil in bags filled with gravel. Just the right amount of water containing nutrients can be pumped through the gravel directly to the plant roots. Fruit trees can be grown in rows, even in hard, tightly packed soil. In between each pair of rows is a trench loosely filled with small pieces of rock and stone. A plastic pipe with small holes in it is buried in the rock and stone, supplying water directly to the tree roots and minimising the amount of water lost by evaporation. This method of irrigation produces 15 per cent more fruit than the old methods, which simply involved spraying water onto the surface of the soil.

Lesson suggestions

Only two lesson plans are included here. These could both be split up, if time is available, so that they occupy several class periods. In addition, a visit to a water treatment works or sewage treatment works, and field work to study water pollution would all be valuable additions to the work.

1. Where our water comes from

Refer to page 76 of the Students' Book

Starter suggestions

Ask the students to write down ten facts about water. Discuss their results and summarize them on the board for the class to copy.

Revise the students' knowledge of the water cycle, with the aid of Worksheet 1.

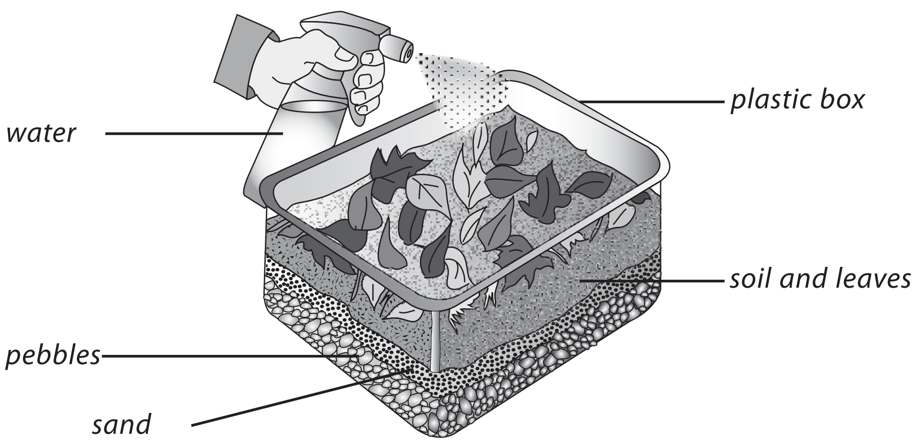
Main lesson

Revise the processes involved in the water cycle and remind the students that on Earth we have only a limited, or finite amount of water. Thanks to the water cycle, we are able to use the same water over and over again. Let the class make the model of the water cycle explained on Worksheet 2.

Most water does not naturally exist in a pure form, or in a form that is safe for people to drink. That is why water must be cleaned before we drink it. Water companies provide such treatment before water is sent through pipes to homes in the community.

The demand for water varies and the availability of water also varies in different places and at different times of the year. To meet these variations, water companies may store extra water in reservoirs. Water is usually contained in reservoirs by a dam. Reservoirs help to ensure that communities do not run out of water and any given time.

Make a model of a reservoir using a clean, clear-plastic box. Line the bottom of the box with small pebbles, and then layers of sand, and soil with some leaves on top. Carefully spray water on to the four corners of the model until the soil mixture is saturated and the water has seeped through to the open area (the reservoir).



Here are some questions you might ask the students: Where does the water in the reservoir comes from? (precipitation in the form of rain or snow, melting glaciers, and rivers and streams and other lakes higher up the hill or mountain)

How does the water get into the reservoir? (It seeps over and through the soil above the reservoir.)

What contains or holds the water in a real reservoir? (dams, made of earth and rocks or, more usually, reinforced concrete)

What kind of natural treatment does water receive in a reservoir? (natural filtration through leaves, grass, rocks, and soil. Some settling also occurs in the reservoir)

What else can the water in a reservoir be used for besides providing drinking water? (irrigation of crops, fish farming, production of hydro-electricity, and leisure activities such as boating and sailing)

Go on to explain that many people obtain their water supplies from wells and groundwater. Ask the students to explain what they think groundwater is. (Many adults still think of groundwater as being an underground lake or river.)

Take the students outside into the school grounds. Take a watering can of water and pour water onto unpaved ground. Ask them to pretend that it is rain. What happens to the water? (First it makes a puddle, then it soaks into the ground.)

Fill a clear-plastic cup, beaker or jar with sand, and another with gravel. Pour water into each of the containers until it reaches the top. Ask the students to observe how the water fills the spaces between the gravel or sand particles.

Explain that when we refer to groundwater we are talking about that part of the soil or underlying rocks where all the pore spaces are saturated with water. When it rains, some of the rain (or other precipitation) sinks into the soil. It moves through the spaces or pores between the particles until it eventually reaches an impermeable layer of clay or some other rock and begins to fill the pore spaces of the soil. Explain that the water table is the place where the rocks or soil become saturated and the drier soil ends.

Explain to the students that many people use groundwater as a source of drinking water or as a source of water to irrigate crops. Wells are dug down below the water table, so that the ground water can be pumped up to the surface. Explain that when water seeps down through the soil it is filtered by the soil and other rock particles. However, water from a well can easily be contaminated by dissolved chemicals, including pesticides, and also by bacteria and viruses in sewage.

Complete this part of the work by either demonstrating, or letting the students carry out, the water filtration activity on Worksheet 4. You might also want them to carry out a survey of the use of water at home, as described on Worksheet 3.

2. Water pollution

Refer to page 81 of the Students' Book

Starter suggestions

Ask the students to list all the ways they can think of in which water becomes dirtied or polluted. The answers they put forward may include litter, sewage and waste water, industrial pollution, agricultural chemicals and manure, oil pollution of the oceans and seas, underground storage leaks of chemicals, oil and petrol, acid rain, heat from power stations, and eutrophication. The latter is the process whereby aquatic plants such as algae grow rapidly because of the presence of dissolved fertilizers or untreated sewage which are rich in nitrates and phosphates. The aquatic plants, and the bacteria which feed on their decaying remains use up the oxygen in the water. This causes the death of fish and other water life.

Discuss which they think are the most important causes of water pollution in the area where they live.

Main lesson

Begin the lesson by showing the students that clear water is not necessarily free from pollutants. Take five perfectly clean, clear, plastic beakers or drinking glasses. Label them A to E. Fill the containers with substances that have a distinctive taste the students will recognize. These could include sugar solution, white vinegar, salt solution, water with citric acid dissolved in it, and tap water.

Have the students taste each of the five samples of liquid using cotton swabs (dispose of the swab after each taste). Ask the students to record what they taste in each of the containers. After all the students have had a chance to taste the samples, explain that not all forms of pollution can be seen. This is particularly true of dissolved chemicals and the presence of dangerous bacteria and viruses.

If possible then proceed to investigate a local rivers, stream, pond or lake for the presence of pollution, using Worksheet 5. Strict supervision of this activity is essential, and the students will need to be equipped with rubber gloves and plastic rubbish bags, as well as the more usual collecting equipment.

Complete the work by discussing where any pollution of the water came from and what can be done to prevent it happening again in the future. You might also want to discuss the case study described on Worksheet 5.

Ideas for investigation and extension work

Dissolved salts

Collect samples of water from different places along a river or stream. Filter each in turn and evaporate known volumes to dryness in a weighed evaporating basin. Compare the weight of dissolved salts in 100 cm^3 or 1 litre of the water at different points along the river or stream.

Water filter

Have a class contest to see who can design and make the best water filter. To make the contest a little fairer, stipulate that the basis of the filter should be a plastic bottle from which the bottom has been removed to turn it into a large funnel. Test each filter with tap water to which a little soil has been added.

Are you water friendly?

Working in groups, ask the students to create a simple questionnaire consisting of, say, ten questions to see whether they, and friends and relatives, are 'water friendly'. Questions to include might be 'Do you have any dripping taps in your home?', 'Do you clean your teeth under a running tap?', and 'Do you use a hose to water your garden or wash your car?' Devise a score to show how 'water friendly' the people who answer the questions are.

A water game

Devise a board game consisting of a curved series of parallel loops divided up into small numbered squares to represent a river from its source in the mountains to its mouth at an ocean or sea. Prepare a set of question cards to be answered when a player lands on a box that says 'Pick a card'. The other players decide whether the answer given is correct or not. At intervals have pictures and statements to indicate that the person who lands on that square misses a turn, goes back two or three squares, or advances two or three squares. The first person to reach the sea is the winner!

Water in food

Collect a range of food substances, including fruits, vegetables, bread, and possibly a sample of meat. Ask the students to devise an experiment to find out how much water is present in each food.

Reservoirs

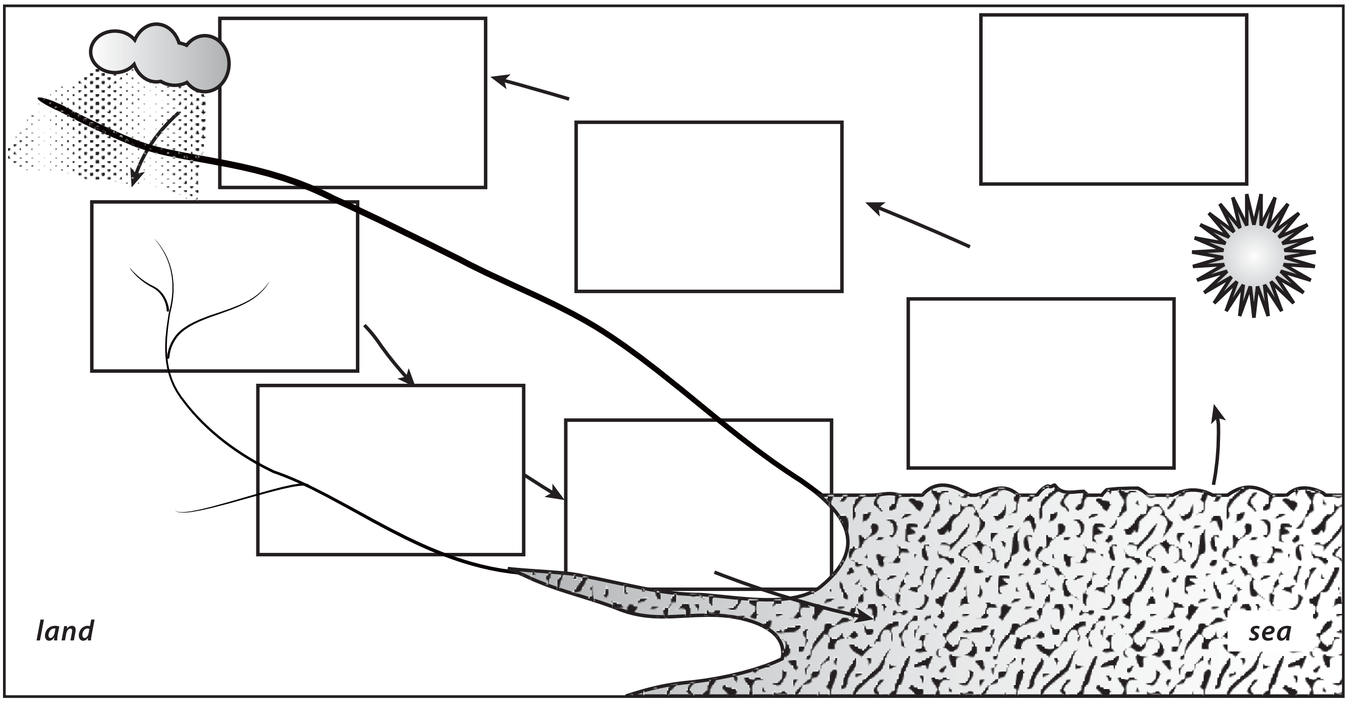
Find out how many reservoirs there are in Pakistan and where they are sited. Draw a map of Pakistan and mark the reservoirs on the map.

Find out which reservoirs provide water for your home and your school and how water is brought from the reservoir to your home or school.

WORKSHEET 1

Do you understand the water cycle?

Materials needed: paper paste or glue; scissors



Water vapour rises in the warm air.	*Rain falls and seeps through the ground to form streams.*	*Streams join up to form rivers.*	*Waste water passes down drains and sewers and runs down towards the sea.*
Clouds move towards the land on onshore winds.	*Water taken from water-treatment works and used in homes and factories.*	*Air rises and cools when it comes from sea to land. Water vapour condenses and forms clouds.*	*The Sun causes water to evaporate from the sea and other wet surfaces.*

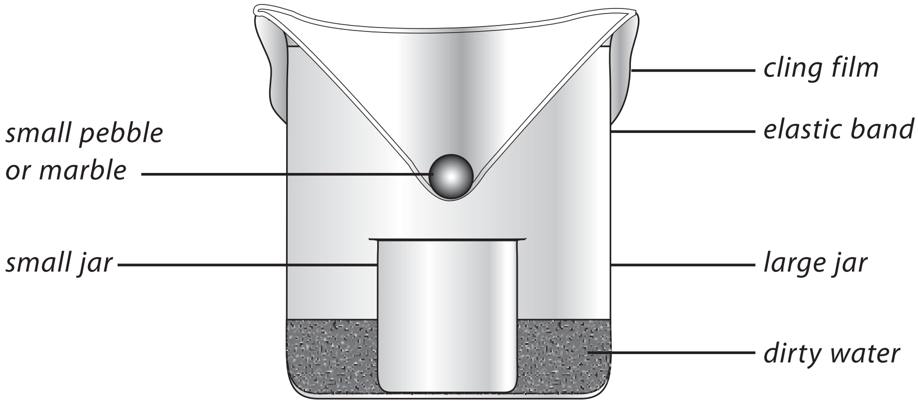
Cut out the boxes and stick them in the correct places in the drawing of the water cycle.

WORKSHEET 2

A model of the water cycle

Materials needed: a large clear-glass jar or a large beaker; cling-film or thin polythene sheeting; a small jar or beaker; a small pebble or marble; an elastic band; soil or food colouring; measuring jug or measuring cylinder; water

1. Stir a little soil or a few drops of food colouring into 500 cm^3 of water in a measuring jug or measuring cylinder.
2. Stand the small jar in the centre of the large jar or beaker.
3. Carefully, without splashing, pour some of the dirty water into the large jar to a depth of a few centimetres.
4. Cover the large jar loosely with cling-film or thin polythene sheeting. Press the centre of the cling-film or plastic sheeting so that it forms a cone shape. Use a small pebble or marble to hold it down.
5. Fasten the cling-film or plastic sheeting in place with an elastic band.
6. Stand the apparatus on a sunny windowsill. Look at it carefully over the next day or so.



What changes have occurred? ______________________________

Explain what has happened. ______________________________

____

WORKSHEET 3

How much water do you use?

Materials needed: a pen or pencil

How much water does your family use each week? The chart below shows the average amount of water used each time you do the activity listed in the first column.

Activity	**Average amount of water used (litres)**	**Number of times each activity is carried out in a week**	**Weekly total of water used**
washing hands	1		
cleaning teeth	1		
shower	30		
bath	110		
cup of tea/coffee	0.25		
washing up by hand	5		
dishwasher	60		
washing machine	110		
flushing toilet	10		
watering garden with watering can	25		
watering garden with hose	23 per minute		
washing car with hose	23 per minute		

1. Carry out a survey of your family's water use. Record your results in the table above. You may need to use a calculator to help you work out the totals.
2. Make a bar chart to show how the water was used. Colour the bars and make a key for the chart.

   Now answer these questions:

   Which activity used most water? ______________________

   Which activity used least water? ______________________

   What could your family do to reduce the amount of water used? ______________________

   ____

   If you can, analyze the class results of this activity using a computer spreadsheet.

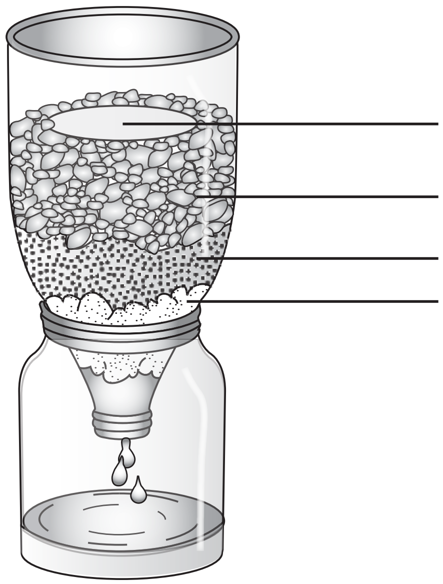
WORKSHEET 4

How can we clean dirty water?

Materials needed: large plastic bottle; two clean, transparent plastic jars or beakers; cotton wool; clean sand; clean washed gravel; soil; water; circle of paper; scissors.

The water we drink comes from rivers, lakes and wells, but first it has to be cleaned. This experiment is a model of the filters used at the water works.

1. Carefully cut the bottom off the plastic bottle. Stand the top part of the bottle upside down in a clean jar or beaker.
2. Put a layer of cotton wool in the bottom of the bottle. Cover it with a thick layer of sand, then a thick layer of gravel. Put a circle of paper on top.
3. Mix together some soil and water in a jar. Slowly pour the muddy water on to the circle of paper.
4. Look at the water which drips through your filter into the jar. Is it clean? Is it fit to drink? ______



Describe what happened. ______

______

What was the circle of paper used for? ______

______

Is it possible to use this filter to remove the salt from salt solution or seawater? Explain your answer.

______

______

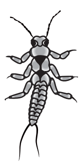
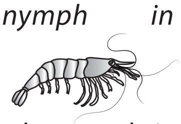
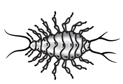
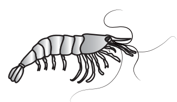
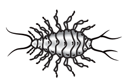
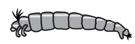
WORKSHEET 5

How polluted is your local river or stream?

Materials needed: long-handled nets; shallow white dishes; hand lenses or magnifying glasses

Safety: This activity requires strict supervision. Warn the students of the dangers of water and the need for stringent hygiene precautions. Return the animals to the river or stream as soon as possible after they have been identified.

1. Carefully use a net to collect some of the small invertebrate animals living in the river or stream.
2. Place the animals in shallow white dishes containing some of the river or stream water.
3. Use magnifying glasses or hand lenses and the chart below to examine and identify the animals.

Group A—Clean water	Group B—Some pollution	Group C—A lot of pollution
 *mayfly nymph*  *stonefly nymph*  *caddisfly larva in its case*  *freshwater shrimp*  *water louse*	 *freshwater shrimp*  *water louse*  *caddisfly larva in its case*	 *bloodworm*  *rat-tailed maggot*  *sludgeworm* *or no life at all*

- If you find all or most of the animals in Group A of the chart, the river or stream water is clean and unpolluted.
- If you find animals mainly from Group B, the water has some pollution in it.
- If you find only animals from Group C, the water is badly polluted.
- If you find no animals at all, the water is very polluted and there is probably little or no oxygen in it.

How polluted is your river or stream? ______________________________

Where does the pollution come from? ______________________________

____

The rat-tailed maggot has a breathing tube which it can push up to the water surface. How does this help it to survive in badly polluted waters? ______________________________

WORKSHEET 6

Poison in the water

Materials needed: a pen or pencil

Read the passage below in groups, discuss what you have read, and then answer the questions that follow. Give **reasons** for your answers.

Aluminium sulphate is used at some water works to remove tiny solid particles from cloudy water. These are particles too small to be separated out by filtering or sedimentation.

In July 1988, a tanker driver with a load of 20 tonnes of aluminium sulphate arrived at a water works in Cornwall, England and found that there was no one there. However, he had been given a key to the gate and told, 'When you are inside the gate, the aluminium sulphate tank is on the left.' The driver searched around and eventually found what he thought was the correct tank. He poured the aluminium sulphate into it. In fact, he had put the aluminium sulphate into a tank that held drinking water for 20,000 local people and up to 10,000 tourists. The water now contained levels of aluminium 500 to 3000 times the levels that were considered safe.

In spite of complaints that the water tasted acid, for several days the water company insisted the water was safe to drink. People who drank or bathed in the water reported many health problems, including stomach cramps, diarrhoea, mouth ulcers, aching joints, headaches, peeling of the skin, fingers and lips sticking together, and hair and fingernails turning blue. Some experts believe that 2000 people may have died as a result of the poisoning.

Do you think the tanker driver was to blame? ______________________

____

Do you think the water company was to blame? ______________________

____

If you had been a scientist living in the area at that time, what would you have done? ______________________

____

If you had been one of the victims, how would your life have been affected by the poisoning? ______________________

____

Why do you think that the water company insisted at first that the water was safe to use? ______________________

____

What do you think the water company should do to make sure that no other tragedy like this will happen again in the future? ______________________

____

What do you think the government should do to make sure that nothing like this will ever happen again?

____

____

Answers to questions in the Students' Book

1. Water forms a high proportion of the body mass of all plants and animals. All plants and animals need water if they are to grow, and water is also home to many plants and animals. Humans, in particular, need large quantities of water for washing, cooking, cleaning, growing their crops, and many industrial processes.
2. The main uses of water in the home are personal washing, toilet flushing, clothes washing, washing up and cleaning, garden watering, drinking and cooking, and car washing.
3. The water cycle cleans and purifies the water we use by first evaporating the water, leaving the dirt and other impurities behind. Later, the water vapour cools and condenses and falls as (clean) rain, hail, sleet, or snow which can be captured in rivers and lakes and used again.
4. Because the evaporation of water from the oceans and seas is roughly balanced by the water that enters the oceans and seas from rivers and rain, the water level of the oceans and seas stays approximately the same.
5. Industry uses vast quantities of water mainly as a solvent and also as a coolant. Water is also used in the preparation of many kinds of food and materials such as cement, concrete, steel, and paper.
6. The main water animals we use as food are fish and shellfish such as crabs, lobsters, shrimps, oysters, mussels, etc. The main water plants we eat are watercress and certain kinds of seaweed.
7. Water from a deep well is usually safer than water from a shallow well because the water has soaked through more layers of rock and soil and is likely to have been effectively filtered by these.
8. Sewage is the waste water which comes from the toilets, baths, sinks, etc. of our homes. A sewer is a large pipe which carries sewage. Sewage in the sea is harmful because not only is it unpleasant to look at or swim in, it can also spread germs to people who swim, surf or sail in the polluted water. The nutrients in sewage can make algae grow rapidly and prevent sunlight reaching other plants, which then die. When the algae die, they use up oxygen as they rot, leaving little for the fish and other forms of wildlife, which are then suffocated.
9. If, i) our planet becomes hotter, the water that is trapped as ice in glaciers and the polar ice caps would begin to melt, raising sea levels. That would result in the flooding of many coastal cities and other low-lying areas. ii) If our planet became colder, the polar ice caps would enlarge and sea levels would be lowered. If our planet became hotter and more ice melted, it is likely that the water cycle would speed up and there would be heavier rainstorms and more extreme weather. If our planet became colder, evaporation from the oceans and seas would slow down. There would probably be less rain and droughts would become more common in some areas.
10. There is only a limited, or finite, amount of water on Earth, so it is important that we do not pollute it or waste it. Some ways of conserving water supplies include putting a brick in the toilet cistern, showering rather that bathing, not wasting food, reusing or recycling materials, and collecting rainwater for watering plants.

Assessment

Question 1

Roughly how much of the Earth's surface is covered by water?

(A) a quarter (B) a half (C) three-quarters (D) five-eights

Question 2

The best way to identify a liquid as being water is to:

(A) taste it (B) show that it can put out fires

(C) show that it boils at 100°C (D) show that it is colourless

Question 3

Water is a:

(A) mixture (B) element (C) compound (D) mixture of elements

Question 4

Each water molecule is made up of:

(A) two hydrogen atoms and one oxygen atom (B) three hydrogen atoms and one oxygen atom

(C) one hydrogen atom and one oxygen atom (D) two hydrogen atoms and two oxygen atoms

Question 5

How much of the human body mass is water?

(A) 10 per cent (B) 30 per cent (C) 50 per cent (D) 70 per cent

Question 6

If your body mass is 40 kg, then how much of you is water?

(A) 7 kg (B) 14 kg (C) 21 kg (D) 28 kg

Question 7

In order to find out whether tap water contains any dissolved solids, you would:

(A) filter it (B) centrifuge it (C) crystallize it (D) evaporate it

Question 8

Which of the following will burn in air to produce water?

(A) nitrogen (B) hydrogen (C) oxygen (D) carbon dioxide

Question 9

The number of bacteria in our water supply is kept at a safe level at the water treatment works by:

(A) boiling it (B) filtering it (C) adding air to it (D) adding chlorine to it

Question 10

Sea water:

(A) freezes at 0°C
(B) consist of salt and water only
(C) has a density of 1 g/cm^3
(D) is distilled to provide drinking water in some hot countries

Question 11

Deserts are extremely dry. Animals are able to survive desert conditions by:

(A) producing large amounts of moist droppings to cool their bodies
(B) running around when it is breezy to keep cool
(C) urinating as little as possible
(D) staying in burrows at night and coming out in the day

Question 12

The special watering of crops is called:

(A) irritation (B) irrigation (C) interruption (D) investigation

Question 13

Read the following statements about water and say whether each one is TRUE or FALSE in the box provided.

a) Pure water boils at 100°C and freezes at 0°C. ☐
b) A molecule of water contains two atoms of hydrogen and one atom of oxygen. ☐
c) Water can dissolve many substances. ☐
d) Like most liquids, water contracts (gets smaller) when it freezes. ☐
e) Water sticks to itself, which is why it forms drops and why small water insects can crawl over the surface of it. ☐
f) Condensation is water coming out of the air. ☐
g) More things can dissolve in sulphuric acid than in water. ☐
h) Rainwater is the purest form of water. ☐
i) Raindrops are tear-shaped. ☐
j) The boiling point of water gets lower as you go up a mountain. ☐
k) The amount of dissolved oxygen in rivers and other waterways is an indication of how clean or polluted the water is. ☐

Question 14

Fill in the blanks in the sentences below using the words from the box. You may need to use some words more than once.

invisible	rain	Sun	snow	water vapour	drops
evaporation	clouds	rivers	oceans	cooler	condenses

When the ________________ shines on the ________________ and other wet surfaces, warm air rises and carries ________________ with it. This process is called ________________.

The water vapour in the air ________________ into lots of tiny ________________ of water, so small we cannot see them.

This warm moist air rises up into the sky.

As the ________________ rises high up in the sky the air gets ________________. The water vapour condenses making the tiny drops of water in the vapour a bit bigger. They are no longer ________________ and form ________________.

The clouds may be blown towards the land and cooled still further. Precipitation as ________________, hail or ________________ occurs. This falls onto the land and eventually runs into the ________________. The rivers flow into the ________________ and the whole cycle starts again.

Question 15

River water is sometimes polluted.

a) What is meant by 'polluted'?

____

b) River water must be purified before the water is safe to drink.

A scientist analyzed a sample of river water to see if it contained any pollutants. The table below shows the results of his analysis.

Pollutant	**Mass of pollutant in the water sample in grams**
lead ions	2.2
nitrate ions	94.3
pesticide	0.4
phosphate ions	50.3

i) Which pollutant was found in the smallest amount in the water sample?

____

ii) Which pollutant was found in the greatest amount in the water sample?

____

iii) Suggest where the nitrate ions may have come from.

____

c) River water may contain dangerous germs.

These germs are killed when the water is processed at the water works.

What is the name of the process that kills germs?

Choose from this list:

- **chlorination**
- **filtration**
- **precipitation**
- **sedimentation**

answer ______________________________

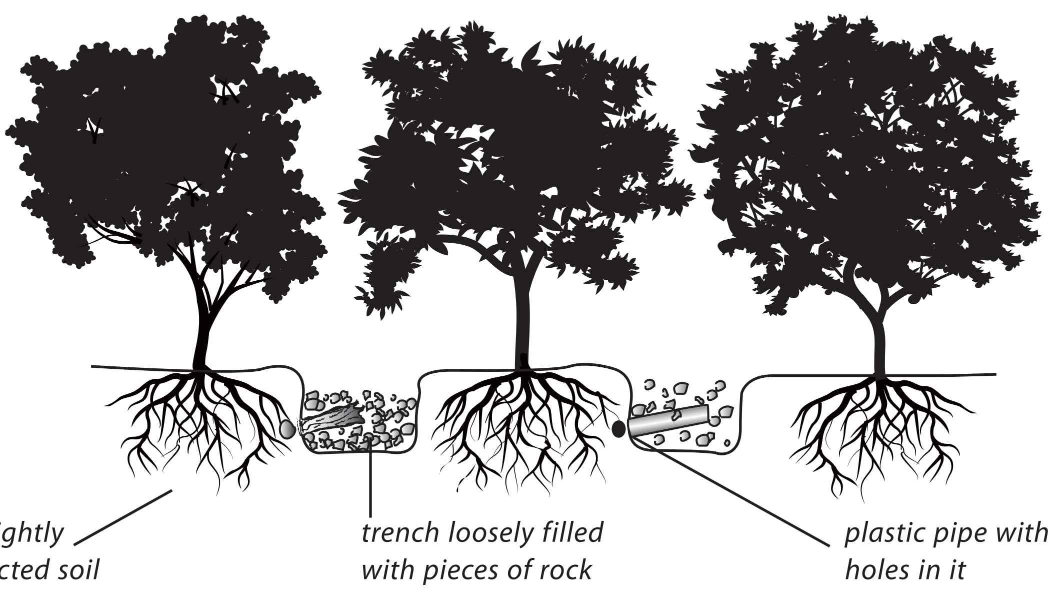
d) Water is an important material for use in industry. Suggest why.

____

Question 16

Mango trees, which grow in hot, dry countries, are often planted in places where the soil is hard and tightly packed. Farmers usually spray water on the soil around the trees. The picture below shows a new way of watering mango trees. Trees watered like this can produce 15 per cent more fruit.

Mango trees



a) What are the problems with the old way of watering mango trees? ______________________

____

b) What are TWO reasons why the new method of growing mango trees is better? ____________

____

Answers to assessment questions

Question 1 (C) **Question 2** (C) **Question 3** (C) **Question 4** (A) **Question 5** (D)

Question 6 (D) **Question 7** (D) **Question 8** (B) **Question 9** (D) **Question 10** (D)

Question 11 (C) **Question 12** (B)

Question 13

a) Pure water boils at 100°C and freezes at 0°C. TRUE

b) A molecule of water contains two atoms of hydrogen and one atom of oxygen. TRUE

c) Water can dissolve many substances. TRUE

d) Like most liquids, water contracts (gets smaller) when it freezes. FALSE

e) Water sticks to itself, which is why it forms drops and why small water insects can crawl over the surface of it. TRUE

f) Condensation is water coming out of the air. TRUE

g) More things can dissolve in sulphuric acid than in water. FALSE

h) Rainwater is the purest form of water. FALSE

i) Raindrops are tear-shaped. FALSE

j) The boiling point of water gets lower as you go up a mountain. TRUE

k) The amount of dissolved oxygen in rivers and other waterways is an indication of how clean or polluted the water is. TRUE

Question 14

When the **Sun** shines on the **oceans** and other wet surfaces, warm air rises and carries **water vapour** with it. This process is called **evaporation**.

The water vapour in the air **condenses** into lots of tiny **drops** of water, so small we cannot see them.

This warm moist air rises up into the sky.

As the **water vapour** rises high up in the sky the air gets **cooler**. The water vapour condenses making the tiny drops of water in the vapour a bit bigger. They are no longer **invisible** and form **clouds**.

The clouds may be blown towards the land and cooled still further. Precipitation as **rain**, hail, or **snow** occurs. This falls onto the land and eventually runs into the **rivers**.

The rivers flow into the **oceans** and the whole cycle starts again.

Question 15

a) Polluted means that an unwanted change has taken place as a direct result of human activities. In the case of a river, it means that the water has been contaminated by oil, chemicals, sewage, pesticides, litter, or some other unwanted material.

b) River water must be purified before the water is safe to drink.

A scientist analyzed a sample of river water to see if it contained any pollutants. The table below shows the results of his analysis.

Pollutant	Mass of pollutant in the water sample in grams
lead ions	2.2
nitrate ions	94.3
pesticide	0.4
phosphate ions	50.3

i) The pollutant found in the smallest amount in the water sample was pesticide.

ii) The pollutant found in the greatest amount in the water sample was nitrate ions.

iii) The nitrate ions in the river water are most likely to have come from agricultural fertilizers.

c) The name of the process that kills germs at the waterworks is chlorination.

d) Water is used in industry as a coolant, as a raw material (e.g. in making cement or paper) and as a solvent.

Question 16

a) The main problems with the old way of watering mango trees are that the water does not easily penetrate the compacted soil and much of it either runs away or evaporates.

b) The new method of growing mango trees is better because the roots can easily grow between the loosely packed pieces of rock and stone to reach the water; and the use of underground pipes reduces the amount of evaporation.

Atoms

CHAPTER 8

Teaching Objectives

- To introduce the idea of atoms, and the use of models, symbols and diagrams to represent atoms
- To explain the differences between atomic number and mass number
- To explain the concepts of valency and the formation of ions
- To examine the differences between anions and cations
- To explain the formation of isotopes, and their uses in agriculture and medicine
- To examine and identify the elements present in simple molecules and compounds
- To show how to make simple chemical formulae when given examples of anions and cations
- To demonstrate the importance of the law of constant composition

Learning Outcomes

After studying this chapter students should be able to:

- describe the structure of an atom
- differentiate between atomic number and mass number
- draw diagrams of the atomic structure of the first eighteen elements in the periodic table
- define valency
- explain the formation of ions
- differentiate between cations and anions
- describe isotopes and their uses in medicines and agriculture
- identify the types and number of elements present in simple molecules and compounds
- form the chemical formulae from a list of anions and cations
- state the law of constant composition and give examples

Introduction

The concept of atoms is difficult for many students to accept and understand. After all, single atoms are far too small to be seen, even with the most powerful microscope. For example, about 4 billion sodium atoms would fit side-by-side across the full-stop at the end of this sentence. We are, in fact, asking students to accept the existence of something for which they have no concrete evidence or experience. As a result, students have to take a great deal of the material in this chapter on trust, and there is no avoiding the fact that a great deal of the material has to be committed to memory if the students are to make progress. Only three suggestions for lessons are given here. Depending on the abilities and working pace of the students, several periods may be needed for each topic, particularly in the case of Lesson 3.

The structure of the atom

In spite of the small size of atoms, scientists have been able to find out a great deal about them. They have found that every atom consists of a nucleus, and a cloud of particles called electrons that whizz non-stop around the nucleus. If it were possible to pull an atom apart, as well as the existence of electrons, we would see that the nucleus is made protons and neutrons. Atoms differ from one another because they are made up of different combinations of these three particles. Again, to give an idea of the small sizes with which we are dealing here, if an atom was enlarged to the size of a football pitch, the nucleus would be the size of a pinhead on the centre spot.

Protons and neutrons have about the same mass, but electrons are much lighter. Protons carry a positive electrical charge, while the electron has an equal but negative charge. Neutrons are neutral, they carry no charge. An atom that has equal numbers of protons and electrons is electrically neutral.

Atomic number

The smallest atom of all is hydrogen. This has only one proton and one electron. The largest naturally occurring atom that we know much about is uranium, which has 92 protons and 92 electrons. It is the number of protons which makes the difference between the atoms, and this number is called the atomic number. Each atom has a different atomic number.

The number of protons in any particular type of atom is always the same. The number of neutrons can vary. A carbon atom, for example, always has six protons, but the number of neutrons can be six, seven, or eight. Neutrons do not affect the chemical properties, so all carbon atoms have the same chemical properties.

Mass number and isotopes

Atoms which have a different number of protons but the same number of neutrons are called isotopes. Protons and neutrons have the same mass (about 2000 times larger than the mass of an electron), so the mass of an atom is concentrated in its nucleus. The mass number of an atom is the number of protons and neutrons in that atom. Isotopes are called by their mass number. Carbon-12, for example, has a mass number of 12.

Bonds and ions

Atoms can be held together by forces which act between them. We call these forces bonds. Most solid materials are made up of a regular arrangement of atoms held together by these bonds. Crystals are a good example, and the regular arrangement of the atoms gives a crystal its definite shape.

An ion is an atom that has gained or lost electrons. If it has gained electrons it is a negative ion, because it has more negatively-charged electrons than positively-charged protons. If it has lost electrons it is a positive ion, because it has more protons than electrons. Salts, including common salt (sodium chloride), and metal ores are common compounds in which the atoms are held together by ionic bonds. The attraction of the electrically charged ions forms the ionic bonds.

Covalent bonds are formed when electrons are shared between atoms. These bonds hold together the atoms of a vast array of materials. Most of the chemicals found in living things are linked by covalent bonds. When atoms are joined together by covalent bonds, molecules are formed. Molecules can contain a fairly small number of atoms, e.g. carbon dioxide, CO_2 has three atoms. Water, H_2O has two atoms of hydrogen joined to one atom of oxygen by a covalent bond, while glucose, $C_6H_{12}O_6$ has 24 atoms. Polythene and polystyrene contain a very large number of atoms because they are made up of a large number of smaller molecules joined together. Some elements exist as molecules, for example oxygen gas, O_2, is made up of a molecule formed from two atoms.

Lesson suggestions

1. Atoms and elements

Refer to page 89 of the Students' Book

Starter suggestions

Ask the students to write down five things they already know about atoms.

Ask the students to work in pairs to name ten different elements. Discuss their answers and help them to decide what is special about an element. (It is made up of only one kind of atom.)

Ask the students to list all the different materials they can see in the room. How many of these materials are elements? (The most likely elements to be identified are copper, iron, and carbon in pencil 'leads'.) This exercise will help you to identify any students who have difficulty distinguishing between materials and objects.

Main lesson

With the aid of the Students' Book, explain how our knowledge about atoms has changed over time.

Use a PowerPoint picture or the picture in the Students' Book, to describe and explain the structure of an atom as we understand it today. Emphasize that the nucleus is much smaller than the atom itself—like a pinhead in the middle of an athletics stadium.

Another point to stress is that, although we often draw atoms as coloured balls, this is not really what they look like. In fact they are too small to see directly because they are smaller than light waves. So it is wrong to think of them as having colour.

Explain that atoms are the building blocks for all the billions of different substances there are in the Universe. Use small building blocks, such as Lego, of different sizes and colours to represent atoms, elements, mixtures and compounds. Explain that the smallest block represents an atom. If a number of identical small blocks are joined together, then we have an element. If we have a handful of loose blocks of different sizes and colours, and they are not joined together, they represent a mixture. If we have blocks of different sizes and colours joined together, then they represent a compound.

Explain that chemists sometimes draw the electrons around the nucleus of an atom in shells. This helps to explain why some atoms lose electrons or gain them. Stress that electrons do not go around in circles with different radii. It is just a way of explaining the behaviour of atoms and electrons. Move on to help the students to draw the distribution of electrons in shells for elements 1 to 18.

The table given on page 91 of the Students' Book, which shows how electrons are arranged in twenty elements, is repeated here for your convenience.

Element	symbol	atomic number	number of electrons	first shell	second shell	third shell	fourth shell
hydrogen	H	1	1	1			
helium	He	2	2	2			
lithium	Li	3	3	2	1		
beryllium	Be	4	4	2	2		
boron	B	5	5	2	3		
carbon	C	6	6	2	4		
nitrogen	N	7	7	2	5		
oxygen	O	8	8	2	6		
fluorine	F	9	9	2	7		
neon	Ne	10	10	2	8		
sodium	Na	11	11	2	8	1	
magnesium	Mg	12	12	2	8	2	
aluminium	Al	13	13	2	8	3	
silicon	Si	14	14	2	8	4	
phosphorus	P	15	15	2	8	5	
sulphur	S	16	16	2	8	6	
chlorine	Cl	17	17	2	8	7	
argon	Ar	18	18	2	8	8	
potassium	K	19	19	2	8	8	1
calcium	Ca	20	20	2	8	8	2

2. Atomic number, mass number, and isotopes

Refer to page 92 of the Students' Book

Starter suggestions

Remind the students of their study of the electronic structure of atoms in the previous lesson. Use a brief question/answer session to assess their understanding.

Main lesson

Begin by showing the students a diagram of the sodium atom. Point out that it has 11 protons, 11 electrons arranged in three shells, and 12 neutrons.

Emphasize that the sodium atom has 11 protons, and this fact could be used to identify it because it is the only atom which has 11 protons. The number of protons in an atom is, therefore an important number. It is called the atomic number. Ask the students to remember that:

the atomic number is the number of protons in an atom.

The atomic number of twenty elements was contained in the table used in the previous lesson.

The sodium atom also has 11 electrons, so it has an equal number of protons and electrons. This is also true of every sort of atom, and because of it, atoms have no overall charge. The charge on the electrons cancels out the charge on the protons.

Go on to explain that the electrons in an atom have almost no mass, so the mass of an atom is nearly all due to its protons and neutrons. For this reason, the number of protons and neutrons in an atom is called is mass number.

mass number = number of protons + number of neutrons in an atom

A sodium atom has 11 protons and 12 neutrons, so the mass number of sodium is 23.

The table below, also contained in the Students' Book, shows the numbers of protons and neutrons for atoms of six elements. It may be useful to copy this table on the board, but to omit the figures for mass number and ask the students to complete the table.

Element	atomic number (number of protons)	mass number	number of neutrons
hydrogen	1	1	0
carbon	6	12	6
nitrogen	7	14	7
oxygen	8	16	8
sodium	11	23	12
gold	79	197	118

As we have seen, all atoms of a particular element have the same number of protons (called the atomic number). However, they may have a different number of neutrons. A carbon atom always has 6 protons, but the number of neutrons can be 6, 7, or 8. Because neutrons do not affect the chemical properties of an atom, all types of carbon atoms have the same chemical properties.

Explain that these different versions of the same element are known as isotopes. Scientists name isotopes by putting the mass number (the number of protons and neutrons) after the name of the element, for example uranium-235. In this case the total number of neutrons and protons in the nucleus is 235.

Complete the lesson by either giving the students some uses of isotopes, particularly in medicine and agriculture, or letting them read the appropriate section of their textbook, or ask them to research isotopes using the Internet.

3. How compounds are formed

Refer to page 98 of the Students' Book

Starter suggestions

Ask the students to work in pairs to list ten compounds.

Use a quick quiz to test the students' knowledge and understanding of the work done in the previous lesson.

Main lesson

Begin the lesson by burning a small piece of magnesium ribbon in air or oxygen. Demonstrate that a white solid called magnesium oxide is formed. It is formed by atoms of magnesium and oxygen joining together, so it is a compound. The reaction can be described like this:

$$\text{magnesium + oxygen} \longrightarrow \text{magnesium oxide}$$

$$2Mg + O_2 \longrightarrow 2MgO$$

Explain, or demonstrate, that in a similar way, a piece of burning sodium plunged into a gas jar of chlorine forms a white solid on the sides of the jar. This is another compound, sodium chloride, which we know better as common or table salt.

$$\text{sodium + chlorine} \longrightarrow \text{sodium chloride}$$

$$2Na + Cl_2 \longrightarrow 2NaCl$$

Refer back to the topic of 'shells', discussed in the last lesson. Point out that the rare or noble gases, such as helium, neon, and argon, are different from all the other elements because they do not usually form compounds. For this reason their atoms are described as unreactive or stable. They are unreactive because their outer electron shells are full, and a full outer shell makes an atom stable. Only the rare or noble gases have full outer shells. The atoms of all other elements have incomplete outer shells. That is why they react. By reacting with each other, atoms can obtain full outer shells and so become stable.

Explain that the atoms of some elements can obtain full shells by losing or gaining electrons when they react with other atoms. The sodium atom, for example, has just one electron in its outer shell. It can obtain a full outer shell by losing this electron to another atom. The result is a sodium ion.

The sodium ion has 11 protons but only 10 electrons, so it has a charge of +1. The symbol for sodium is Na, so the sodium ion is called Na^+. The $^+$ means 1 positive charge, so Na^+ is a positive ion.

A chlorine atom has 7 electrons in its outer shell. It can have a full shell by accepting just 1 electron from another atom. It then has 17 protons and 18 electrons and becomes a chloride ion. The chloride ion has a charge of –1, so it is a negative ion. Its symbol is Cl^-.

To sum up, any atom becomes an ion if it loses or gain electrons. An ion is a charged particle because it contains an unequal number of protons and electrons. A table giving the formulae and charges of some common ions is given on page 99 of the Students' Book.

Sodium is a metal and chlorine is a non-metal. They react together to form an ionic compound, in this case sodium chloride, with the formula NaCl.

When magnesium burns in air or oxygen to form magnesium oxide, we have another example of an ionic compound. A magnesium atom has 2 outer electrons and an oxygen atom has 6. During the reaction, each magnesium atom loses its 2 outer electrons to an oxygen atom. Magnesium and oxide ions are formed. The ions attract each other because of their opposite charges. Magnesium oxide contains one magnesium ion for each oxide ion, so its formula is MgO.

When two non-metal atoms react together, both of them need to gain electrons to reach full shells. They can manage this only by sharing electrons between them. It is important to remember that atoms can only share their outer electrons.

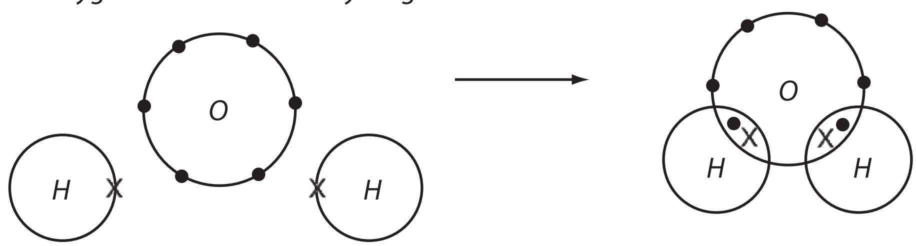
A hydrogen atom has only one electron, but its shell can hold two electrons, so it is not full. When two hydrogen atoms get close enough, their shells overlap and then they share electrons. Because the atoms share electrons, there is a strong force of attraction between them, holding them together. This force is called a covalent bond. The pair of bonded atoms is called a molecule, and so a molecule is a small group of atoms which are held together by covalent bonds.

Hydrogen gas is made up of hydrogen molecules, and for this reason it is called a molecular substance. Its formula is H_2. Several other non-metals are also molecular, including chlorine Cl_2, nitrogen N_2, iodine I_2, sulphur S_8, oxygen O_2, and phosphorus P_4.

A huge number of compounds also exist as molecules. In a molecular compound, atoms of ***different*** elements share electrons with each other. These compounds are often called covalent compounds because of the covalent bonds in them. Water, ammonia, and methane are all covalent compounds.

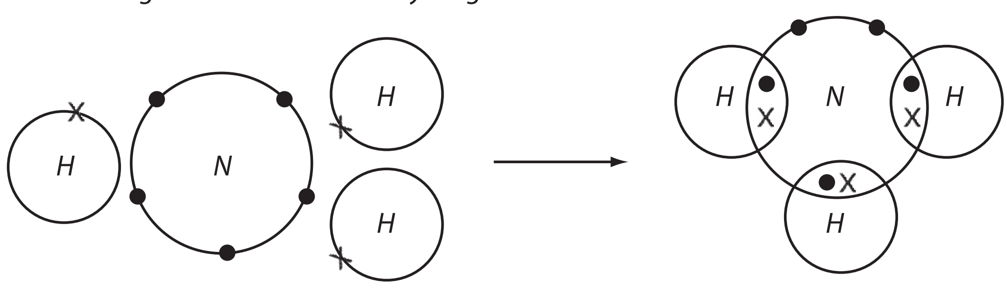
Water

one oxygen atom and two hydrogen *atoms a molecule of water H_2O*



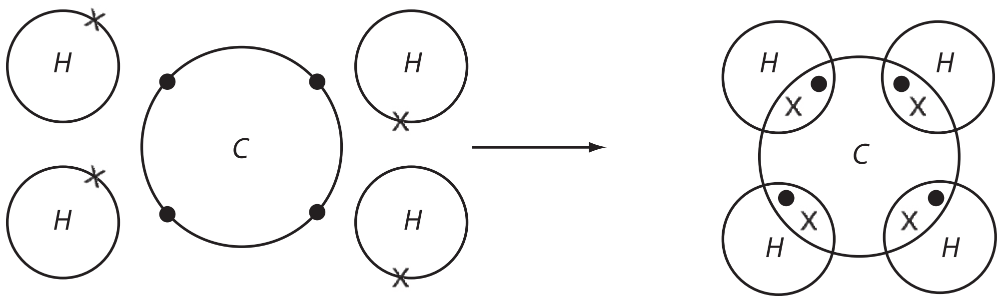
Ammonia

one nitrogen atom and three hydrogen atoms *a molecule of ammonia NH_3*



Methane

one carbon atom and four hydrogen atoms *a molecule of methane CH_4*



As we have seen, atoms are linked together in molecules by chemical bonds, such as ionic or covalent bonds. The number of bonds an atom can form is called its valency. **Valency**, then, is the combining power of an atom or ion. Carbon, for example, has a valency of 4. In the gas methane, each carbon atom is bonded to four hydrogen atoms. Each hydrogen atom forms one bond, because hydrogen has a valency of one.

It sometime helps students to think of each atom having hooks coming from it which represent the valency bonds.

Here are the valencies of some elements which you will meet quite often.

Metals			**Non-metals**		
name	**symbol**	**valency**	**name**	**symbol**	**valency**
sodium	Na	1	helium	He	0
potassium	K	1	neon	Ne	0
silver	Ag	1	hydrogen	H	1
calcium	Ca	2	chlorine	Cl	1
magnesium	Mg	2	bromine	Br	1
zinc	Zn	2	iodine	I	1
aluminium	Al	3	oxygen	O	2
			nitrogen	N	3
			carbon	C	4

Valencies are always small whole numbers. The inert or rare gases such as helium and neon have zero valencies because they unreactive and do not normally form compounds. As we saw earlier, that is the reason they are often called the inert gases.

Worksheets 1, 2, and 3 may all prove useful as revision for this lesson.

Answers to worksheet 2:

Element	Protons	Electrons	Charge
hydrogen	1	0	charged
hydrogen	1	1	atom (neutral)
iron	26	24	charged
iron	26	23	charged
sodium	11	11	atom (neutral)
sodium	11	10	charged
oxygen	8	9	charged
oxygen	8	8	atom (neutral)

Answers to Worksheet 3:

Element	Protons	Electrons	Charge
hydrogen	1	1	0
hydrogen	1	0	+1
iron	26	24	+2
iron	26	23	+3
sodium	11	11	0
sodium	11	10	+1
oxygen	8	9	-1
oxygen	8	8	0

Ideas for investigation and extension work

Atoms, elements and compounds

Use different coloured Plasticine or coloured polystyrene balls to make models of atoms and molecules. Explain that each coloured ball represents an atom of an element. Arrange them to make molecules of elements, perhaps starting with oxygen, then hydrogen, chlorine and nitrogen, each with two atoms per molecule, then perhaps phosphorus which has four atoms per molecule. Move on to compounds, starting with water H_2O, consisting of one oxygen atom and two hydrogen atoms, then carbon dioxide CO_2, carbon monoxide CO, sulphur dioxide SO_2 and methane CH_4. Ask the students to fill in the table in Worksheet 1, making a graphic representation of the molecules of each of the elements and compounds that models have been made of.

WORKSHEET 1

Atoms, elements, and compounds

Materials needed: pen or pencil

Complete the two tables below.

Element which is made up of molecules	Number of atoms per molecule	Drawing of a molecule of the element
chlorine gas	2 atoms of chlorine	
hydrogen gas		
nitrogen gas		
oxygen gas		
phosphorus		

Compound	Number of atoms per molecule	Drawing of a molecule of the compound
water	1 atom of oxygen	
carbon dioxide gas		
carbon monoxide gas		
sulphur dioxide gas		
methane gas		

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WORKSHEET 2

Atoms and elements

Materials needed: pen or pencil

In ordinary elements, the number of electrons in an atom is the same as the number of protons. The negative charges of the electrons balance the positive charges of the protons. The atom is uncharged or neutral.

If something happens to make an atom gain or lose an electron, the atom will no longer be neutral.

Look at the numbers of protons and electrons in the atoms below. Decide whether the atom is neutral or charged.

Choose your answers from the following words: neutral, charged, positive ion, atom.

Element	Protons	Electrons	Charge
hydrogen	1	0	
hydrogen	1	1	
iron	26	24	
iron	26	23	
sodium	11	11	
sodium	11	10	
oxygen	8	9	
oxygen	8	8	

WORKSHEET 3

Atoms and ions

Materials needed: pen or pencil

If an atom gains or loses an electron, it becomes an ion. An atom that gains a negative electron becomes a negative ion. An atom that loses an electron becomes a positive ion. The gain of each electron represents one negative charge. The loss of each electron represents one positive charge.

Look at the number of particles in the atoms below. In each case decide what the charge on the atom or ion will be.

In your answers choose from: **–2, –1, 0, +1, +2, +3.**

Element	Protons	Electrons	Charge
hydrogen	1	1	
hydrogen	1	0	
iron	26	24	
iron	26	23	
sodium	11	11	
sodium	11	10	
oxygen	8	9	
oxygen	8	8	

Answers to questions in the Students' Book

1. An element is a substance which cannot be broken down into simpler substances by any ordinary chemical method. An element is made up of one type of atom. So far, 117 elements have been discovered.
2. a) An atom is the smallest part of an element that can exist. b) A molecule is two or more atoms chemically combined together. The atoms in the molecule can be of the same kind, as in a molecule of oxygen or hydrogen, or different as in a molecule of water or carbon dioxide. c) A chemical bond is the force of attraction between the atoms inside a molecule or crystal. d) Valency is the combining power of the atoms of one element.
3. Atomic mass is a result of the combined masses of the protons and neutrons in an atom. The mass of an electron is 1/1840 of a proton. The mass number of an element is the number of protons plus the number of neutrons in the nucleus of one atom of the element. Atomic number is the number of protons in an atom. Each atom has a different number of protons and, therefore, a different atomic number.
4. A symbol is a letter or pair of letters which represent an element. Some common symbols are H = hydrogen, He = helium, C = carbon, N = nitrogen, O = oxygen, Al = aluminium, and Fe = iron.
5.

Proton	**Neutron**	**Electron**
has mass	has mass	negligible mass
positive charge +1	neutral—no charge	negative charge –1
part of nucleus of atom	part of nucleus of atom	occur in layers, or 'shells', around the nucleus

6. The number of protons in a particular atom is called the atomic number. Each element has a different atomic number.
7. A glucose molecule is $C_6H_{12}O_6$. It has six carbon atoms, twelve hydrogen atoms, and six oxygen atoms, making 24 atoms altogether.
8. A molecule of sulphuric acid, H_2SO_4, has two hydrogen atoms, one sulphur atom, and four oxygen atoms, or seven atoms altogether.
9. Ionic compounds have ions that are strongly attracted to each other because they carry opposite electrical charges. Most ionic bonds are difficult to break. Ionic compounds are usually solids and will only melt at very high temperatures. Common salt, sodium chloride, is an example of an ionic compound.
10. The atoms in a covalent compound share electrons between them. Such bonds are quite weak, which is why many covalent compounds are gases or liquids. They have low melting and boiling points because it does not take much energy to break the bonds between them.
11. Isotopes are atoms of the same element which have different numbers of neutrons and so different atomic masses. Some elements which have isotopes include carbon, phosphorus, and uranium.
12. Radioisotopes are used to produce atomic energy in nuclear power stations and in nuclear weapons. They are used in medicine in pacemakers, to destroy cancer cells and to sterilize medical instruments. In industry, radioisotopes are used to show up leaks in pipes and weaknesses in metal objects. In agricultural research, radioisotopes can be used to trace the path of mineral salts through plants.

Assessment

Question 1

The BEST description of an element is a substance in which:

(A) all the atoms are the same
(B) all the atoms have the same atomic number
(C) all the molecules are the same
(D) the atoms cannot be split up by any means

Question 2

Which element has the symbol C?

(A) chlorine (B) calcium (C) chromium (D) carbon

Question 3

Sulphur is an example of:

(A) an element (B) a compound (C) a metal (D) a mixture

Question 4

Copper chloride is an example of:

(A) an element (B) A compound (C) a metal (D) a mixture

Question 5

Roughly how many chemical elements are there? Just over:

(A) 25 (B) 50 (C) 100 (D) 1000

Question 6

The four substances below are all solids. Which of them is made up of more than one kind of atom?

(A) iron (B) tin (C) ice (D) carbon

Question 7

Which one of the following substances does NOT contain atoms of oxygen?

(A) H_2SO_4 (B) NaCl (C) MgO (D) HNO_3

Question 8

Which element is present in all three of these substances?

H_2SO_4 Na_2SO_4 FeS

(A) iron (B) oxygen (C) sulphur (D) hydrogen

Question 9

Which particles are found in shells around the nucleus of an atom?

(A) neutrons
(B) protons and neutrons
(C) protons
(D) electrons

Question 10

Which particles may be found in the nucleus of an atom?

(A) protons and neutrons
(B) protons and electrons
(C) electrons only
(D) neutrons only

Question 11

A new substance is found to be made of only one type of atom. How could this substance be best described?

(A) an element
(B) a mixture
(C) a compound
(D) a metal

Question 12

The number of protons in the nucleus of an atom is referred to as its:

(A) mass number
(B) atomic number
(C) atomic weight
(D) density

Question 13

Isotopes are forms of the same element which have different:

(A) atomic numbers
(B) electronic structures
(C) numbers of electrons
(D) numbers of neutrons

Question 14

The valency of an element is:

(A) its combining power
(B) the number of electrons in its atoms
(C) the number of neutrons in its atoms
(D) the number of protons in its atoms

Question 15

Valencies are always:

(A) fractions
(B) large whole numbers
(C) small whole numbers
(D) large and small numbers

Question 16

Imagine three different elements called A, B, and C. How many combinations of two atoms can we make with them?

(A) 2
(B) 3
(C) 6
(D) 9

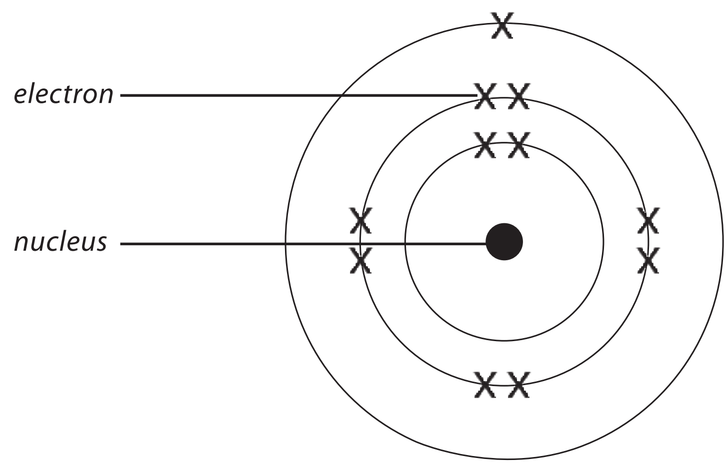
Question 17

Referring back to the previous question, how many of the combinations of two atoms are still elements?

(A) 2 (B) 3 (C) 6 (D) 9

Question 18

The diagram below shows the structure of a sodium atom.



a) Atoms contain electrons.

(i) How many electrons are there in this sodium atom? ______________________

(ii) What is the electrical charge on an electron?

Choose from: **negative** **neutral** **positive**

Answer ______________________

(iii) What is the name given to the different levels of the electrons around the nucleus?

____

b) The nucleus of the atom contains two types of particles.

(i) What are the names of these two types of particles?

______________________ and ______________________

(ii) What is the electrical charge on the nucleus of the atom?

____

Question 19

Fill in the blanks in the sentences below using the words from the box. You may need to use some words more than once.

neutrons	element	positive	electrons	protons	ions	negative	ion	nucleus

Atoms are made up of a small dense ______________ around which the ______________ move. The ______________ contains protons and ______________. Protons have a ______________ charge, while ______________ have no charge. The ______________ and ______________ have approximately the same mass.

All the atoms of the same ______________ contain the same number of ______________, but the number of ______________ can vary. Where atoms exist which have the same number of ______________ but different numbers of ______________ they are called isotopes.

Atoms form ______________ by gaining or losing ______________. If ______________ are gained the resulting ______________ has a ______________ charge. An atom which has lost one or more ______________ forms a positive ______________.

Question 20

Think about the following statements. Decide whether each one is TRUE or FALSE.

a) Most elements are metals. ______________

b) There are 55 known elements. ______________

c) Elements contain only one type of atom. ______________

d) A compound is formed when the atoms of two or more elements are joined together. ______________

e) Atoms of gold are the same as atoms of silver. ______________

f) Mercury is the only metal element which is a liquid at room temperature. ______________

Question 21

a) Symbols are a shorthand way of representing elements. Draw lines between the boxes to link each symbol to its name.

Symbol	Name
Ca	oxygen
Mg	calcium
Cu	magnesium
O	copper
Fe	nitrogen
N	iron

b) Read these three statements below and then answer the questions about them.

- Iron, sodium, and magnesium are elements. They conduct electricity and have a shiny appearance when they are freshly cut.
- Oxygen and nitrogen are gases. They do not conduct electricity.
- Sulphur is a yellow solid. It does not conduct electricity.

(i) Name one of the elements above which is a non-metal. ________________

(ii) Name one of the elements above which exists as molecules. ________________

(iii) Name one of the elements which is a metal. ________________

(iv) Name one of the elements which will rust if it is exposed to water and oxygen. ________________

c) Name the compound that is made when:

(i) Iron is heated with sulphur. ________________

(ii) Magnesium is burned in air or oxygen. ________________

Question 22

a) The formula for sulphuric acid is H_2SO_4.

(i) How many elements are there in sulphuric acid?

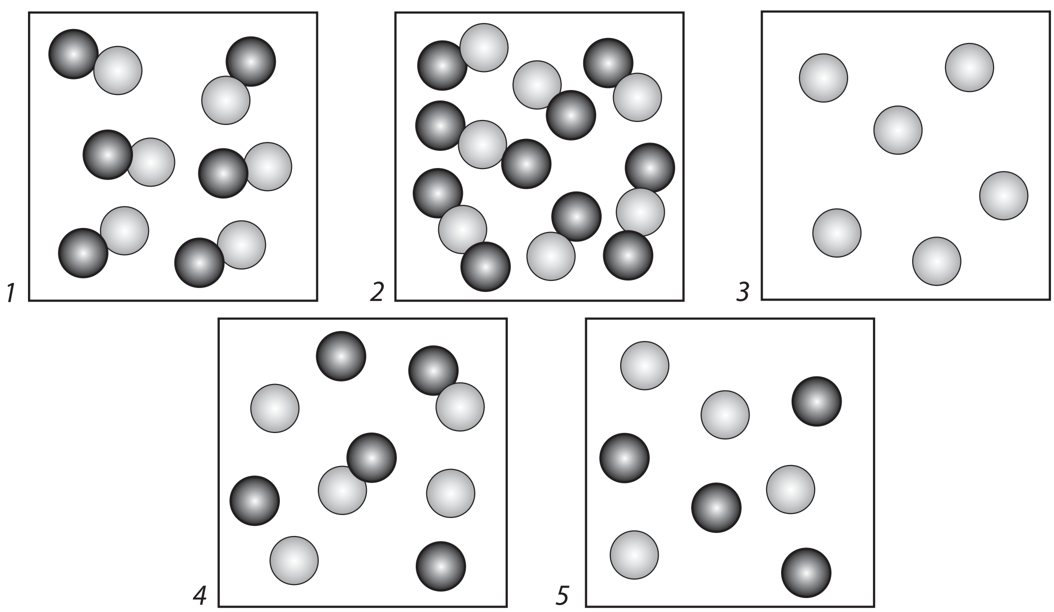
(ii) How many atoms are there in a molecule of sulphuric acid?

b) The formula for aluminium sulphate is $Al_2(SO_4)_3$.

(i) How many elements are there in aluminium sulphate?

(ii) How many atoms are there in a molecule of aluminium sulphate?

c) Look at the five diagrams below.



(i) Which of the diagrams represents an element? ____________

(ii) Which diagram represents a pure compound? ____________

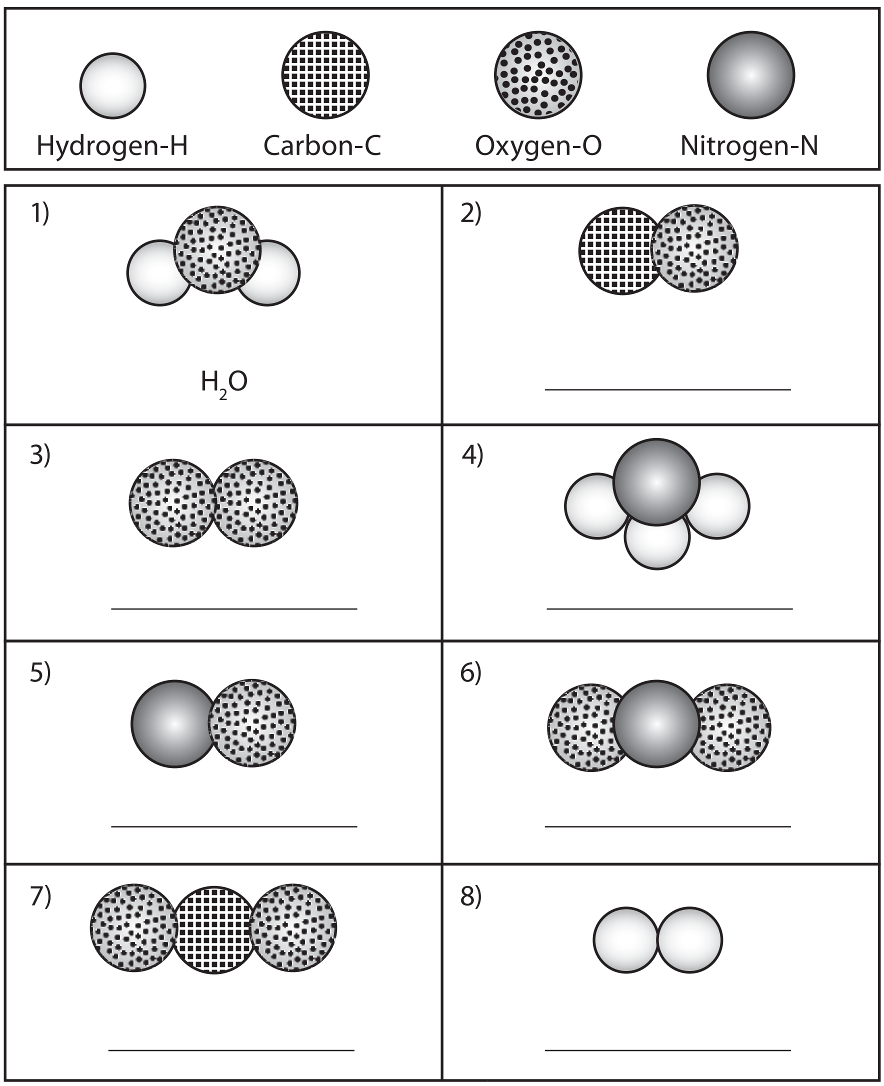
(iii) Which diagram represents a mixture of elements? ____________

(iv) Which diagram represents a mixture of compounds? ____________

(v) Which diagram represents a mixture of elements and compounds? ____________

Question 23

a) The four circles below represent atoms of four common chemical elements. Study these carefully and then write the chemical formula for each of the eight molecules shown in the chart. One, water (H_2O), has already been done for you.



b) What do you understand by the term *valency*? ______________________________

____

c) Study the diagrams of molecules and then write down the valency for each of the four elements:

(i) hydrogen ii) carbon iii) oxygen iv) nitrogen

Question 24

a) Draw a straight line from each particle to the correct example.

Particle	**Example**
atom	K+
ion	O_2
molecule	Na

b) Magnesium reacts with chlorine to make magnesium chloride.

In this reaction, magnesium atoms lose electrons to make magnesium ions, Mg^{2+}.

At the same time, chlorine atoms make chloride ions, Cl^-.

Describe what happens to chlorine when it forms chloride ions.

____

____

c) Water is a compound. It is made of water molecules, H_2O.

i) Complete this sentence about compounds:

A compound is two or more different ______________ chemically joined together.

ii) The atoms in a water molecule are held together by shared pairs of electrons.

What is the name for this type of chemical bond?

____

Answers to assessment questions

Question 1 (B) **Question 2** (D) **Question 3** (A) **Question 4** (B) **Question 5** (C)
Question 6 (C) **Question 7** (B) **Question 8** (C) **Question 9** (D) **Question 10** (A)
Question 11 (A) **Question 12** (B) **Question 13** (D) **Question 14** (A) **Question 15** (C)
Question 16 (C) **Question 17** (B)

Question 18

a) (i) There are 11 electrons in the sodium atom.

(ii) The electrical charge on an electron is **negative**.

(iii) The different levels of the electrons around the nucleus are called **shells** or **electron shells**.

b) (i) The nucleus of the atom contains two types of particles, **protons**, and **neutrons**.

(ii) The electrical charge on the nucleus of the atom is **positive**.

Question 19

Atoms are made up of a small dense **nucleus** around which the **electrons** move. The **nucleus** contains protons and **neutrons**. Protons have a **positive** charge, while **neutrons** have no charge. The **protons** and **neutrons** have approximately the same mass.

All the atoms of the same **element** contain the same number of **protons**, but the number of **neutrons** can vary. Where atoms exist which have the same number of **protons** but different numbers of **neutrons** they are called isotopes.

Atoms form **ions** by gaining or losing **electrons**. If **electrons** are gained the resulting **ion** has a **negative** charge. An atom which has lost one or more **electrons** forms a positive **ion**.

Question 20

True/False

a) Most elements are metals. ____________ TRUE

b) There are 55 known elements. ____________ FALSE

c) Elements contain only one type of atom. ____________ TRUE

d) A compound is formed when the atoms of two or more elements are joined together. ____________ TRUE

e) Atoms of gold are the same as atoms of silver. ____________ FALSE

f) Mercury is the only metal element which is a liquid at room temperature. ____________ TRUE

Question 21

a) Ca = calcium; Mg = magnesium; Cu = copper; O = oxygen; Fe = iron; N = nitrogen

b) (i) The elements which are non-metals are nitrogen, oxygen, and sulphur.

(ii) The elements which exist as molecules are nitrogen and oxygen.

(iii) The elements which are metals are iron, sodium, and magnesium.

(iv) Iron will rust if it is exposed to water and oxygen.

c) (i) The compound that is made when iron is heated with sulphur is iron sulphide.

(ii) The compound formed when magnesium is burned in air or oxygen is magnesium oxide.

Question 22

a) (i) There are three elements in sulphuric acid (hydrogen, sulphur, and oxygen).

(ii) There are seven atoms in a molecule of sulphuric acid.

b) (i) There are three elements in aluminium sulphate (aluminium, sulphur, and oxygen).

(ii) There are 17 atoms in a molecule of aluminium sulphate.

c) (i) Diagram 3 represents an element.
   (ii) Diagram 1 represents a pure compound.
   (iii) Diagram 5 represents a mixture of elements.
   (iv) Diagram 2 represents a mixture of compounds.
   (v) Diagram 4 represents a mixture of elements and compounds.

Question 23

a) The eight molecules are: 1. H_2O (water); 2. CO (carbon monoxide); 3. O_2 (oxygen); 4. NH_3 (ammonia); 5. NO (nitric oxide); 6. NO_2 (nitrogen dioxide); 7. CO_2 (carbon dioxide); 8. H_2 (hydrogen)

b) *Valency* is the combining power of an atom or ion.

c) The valencies for the four elements are:
   i) hydrogen: 1 ii) carbon: 4 iii) oxygen: 2 iv) nitrogen: 3

Question 24

a)

Particle	**Example**
atom	Na
ion	K+
molecule	O_2

b) A chlorine atom has seven electrons in its outer shell. It can reach a full shell by accepting or gaining one electron from the magnesium atom. It then becomes a chloride ion.

c) Water is a compound. It is made of water molecules H_2O.
   i) A compound is two or more different atoms chemically joined together.
   ii) The atoms in a water molecule are held together by shared pairs of electrons.
   This type of chemical bond is called a covalent bond.

Physical and chemical changes

CHAPTER 9

Teaching Objectives

- To extend earlier learning on physical and chemical changes
- To identify examples of physical and chemical changes occurring in the environment
- To explain the importance of hydrocarbons as fuels
- To explain the physical and chemical properties of fertilizers, their uses, and harmful effects when used improperly
- To introduce simple ideas on the hydrogenation of vegetable oil into fat
- To introduce simple ideas on the manufacture, properties and uses of plastics
- To compare and contrast reversible and non-reversible changes in a variety of materials and situations

Learning Outcomes

After studying this chapter students should be able to:

- differentiate between physical and chemical changes
- identify some physical and chemical changes taking place in the environment
- explain the use of hydrocarbons as fuels
- explain the physical and chemical properties of fertilizers, which make them useful in agriculture
- discuss the harmful effects of the improper use of fertilizers
- describe the chemical process by which vegetable oil changes into fat
- describe, simply, the process for the manufacture of plastics
- distinguish between the reversible and non-reversible changes in materials
- identify a variety of reversible and non-reversible changes in materials in their surroundings

Introduction

A substance can be changed by heating it, adding water to it, mixing it with another substance, and so on. The change which takes place will be either a chemical one or a physical one.

Mixtures and chemical reactions

The classic demonstration of the difference between a physical and a chemical change involves mixing together some black iron filings with yellow sulphur. The mixture is easily separated again, by using a magnet to attract the iron filings. Alternatively, and less easily, the sulphur can be separated by dissolving it in methylbenzene. The iron filings do not dissolve.

If, however, the mixture of iron filings and sulphur is heated, it glows brightly. The yellow sulphur disappears and a black solid forms. The black solid is not at all like the mixture. It is not affected by a magnet and none of it dissolves in methylbenzene. The black solid is obviously a new substance and a chemical change has taken place. The iron and sulphur have reacted together to form the compound iron sulphide.

In the mixture of iron and sulphur, described above, iron and sulphur particles are mixed closely together, but they have not bonded to each other. In fact, they can be mixed in any proportion you wish. During the chemical reaction, the iron and sulphur atoms form ions which bond to each other in definite ratios or proportions. The magnet and solvent now have no effect.

Properties of chemical changes

A chemical change is usually called a chemical reaction. You can usually tell that a chemical reaction has taken place by these signs:

- One or more new substance is formed. The new substance, the product, usually looks quite different from the starting substances (the reactants).
- Energy is taken in or given out during the reaction. In the iron and sulphur example, a little heat from a Bunsen burner is needed to start the reaction, but then the reaction gives out its own heat, even after the Bunsen burner is removed.
- A reaction which gives out heat energy is called an exothermic reaction. The combustion of fuels is exothermic, producing heat and sometimes also light.
- A reaction which takes in heat energy is called an endothermic reaction. The reactions that take place during cooking are endothermic.
- The change is usually very difficult to reverse. You would need to carry out several other reactions to get the iron and sulphur back from iron sulphide.

Properties of physical changes

Ice turns back to water at 0°C. It is easy to change the water to ice again by cooling it.

Iodine crystals sublime when they are heated. The iodine vapour changes back to solid iodine when it touches a cold surface.

Sugar dissolves in ethanol. You can separate the two again by distilling the solution.

All three of the above examples are physical changes. No new chemical substances are formed in any of the changes and, although ice and water look different, they are both made of water molecules and have the formula H_2O.

Physical changes, like those above, are usually quite easy to reverse.

Safety considerations

Strict attention to safety is necessary during work on this chapter, and the students should wear safety spectacles even if they are simply observing an experiment carried out by the teacher. The Students' Book describes, briefly, the formation of plastics. Some suggestions for simple observation activities with plastics are included in the **Ideas for investigation and extension work** section of this chapter. Many textbooks suggest heating small pieces of different kinds of plastic to compare their reaction to heat. However, all forms of plastic give off toxic fumes when they burn, and it is recommended that you only heat or burn plastics if you have access to an efficient fume cupboard.

Lesson suggestions

1. Reversible and non-reversible changes

Refer to page 106 of the Students' Book

Starter suggestions

Ask the students what they remember about physical and chemical changes from their primary school science.

Ask the students to make a table to compare the properties of solids, liquids and gases and to include details or diagrams showing how the particles of each are arranged.

Main lesson

Start the lesson by discussing what is meant by the words 'reversible' and either 'non-reversible' or 'irreversible'. Ask them to give you a sentence which uses one or other of these words, to see that they understand the meaning.

Explain them that in chemistry a reversible change is one in which no new substances are formed, whereas a non-reversible or irreversible change is one in which one or more new substances are formed. Explain that we often call reversible changes physical changes, while non-reversible or irreversible changes are often called chemical changes.

Demonstrate the iron filings and sulphur experiment, using a magnet to separate the components of the mixture (a reversible change), and then heat the mixture to show that an irreversible or non-reversible change has occurred, with the formation of iron sulphide.

Add some common salt (sodium chloride) to some crushed ice. The ice melts and salt solution is formed (a reversible or physical change because the salt can be separated from the water, and then the water can be frozen again to form ice cubes).

Heat a few iodine crystals in a test-tube. The iodine turns directly to a purple vapour which solidifies in the cooler, upper parts of the tube (a reversible or physical change).

Heat a few blue copper sulphate crystals in a boiling tube until they turn white, because water has been driven off from the crystals. Leave the white substance (now called anhydrous copper sulphate) to cool and then add a few drops of water (another reversible or physical change).

Add a small length of magnesium ribbon to dilute hydrochloric acid in a test-tube. Show that the mixture fizzes, and test the gas given off with a lighted splint to show that it is hydrogen.

This is an irreversible or non-reversible reaction because the new substances magnesium chloride and hydrogen are formed.

Ask the students how many other reversible changes or reactions they can think of. Then give them Worksheet 1 to complete.

2. Chemical changes

Refer to page 108 of the Students' Book

Starter suggestions

Remind the students that in a chemical change or chemical reaction a new substance is made. In a reversible or physical change no new substance is formed.

Main lesson

Ideally the students need to have lots or practical experience of chemical reactions. If possible, let the class carry out the experiment of burning magnesium, with suitable safety precautions, as described on Worksheet 5. If this is not possible, then the teacher can demonstrate the experiment and have student volunteers to carry out the weighing part of the activity.

Worksheets 2, 3, and 4 describe simple, less expensive experiments that the students may be able to carry out. In Worksheet 2, the students should discover that heat causes a chemical change in the lemon juice, vinegar or milk. The heat causes the formation of molecules which absorb light, giving the liquid a dark colour; this is clearly visible. This is an example of a chemical change and such chemical changes can rarely be reversed.

As a result of this lesson, the students should become aware that, in a chemical change or chemical reaction, they may see a gas being produced, a colour change, the emission of light, or fizzing. None of these is absolute proof of a chemical change. The four definite proofs that a chemical change has occurred are:

- A new substance is produced which usually looks quite different from the substances you started with.
- Energy (usually heat energy) is given out or taken in during the reaction.
- The change may be impossible to reverse. In other words, most chemical changes are non-reversible.
- Although the atoms of each element combine in different ways, the same atoms that were there at the start are there at the end of the reaction. Because of this, the total mass stays the same.

The other aspect of chemical changes to stress here is the meaning of the terms endothermic and exothermic in connection with chemical changes or chemical reactions. An endothermic reaction is one which takes in heat, as for example in all forms of cooking. An exothermic reaction gives out heat. Examples include the reaction when iron filings and sulphur are heated and produce iron sulphide, the burning of magnesium ribbon in air or oxygen, and the combustion of fuels. The **Ideas for investigation and extension work** section on page 144 describes a simple example of each type of reaction, where the energy changes can be monitored with the aid of a thermometer.

3. Combustion and energy from fuels

Refer to page 110 of the Students' Book

Starter suggestions

Remind the students of the work carried out during the last lesson and ask them to explain the meaning of the words *endothermic* and *exothermic* in connection with chemical reactions.

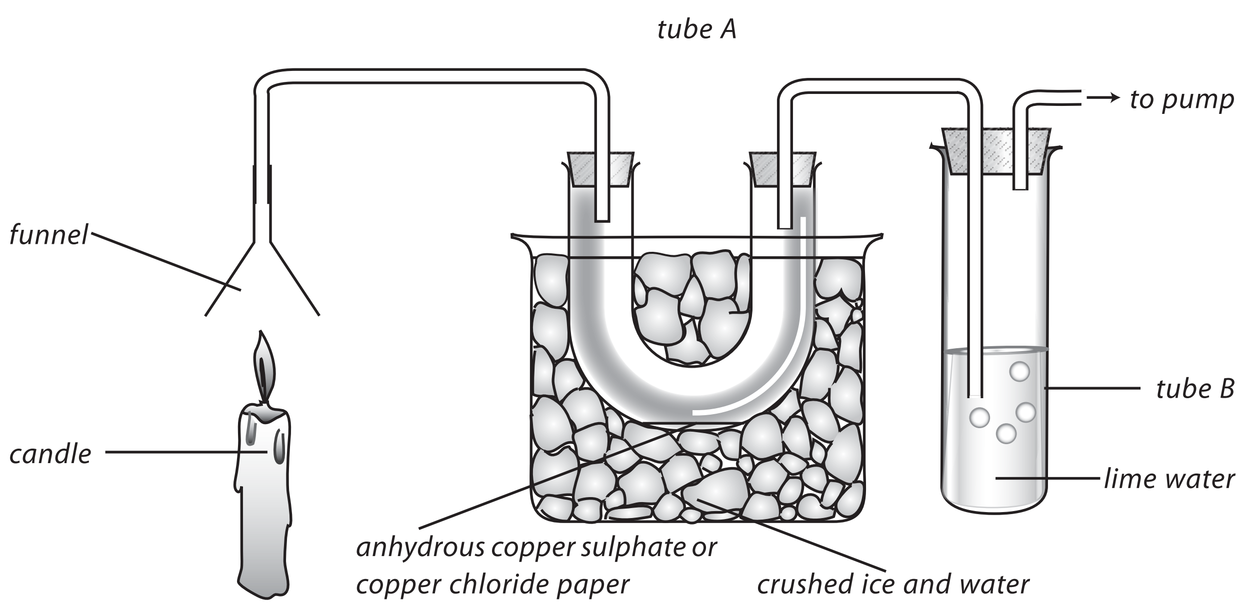
Ask them which type of reaction is taking place in a bonfire where garden rubbish is being burned. What are the three things a fire needs to start it burning? (fuel, air or oxygen, and heat). What happens if you remove one of these three things? (The fire goes out.) What new substances are produced when a bonfire burns? (soot, smoke, ash, carbon dioxide and other gases).

Main lesson

Introduce the students to the word *combustion* as an alternative to the word 'burning'. Combustion is a chemical reaction in which a substance (called a fuel) reacts rapidly with oxygen and produces heat and light. All combustion reactions are exothermic.

Explain that all of the important fuels we obtain energy from are hydrocarbons. They contain only carbon and hydrogen. We cannot easily and safely experiment with oil or petrol, but the wax of a candle is also a hydrocarbon.

Set up the apparatus shown in the diagram below:



It is important to turn the pump on before lighting the candle to show that drawing air through the apparatus has no effect on the anhydrous copper sulphate or cobalt chloride paper, or the lime water. Shortly after the candle has been lit, the anhydrous copper sulphate will turn blue or the cobalt chloride paper will turn from blue to pink, in both cases showing the presence of water, while the lime water will be turned cloudy or milky by carbon dioxide.

The carbon and hydrogen in the candle wax have been changed into carbon dioxide and water, and heat and light energy have been released.

Now demonstrate what happens with a Bunsen burner flame, first of all when the air-hole is closed, and then when it is fully open. Using tongs, hold a piece of white tile in the flame. In the case of the flame with the air-hole closed, particles of soot will quickly be deposited on the white tile.

Remind the students that natural gas is also a hydrocarbon, methane. When it burns completely in air or oxygen, like the candle wax, it produces carbon dioxide and water. The equation for the reaction is:

$$\text{methane} + \text{oxygen} \longrightarrow \text{carbon dioxide} + \text{water}$$

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

When the gas is not burned completely because there is insufficient air or oxygen, soot (carbon) is produced which, in quantities, can cause respiratory problems. Poisonous carbon monoxide gas is also formed but, fortunately in the case of the Bunsen burner, this is inflammable.

By this stage of the lesson the students should understand that:

- The combustion or burning of a fuel requires oxygen (or air containing oxygen).
- The combustion of a fuel releases heat energy.
- Complete combustion requires a plentiful supply of oxygen (air).
- Complete combustion of a hydrocarbon produces only carbon dioxide and water.
- Incomplete combustion takes place when there is a shortage of oxygen (air).
- A blue Bunsen burner flame produces more heat energy than a yellow flame.
- A yellow Bunsen flame produces a lot of soot (carbon).
- Incomplete combustion of a hydrocarbon fuel produces carbon monoxide (a poisonous gas), carbon in the form of soot, and water.

Now ask the students to research the many ways in which we use combustion to produce useful energy.

Ideas for investigation and extension work

Endothermic reactions

Here are two examples of endothermic reactions that are easy to demonstrate to the students.

a) Take the temperature of about 25 cm^3 of dilute hydrochloric acid in a small beaker. Add to this about four spatula measures of potassium hydrogencarbonate. Observe what happens to the temperature as shown by the thermometer.

b) Mix together roughly equal amounts of sodium hydrogencarbonate (bicarbonate of soda) and citric acid crystals (the acid contained in citrus fruits). Find the temperature of about 25 cm^3 of distilled water in a small beaker. Then add the solid mixture to the water and notice the temperature change.

Experiments with plastics

Test plastics for strength and durability. Cut strips of polythene (from a polythene bag) 20 cm long and 1 cm wide. Hold the strip at each end and see if you can break it by pulling. If the strip does break, examine the break. Does the strip get narrower at the break? How long does a 20 cm long strip become before it breaks? Does the stretched plastic strip spring back like elastic when you let it go? Take another strip of polythene 30 cm long and 1 cm wide. Attach a small plastic pot to one end and hold the other end firmly in a clamp. Add weights, one at a time, to the pot. How much weight is needed to break the strip? If you repeat the experiment with a strip 2 cm wide, does it take twice the weight to break it?

Examine a piece of expanded polystyrene. Break a piece off and look at the broken edge. What does it look like? Can you squash the expanded polystyrene in your fingers? Does it spring back like rubber when you let go? Devise an experiment to see how much force is needed to make a dent in expanded polystyrene. Discuss what expanded polystyrene is used for. Ask the students what they have found out that tells them that it is good for packing and protecting fragile items.

What happens when you twist plastics? Use a piece of plastic strip cut from a squeezy bottle. Try twisting it and then letting it go. What happens?

Test the strength of threads made from nylon and other kinds of artificial fibres. Which is the strongest?

WORKSHEET 1

Physical and chemical changes

Materials needed: none

It is very difficult to reverse a chemical reaction and get the original substances back. Signs that a chemical reaction has taken place include a change in colour, heat being given off or bubbles of gas being produced. Physical changes are usually easily reversed.

For each activity below, say whether a chemical change or a physical change is taking place.

adding acid to an alkali change ______________	fireworks change ______________	driving a car change ______________
ice cream melting change ______________	boiling the kettle change ______________	frying an egg change ______________
burning a candle change ______________	melting candle wax change ______________	dissolving sugar in tea change ______________
lighting a match change ______________	making ice cubes change ______________	ironing clothes change ______________
baking a cake change ______________	launching a space rocket change ______________	iron rusting change ______________

WORKSHEET 2

Secret messages

Materials needed: freshly-squeezed lemon juice, or white vinegar, or full-fat milk; small containers; toothpicks, cotton buds or fine paintbrushes; paper; a heat source such as a light bulb or candle.

1. Use lemon juice, vinegar or milk as your ink to write a secret message on a sheet of paper. If you are using a toothpick as the pen, write with the round end so that you do not tear the paper, and press lightly.
2. Allow the paper to dry thoroughly.
3. Heat the paper gently by holding it over a light bulb or some other heat source. Move the paper around so that all of the invisible writing is warmed. The secret message should slowly become visible.

   Safety: Do not hold the paper too close to the heat source or the paper may burn.

4. Is it possible to make the visible writing invisible again? Why or why not? ______________________

   ____

   ____

5. Try other liquids as the secret ink. Which liquids work well? ______________________

   ____

   What type of liquids do not work? ______________________

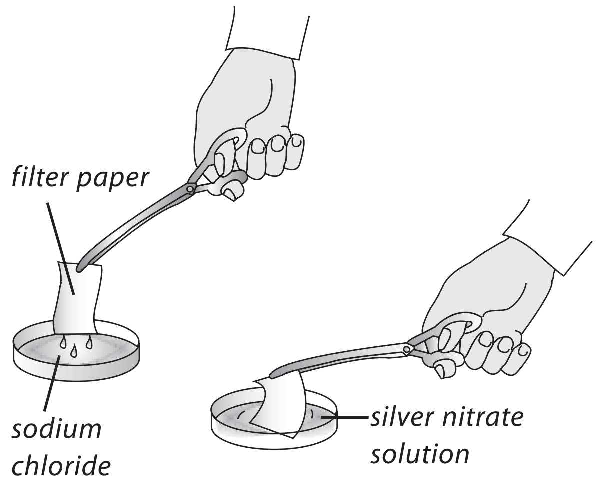
   ____

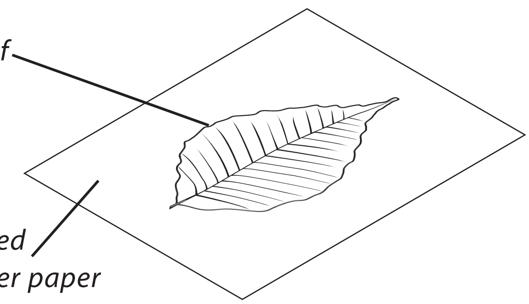
WORKSHEET 3

Light-sensitive paper

Materials needed: 2 petri dishes; tongs; filter paper; scissors; sodium chloride solution (30 g/l); silver nitrate solution

It is not just heat which can bring about chemical changes, light can also change certain substances.





1. Carefully pour bench silver nitrate solution into one petri dish.

   Pour sodium chloride solution into the other dish.
2. Cut a strip of filter paper about 2 cm wide and 5 cm long.
3. Use the tongs to dip the filter paper strip into the sodium chloride solution. Lift the paper and drain off the excess liquid.
4. Now dip this piece of paper into the silver nitrate solution. Again, lift the paper and allow the excess liquid to drain off.
5. Dry the filter paper in a dark place such as in an oven or in a dark cupboard.
6. When the paper is dry, lay some small objects on it. Suitable objects include a coin, a key, a leaf, a badge, or a paper clip. Place the paper in bright sunlight or bright artificial light for about 15 minutes.
7. Carefully remove the objects from the paper.

   a) Describe what you observe. ______________________________

   ____

   b) Can you think of a use for this chemical reaction? ______________________________

   ____

   c) Can you think of another chemical reaction which needs light if it is to take place? ______________________________

   ____

WORKSHEET 4

What kind of change is it?

Materials needed: small glass or plastic bottle; cork that fits tightly in the bottle; metal teaspoon or spatula; 50 cm^3 measuring cylinder; dropper; baking soda; vinegar (or dilute ethanoic acid.)

Draw simple labelled diagrams in the boxes below to show the first three stages of the activity.

1. Put three large spoonfuls or spatulas of baking soda into the bottle.
2. Use the dropper to wet the cork with water.
3. Using the measuring cylinder, pour 50 cm^3 of vinegar into the bottle. Put the cork on the bottle immediately.
   a) What do you observe? ______________________________
   ____
   b) What do you think caused this change? ______________________________
   ____
   c) Is this an example of a physical or a chemical change? ______________________________
   d) How do you know what kind of change it is? ______________________________
   ____
   e) How is this type of change useful in cake making? ______________________________
   ____

WORKSHEET 5

Investigating the burning of magnesium in air

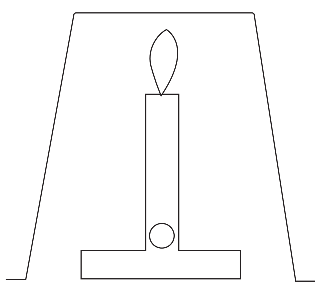
Materials needed: crucible and lid; Bunsen burner; heatproof mat; strip of magnesium ribbon; tripod; wire gauze; tongs; electronic balance

Safety: Wear safety spectacles. Do not stare directly at the burning magnesium and do not touch the crucible or lid with your hands at any time after you begin heating.

1. Place the strip of magnesium ribbon into the crucible and put on the lid.
2. Use the electronic scales to weigh the crucible, lid, and magnesium. Record the mass in the table below.
3. Heat the crucible strongly for about 5 minutes. Once the magnesium begins to burn, **briefly** lift the lid of the crucible so that you can see the reaction that is occurring.
4. Turn off the Bunsen burner and leave the crucible for 10 to 15 minutes to cool.
5. When the crucible has cooled down, weigh it and the lid again. Record your results in the table below.

Mass of crucible before burning (g)	Mass of crucible after burning (g)

Complete and label the diagram of the apparatus you used.



Now answer the following questions:

What was the appearance of the magnesium **before** it was burned? ______

What was the appearance of the magnesium **after** it was burned? ______

Did the mass of the crucible increase or decrease? ______

The magnesium has reacted with another element to form a compound. What element do you think it reacted with? ______

If a reaction has taken place, how do you explain the change in mass? ______

Complete the word equation for the reaction:

magnesium + ______ $\longrightarrow$ magnesium ______

Now write the equation for the reaction using symbols.

______

Answers to questions in the Students' Book

1. A gas is the only state of matter that can be easily compressed.
2. When particles of a liquid or gas are heated they move around faster. If the particles are of a solid, then they vibrate faster.
3. The two states of matter which flow easily are liquids and gases.
4. The particles in a solid have least energy of the three states of matter and they are packed close together.
5. The opposite process to melting is freezing.
6. When a substance, i) boils, its atoms or molecules move faster and faster and the bonds between them weaken and break. The liquid has turned into a gas. ii) melts, its particles vibrate more and the forces which hold them together weaken. The solid expands and at a certain temperature the particles have enough energy to break free from each other. The solid has become a liquid. iii) freezes, its particles have less and less energy as the temperature falls. Eventually the particles stop moving or vibrating, and the liquid becomes a solid. iv) condenses, its particles have less energy because it has been cooled. Eventually the gas turns into a liquid.
7. The particle theory explains gases by saying that the particles are far apart and the forces between them are weak. As a result, gases have no definite volume—they always fill the container they are in. They are also easily compressed, when the particles are squashed together, and they expand greatly when they are heated and the particles gain more energy.
8. i) An element is a substance which cannot be broken down into simpler substances by ordinary chemical methods. Iron, sodium, calcium, phosphorus, and oxygen are just a few examples of elements.
   ii) A compound is a substance made up of two or more elements combined by a chemical reaction—common salt, water, sulphuric acid, copper sulphate, and iron sulphide are examples of compounds.
   iii) A mixture is two or more substances in any proportions where no chemical reaction has taken place to combine them.
   iv) A physical change is one where a material alters but its chemical make-up remains the same. Some examples of physical change include melting, freezing, boiling, condensing, and dissolving substances.
   v) A chemical change is a change in which one or more new substances are formed. It is not easy to reverse a chemical change and examples include burning wood, toasting bread, rusting of iron, and boiling an egg.
9. During a chemical change or chemical reaction, a new substance is produced which looks different from the substances you started with. Energy (usually heat energy) is given out or taken in during the reaction. The change is usually impossible to reverse, and the total mass of the substance or substances involved stays the same, even though the atoms of each element have combined in new and different ways.
10. Examples of chemical changes include cooking food, burning fuels, heating iron and sulphur together, burning magnesium ribbon, and the rusting of iron.

11. An endothermic reaction is one which takes in heat. Photosynthesis, cooking foods, and heating lead oxide to produce the metal lead are endothermic reactions. An exothermic reaction is one which gives out heat. Examples of exothermic reactions include heating a mixture of iron and sulphur to form iron sulphide, burning magnesium ribbon, and burning fuels such as coal, oil, gas, and wood.
12. A fuel is any substance which can be burned to give heat or light. Fuels include wood, coal, oil, petrol, and natural gas (methane).
13. A hydrocarbon is a compound of carbon and hydrogen. Most fuels are hydrocarbons.
14. Chemical fertilizers contain mineral salts that help plants to grow better. Natural fertilizers, such as manures, not only provide plants with mineral salts, they also add humus to the soil, so improving its structure and its population of useful microorganisms. Used in excess, fertilizers can weaken or kill plants and pollute water.
15. Hydrogen gas is used in the manufacture of margarine because it raises the melting point of the vegetable oil so that it becomes a solid rather than a liquid at room temperature. This process is known as hydrogenation.
16. Plastics are better than metals in some cases because plastics do not rot or corrode, they are light in weight, they can be made in many different colours. In addition, most plastics are good insulators of heat and electricity.
17. Perfume soon spreads throughout a room because the liquid perfume has a very low boiling point. It evaporates at room temperature and the gas or vapour particles, like all gases, spread out to fill the container they are in, in this case the room.
18. PVC is short for polyvinylchloride. This common plastic is easily moulded into different shapes. It is rigid and colourless at first, but can be hardened and coloured if necessary. It is used for gutters and pipes for houses, insulation on electrical cables, plastic raincoats, washable 'vinyl' wallpaper, the soles of some shoes, and plastic or vinyl tiles.

Assessment

Question 1

Use the words from the list below to complete the seven sentences.

heat	solids	freezes	shape	volume	cool	melted

i) Liquids change ________________ when you move them around in a container.

ii) ________________ do not change shape when you move them.

iii) Moving a liquid from a bottle to a drinking glass does not change its ________________.

iv) When a liquid ________________ it turns into a solid.

v) When a solid turns into a liquid, we say it has ________________.

vi) To turn a solid into a liquid, you must ________________ it.

vii) To turn a liquid into a solid, you must ________________ it.

Question 2

Which of the following is a chemical change?

(A) boiling (B) distillation (C) evaporation (D) rusting

Question 3

An example of a physical change is the:

(A) ignition of petrol in a car engine
(B) dissolving sugar in tea
(C) conversion of glucose to energy in the body
(D) lighting a match

Question 4

An example of a chemical change is:

(A) cutting bread with a knife
(B) baking bread dough
(C) evaporation of a puddle of water
(D) making salt from sea water

Question 5

Which of the following statements does NOT describe a reversible change?

(A) boiling water in a kettle
(B) dissolving sugar in tea
(C) melting an ice cube
(D) exploding a firework

Question 6

The rusting of iron is considered to be a chemical reaction because:

(A) No heat is given out during the process.
(B) The rust looks different from the iron.
(C) The rust cannot be changed back to iron.
(D) The rust forms only when water and air are present.

Question 7

Which word would you use to describe a substance that releases energy when it is burnt?

(A) endothermic (B) reactive (C) exothermic (D) fuel

Question 8

When a fuel burns it releases heat energy. How is heat energy measured?

(A) degrees Centigrade (B) grams (C) Joules (D) metres

Question 9

Which of the following is TRUE about burning fossil fuels such as coal, oil, and gas?

(A) Clean fuels burn with a yellow flame.
(B) Most fuels contain very little carbon.
(C) The fuel reacts with nitrogen.
(D) A lot of heat energy is released.

Question 10

A mixture of iron filings and sulphur was heated over a Bunsen flame for two or three minutes. When the Bunsen was taken away, the solid remained hot for several minutes. Which of the following statements is true?

(A) The reaction was endothermic (absorbed heat).
(B) The iron dissolved in the hot liquid sulphur.
(C) A hot mixture of iron and sulphur was produced.
(D) A compound of iron and sulphur was produced.

Question 11

Which of the following NEVER occurs during a chemical reaction?

(A) Atoms are changed to different atoms.
(B) Molecules are changed to different molecules.
(C) Atoms are combined to form molecules.
(D) Molecules break down into atoms.

Question 12

Which of the following is a physical change?

(A) molten steel solidifying
(B) zinc dissolving in hydrochloric acid
(C) petrol burning
(D) steel rusting

Question 13

Many fuels contain the elements carbon and hydrogen.

a) What name is given to compounds that contain carbon and hydrogen? ____________________

b) Name the gas produced when carbon burns in a good supply of oxygen. ____________________

c) When hydrogen burns in oxygen, water vapour H_2O is produced. Write a word equation for this reaction.

____

d) This reaction can also be summed up using an equation with symbols. The symbol equation below sums up this reaction. Balance this equation.

$H_2 + O_2 \longrightarrow H_2O$

Question 14

Use the words from the list below to complete the following sentences.

boiling	bubbles	colour	compound	condensation
element	equation	gases	heat	products
reaction	reactants	reversed	word	

a) Hydrogen and carbon dioxide are both ____________. If they are formed in an experiment you will see ____________. This can be a sign that a chemical ____________ has taken place.

b) Other signs of a chemical reaction include an increase in temperature if ____________ is released, or a change in ____________.

c) Physical changes, such as ________________, do not make new materials and are easily ________________, for example by cooling which causes ________________.

d) The substances you start with are called ________________, and after a chemical change the substances formed are called the ________________.

e) Because zinc consists of only one type of atom it is called an ________________.

f) In carbon dioxide, the atoms of carbon and oxygen have been combined, so carbon dioxide is known as a ________________.

g) A shorthand way of showing a chemical reaction is to use a ________________ ________________.

Question 15

The fuels methane and octane are both hydrocarbons: octane has the formula C_8H_{18}; methane has the formula CH_4.

a) Which two elements do methane and octane contain? ________________

b) Name the two compounds formed when methane is burnt. ________________

c) Give the formulae for the two products formed when methane is burnt. ________________

d) Write a word equation to describe the burning of methane.

____

e) Write a balanced symbol equation to represent the complete combustion or burning of methane.

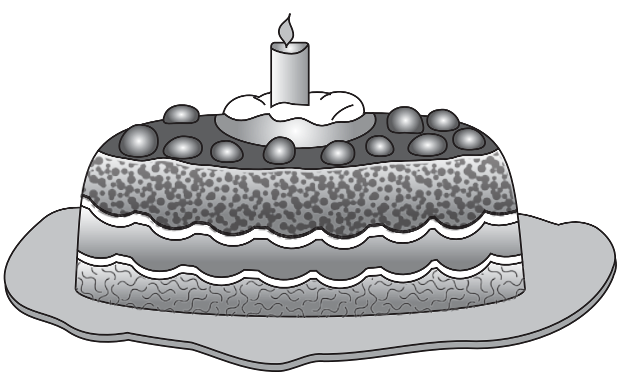
____

f) Why does the complete combustion of methane and octane produce the same products?

____

Question 16

Kaleem baked this cake in an oven.



a) Baking a cake is a chemical change. Describe ONE change that happens during a chemical change.

____

____

b) Kaleem added baking powder to the cake mixture before he put it in the oven.

Baking powder contains sodium hydrogencarbonate (also called bicarbonate of soda or sodium bicarbonate).

When sodium hydrogencarbonate is heated it breaks down. It makes sodium carbonate, carbon dioxide, and water.

(i) Write down the word equation for the breakdown of sodium hydrogencarbonate.

_______________ $\longrightarrow$ _______________ + _______________ + _______________

(ii) Why is baking powder added to cake mixture?

____

(iii) Explain how you would test for carbon dioxide gas.

____

____

Question 17

Ammonium chloride is a fertilizer often used by farmers.

Ammonium chloride has the chemical formula NH_4Cl.

a) Ammonium chloride contains one element that is essential for the growth of plants. What is the name of that element? _______________

b) What other elements are present in ammonium chloride? _______________

____

c) How many atoms are present in one molecule of ammonium chloride? _______________

____

d) What is ONE property of ammonium chloride that is essential if it is to be used as a fertilizer? _______________

____

e) Why do farmers use fertilizers? ______________________________

____

f) Give TWO possible disadvantages of using fertilizers such as ammonium chloride.

i) ______________________________

ii) ______________________________

Question 18

Chemical reactions can be classified as exothermic or endothermic.

(i) What is the meaning of the term *endothermic*?

____

(ii) What is the meaning of the term *exothermic*?

____

(iii) The table below shows the temperature change during three chemical reactions:

Reaction	**Reactants**	**Temperature before the reaction (°C)**	**Temperature during the reaction (°C)**
A	iron and sulphur	17	200
B	sodium hydrogencarbonate and citric acid	17	14
C	zinc and copper sulphate solution	17	22

Which of the reactions A, B, and C is exothermic and which is endothermic?

Exothermic ______________________________

Endothermic ______________________________

(iv) Complete the following sentence using either *exothermic* or *endothermic*.

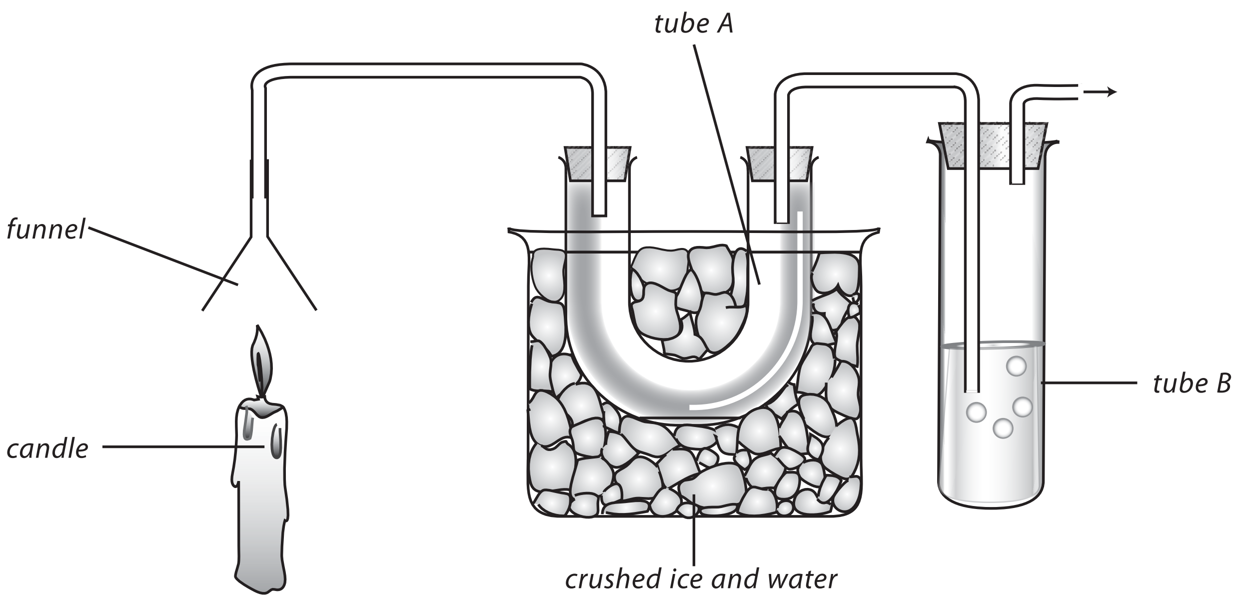
All combustion reactions are ______________________________.

The reactions which take place during cooking are ______________________________.

Question 19

Candle wax is an example of a hydrocarbon. It contains carbon and hydrogen.

Look at the diagram on page 158. It shows a candle burning. The chemicals made when the candle burns go through the apparatus.



a) (i) Tube **A** is surrounded by ice. A colourless liquid slowly collects in this tube. What is the name of this liquid?

(ii) The liquid in tube **B** is used to test for carbon dioxide. What is the name of this liquid?

(iii) What will happen to the liquid in tube **B** if carbon dioxide is produced?

b) Write a word equation for the burning of a hydrocarbon such as candle wax.

c) The complete combustion of a hydrocarbon is **better** and **safer** than incomplete combustion. Give TWO reasons why this is so.

d) The amount of energy released when a fuel is burned is measured in joules (J) or kilojoules (kJ). The table below shows the amount of energy released when one gram of each of five fuels was burnt.

Fuel	Energy released by one gram of fuel (in kJ)
ethanol (a biofuel)	44.3
hydrogen	143.0
methane	55.6
methanol	22.3
petrol	48.3

Which fuel released most energy? ____________________

e) One factor to think about when choosing a fuel is the amount of energy released.

Write down ONE other factor.

____

Answers to assessment questions

Question 1

i) Liquids change shape when you move them around in a container.

ii) Solids do not change shape when you move them.

iii) Moving a liquid from a bottle to a drinking glass does not change its volume.

iv) When a liquid freezes it turns into a solid.

v) When a solid turns into a liquid, we say it has melted.

vi) To turn a solid into a liquid, you must heat it.

vii) To turn a liquid into a solid, you must cool it.

Question 2 (D) **Question 3** (B) **Question 4** (B) **Question 5** (D)

Question 6 (C) **Question 7** (C) **Question 8** (C) **Question 9** (D)

Question 10 (D) **Question 11** (A) **Question 12** (A)

Question 13

a) Compounds that contain carbon and hydrogen are called hydrocarbons.

b) The gas produced when carbon burns in a good supply of oxygen is carbon dioxide.

c) The word equation for when hydrogen burns in oxygen, producing water vapour, is:

$$\text{hydrogen} + \text{oxygen} \longrightarrow \text{water}$$

d) The balanced symbol equation for the reaction is:

$$2H_2 + O_2 \longrightarrow 2H_2O$$

Question 14

a) Hydrogen and carbon dioxide are both **gases**. If they are formed in an experiment you will see **bubbles**. This can be a sign that a chemical **reaction** has taken place.

b) Other signs of a chemical reaction include an increase in temperature if **heat** is released, or a change in **colour**.

c) Physical changes, such as **boiling**, do not make new materials and are easily **reversed**, for example by cooling which causes **condensation**.

d) The substances you start with are called **reactants**, and after a chemical change the substances formed are called the **products**.

e) Because zinc consists of only one type of atom it is called an **element**.

f) In carbon dioxide, the atoms of carbon and oxygen have been combined, so carbon dioxide is known as a **compound**.

g) A shorthand way of showing a chemical reaction is to use a **word equation**.

Question 15

a) The two elements methane and octane contain are carbon and hydrogen.

b) When methane is burnt, the two compounds formed are carbon dioxide and water vapour.

c) The formulae of the two products formed when methane is burnt are CO_2 and H_2O.

d) The word equation to describe the burning of methane is:

$$\text{methane + oxygen} \longrightarrow \text{carbon dioxide and water vapour + energy}$$

e) The balanced symbol equation which represents the complete combustion or burning of methane is:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O + \text{energy}$$

f) The complete combustion of methane and octane produces the same products because they are both made of the same elements, carbon and hydrogen.

Question 16

a) The changes that happen during this particular chemical change are that there is a change of colour, a gas (carbon dioxide) is produced, and the reaction cannot be reversed.

b) (i) The word equation for the breakdown of sodium hydrogencarbonate is

$$\text{sodium hydrogencarbonate} \longrightarrow \text{sodium carbonate + water + carbon dioxide}$$

(ii) Baking powder is added to cake mixture to make the mixture 'rise' (or become spongy in texture) due to the carbon dioxide that is produced when the mixture is heated.

(iii) The test for carbon dioxide is to bubble the gas into lime water, which then goes milky or cloudy.

Question 17

a) The element in ammonium chloride that is essential for the growth of plants is nitrogen (N).

b) The other elements present in ammonium chloride are hydrogen and chlorine.

c) There are 6 atoms in one molecule of ammonium chloride.

d) The properties of ammonium chloride that are essential if it is to be used as a fertilizer are that it must be soluble in water and be able to be absorbed by plant roots.

e) Farmers use fertilizers to increase the yield of their crops (or make them grow better or faster).

f) Possible disadvantages of using fertilizers such as ammonium chloride are that they could make the plants grow too fast and become weak and liable to disease. If the concentration of fertilizer in the soil is too high, it could draw water out of the plant roots and make the plant wilt and die. Surplus fertilizer could be washed into rivers, streams, lakes, and wells and pollute the water.

Question 18

(i) An endothermic reaction is one which takes in heat energy from the surroundings.

(ii) An exothermic reaction is one which gives out heat energy to the surroundings.

(iii) Reactions A and C are exothermic.

Reaction B is endothermic.

(iv) All combustion reactions are exothermic.

The reactions which take place during cooking are endothermic.

Question 19

a) (i) The colourless liquid which slowly collects in tube **A** is water.

(ii) The liquid in tube **B** which is used to test for carbon dioxide is lime water.

(iii) If carbon dioxide is produced, the lime water in tube **B** will turn cloudy or milky.

b) The word equation for the burning of a hydrocarbon such as candle wax is:

$$\text{hydrocarbon} + \text{oxygen} \longrightarrow \text{water} + \text{carbon dioxide}$$

c) The complete combustion of a hydrocarbon is better and safer than incomplete combustion. This is because incomplete combustion may produce soot (carbon particles) or poisonous carbon monoxide, both of which are pollutants of the air. Incomplete combustion also produces less heat energy than complete combustion.

d) Hydrogen is the fuel which releases most energy.

e) Other factors to think about when choosing a fuel, besides the amount of energy released, include how easy or safe it is to store the fuel, how safe it is to use the fuel, and what pollutants are produced.

Heat on the move

CHAPTER 10

Teaching Objectives

- To explain that heat is a form of energy that is transferred from a region of higher temperature to one of lower temperature
- To explain conduction, convection, and radiation with the aid of practical examples
- To examine appliances that make use of the different modes of heat transfer
- To examine some examples of good and poor conductors of heat and their applications
- To explain the structure and functioning of a vacuum flask

Learning Outcomes

After studying this chapter students should be able to:

- explain the flow of heat from a hot body to a cold body
- explain conduction, convection, and radiation through experimentation
- recognize the three modes of transfer of heat from the environment
- suggest how birds can glide in the air for hours
- identify examples of appliances that make use of the different modes of transfer of heat
- list heat-conducting materials in their surroundings
- describe the working and principle of the vacuum flask
- explain how a vacuum flask reduces the transfer of heat

Introduction

Heat and temperature

It is important for students not to confuse the temperature of an object with the heat energy that can be obtained from it. A red-hot spark from a fire is at a higher temperature than the boiling water in a saucepan. If the spark landed in the water, heat would pass from it to the water, even though much more heat energy could be supplied by the water. Heat flows naturally from an object at a higher temperature to one at lower temperature.

Temperature is thus a measure of the degree of hotness of an object or material and can be read on a thermometer. Heat is a form of energy. When an object is hot, its atoms or molecules vibrate more vigorously than when it is cold. The heat of an object is a measure of the total of all the energy of motion of its atoms and molecules. Its temperature is a measure of the average energy of motion of these atoms and molecules.

To refer back to our original example, there are more molecules in the saucepan of boiling water than there are in the tiny spark. (The water weighs much more than the spark.) The water therefore contains more energy in its moving molecules than the spark. But the spark is at a higher temperature because the average energy of its molecules is greater than that of the water.

Conduction

The handle of a metal spoon placed in a hot drink soon gets warm. Heat passes along the spoon by conduction. Conduction is the flow of heat through matter from places of higher temperature to places of lower temperature.

Most metals are good conductors of heat; materials such as wood, glass, cork, plastics and fabrics are poor conductors. Metal objects below body temperature feel colder than those made of poor conductors because they carry heat away from your hand faster—even though all the objects are at the same temperature.

Liquids and gases also conduct heat, but only slowly. Water is a poor conductor of heat, as may be shown by the experiment described in the **Ideas for investigation and extension work** section of this chapter.

Good conductors of heat are used wherever heat is required to travel quickly through something. Kettles, saucepans, boilers and heaters are made of metals such as aluminium, steel and copper. If an electric kettle is made of plastic, then the heating element is made of metal. Poor conductors are also called insulators, or thermal insulators, and are also widely used. The handles of teapots, kettles and saucepans are made of wood or plastic. Cork is often used for tablemats.

Air is one of the worst conductors (or best insulators). That is why houses with cavity walls (i.e. two walls separated by an air space) and double-glazed windows, keep warmer in winter and cooler in summer. Materials which trap air, such as wool, felt, fur, feathers, polystyrene, and fibre glass, are also very bad conductors or good insulators. Some are used as 'lagging' to insulate hot water pipes, hot water cylinders, ovens, refrigerators, and the roofs and walls of houses. Others are used to make warm winter clothes.

Convection

Convection is the usual method by which heat travels through liquids and gases. It is the flow of heat through a liquid or gas from places at higher temperature to places of lower temperature by movement of the liquid or gas itself. This is easily demonstrated by dropping a few potassium permanganate crystals down a tube to the bottom of a beaker of water. When the beaker is heated just below the crystals by a small flame, purple streaks rise upwards and fan outwards.

Streams of warm moving liquids or gases are called convection currents. They form when a liquid or gas is heated. The liquid or gas expands and becomes less dense, and is forced upwards by surrounding cooler, denser liquid or gas which moves under it.

Black marks often appear on the wall or ceiling above a lamp or heater. They are caused by dust being carried upwards in air convection currents caused by the hot lamp or heater.

Convection currents set up by electric, gas, or oil heaters help to warm our homes. The domestic hot-water system or central heating system is another application of convection currents. Many so-called 'radiators' are really convector heaters. The water pump in a car helps the natural convection currents to circulate the water more quickly.

Natural convection currents

During the day the temperature of the land increases more quickly than that of the sea. The hot air above the land rises and is replaced by colder air from the sea. A breeze from the sea results. At night the opposite happens: the sea has more heat to lose and cools more slowly. The air above the sea is warmer than that over the land and a breeze blows from the land towards the sea.

Gliders, including hang-gliders, and many birds of prey depend on rising hot air currents, called thermals. By flying from one thermal to another, gliders and birds of prey can stay airborne for several hours. In the case of the birds, it is without the need to flap their wings.

Radiation

Radiation is a third way in which heat can travel. Whereas conduction and convection both need matter to be present, radiation can occur in a vacuum. It is the way heat reaches us from the Sun. Radiation is the flow of heat from one place to another by means of electromagnetic waves. Radiation consists mostly of infra-red radiation, but light and ultraviolet are also present if the body is very hot (e.g. from the Sun).

When radiation falls on an object, it is partly reflected, partly transmitted and partly absorbed. The absorbed part raises the temperature of the object.

Dull black surfaces are better absorbers of radiation than shiny white surfaces. The latter are good reflectors of radiation, which is why buildings in hot countries are often painted white, and why light-coloured clothes are cooler in summer. Reflectors on electric fires are made of polished metal because of its good reflecting properties.

Some surfaces also emit radiation better than others when they are hot. A dull black surface is a better emitter of radiation than a shiny one. Teapots and kettles which are polished are poor emitters and keep their heat longer. In general, surfaces that are good absorbers of radiation are also good emitters when hot.

Vacuum flasks

A vacuum or Thermos flask keeps hot liquids hot or cold liquids cold. It is very difficult for heat to travel into or out of the flask.

Transfer of heat by conduction or convection is minimized by making the flask a double-walled glass vessel with a vacuum between the walls. Radiation is reduced by silvering both walls on the vacuum side. Then if, for example, a hot liquid is stored, the small amount of radiation from the hot inside wall of the flask is reflected back across the vacuum by the silvering on the outer wall. The slight heat loss which does occur is by conduction up the walls and through the stopper. The latter is usually either hollow and filled with air, or filled with an insulating material, to reduce heat loss through it.

Lesson suggestions

1. Heat and conduction

Refer to page 119 of the Students' Book

Starter suggestions

Make sure that the students are clear about the difference between heat and temperature by giving them some examples, such as the red-hot spark and pan of boiling water, described above.

Show some photographs or a DVD of animals that live in the Antarctic. Discuss with the students how these animals manage to survive in sub-zero temperatures.

Main lesson

Introduce the word *conduction* and explain that it refers mainly to solids.

Describe or demonstrate what happens when a metal spoon is put into a hot drink.

If possible demonstrate the activity on conduction described in the **Ideas for investigation and extension work** section of this chapter. If comparisons are made between materials here, then the rods used should really be the same length and diameter and placed in the same part of the flame. The experiment on Worksheet 1 could also be carried out, either as a demonstration or as a class activity. The latter is not really a fair experiment because, ideally, all the piece of material tested should be or the same size and thickness and, of course, the hot-water bottle is losing heat all the time. Discuss the uses of conductors of heat in the home and school.

Go on to discuss poor conductors of heat, and explain that they are also known as insulators.

Point out that materials that feel 'warm' are poor conductors of heat. Examine some of the uses of insulators, perhaps with the aid of the activities described in the **Ideas for investigation and extension work** section of this chapter. You could also compare the insulating properties of pairs of different materials by wrapping them around two identical cans or beakers which contain the same amount of hot water at the same temperature. Measure the loss in temperature at set intervals for, say, thirty minutes. A third identical can or beaker of hot water, without the insulating material, is necessary to act as the control.

The activity on Worksheet 2 is partly to do with insulation, in that the animals at the centre of the group are insulated by the bodies of those around them. Normally, at intervals, the animals on the outside of the group change places with those nearer the centre. But the experiment also demonstrates that small bodies (the individual tubes or animals) lose heat to the air much more quickly than large bodies (the group of tubes or animals). A human baby, for example, will lose heat much faster than one of its parents and therefore it needs warmer clothes.

2. Convection and convection currents

Refer to page 121 of the Students' Book

Starter suggestions

Make a 'wand' by taping short lengths of tissue paper to the end of a short stick. Hold it about 20 cm above the flame of a candle or Bunsen burner (Careful!) or above a hot radiator or heater. Ask the students why the pieces of tissue paper are moving up and down. Alternatively, cut a circle of thin cooking foil and make a pinhole in the centre. Cut several slits, equal distances apart, towards the middle of the circle and then bend them to make the blades of a fan. Use a drawing pin to fix the 'fan' onto the end of a short stick and make sure that the fan turns freely. Again, hold it above a flame or heater, and watch the fan turn. Ask the students what is turning the fan.

Main lesson

Explain that we are about to study convection. We have seen that heat travels through solids by conduction. Liquids and gases also conduct heat, but only slowly. The usual method by which heat travels through liquids and gases is by convection. This relies on the fact that if a liquid or a gas is heated it becomes less dense ('lighter') and rises. We have already seen how rising hot air made the tissue paper or the fan move.

Demonstrate to the students how convection currents form in water when it is heated, using the potassium permanganate experiment described in the **Ideas for investigation and extension work** section on page 168. Do remember that potassium permanganate is an oxidising agent and harmful, and you should handle the crystals with forceps or tweezers. The pink solution is relatively harmless.

Demonstrate convection currents in gases using the smoke chimney activity described in the

Ideas for investigation and extension work section on page 169.

Round off the lesson by describing the uses of convection currents in heating our homes or cooling our car engines, and how convection currents form sea and land breezes as well as thermals. If you are able to find photographs or DVDs of gliders, hang-gliders or soaring birds of prey you can show the students how thermals are used to enable the glider or bird of prey to stay in the air for long periods with minimal effort. A DVD or film of the launch and flight of a hot-air balloon will show another use of convection currents.

3. Radiation

Refer to page 125 of the Students' Book

Starter suggestions

Ask the students what they can remember about light. If they look surprised, tell them that radiation is a third way in which heat can travel, and light is a form of radiation to which the human eye is sensitive. Whereas conduction and convection both need matter to be present, radiation can occur in a vacuum. It is the way heat reaches us from the Sun. Radiation is the flow of heat from one place to another by means of electromagnetic waves. Radiation consists mostly of infra-red radiation, but light and ultraviolet are also present if the object is very hot, like the Sun.

Main lesson

When radiation falls on an object, it is partly reflected, partly transmitted and partly absorbed. The absorbed part raises the temperature of the object.

If the equipment is available let the students carry out the activity described on Worksheet 4. Alternatively, a smaller-scale activity is described in the **Ideas for investigation and extension work** section of this chapter.

An alternative to both these investigations is to take two identical conical flasks, one painted silver, the other painted black. Fill them with equal amounts of cold water. Place each flask about 20 cm from a heater and switch the heater on. Measure the temperature of the water in each flask every minute for ten minutes. Which flask is better at absorbing heat energy? (The black one.) As an extension, take the same two flasks. Fill them with equal amounts of hot water. Measure the temperature of the water in each flask every minute for ten minutes. Which flask cools down more quickly? (A dull black surface is a better emitter of radiation than shiny one.)

Round off this part of the topic by getting the students to conclude that dull black surfaces are better absorbers of radiation than shiny white surfaces. The latter are good reflectors of radiation, which is why buildings in hot countries are often painted white, and why light-coloured clothes are cooler in summer. Also, reflectors on electric fires are made of polished metal because of its good reflecting properties. You can also link the topic of radiation with their work in geography. During the day in desert regions the Sun blazes down on the bare ground and only about 10 per cent of the solar radiation is deflected by dust particles and cloud. The temperature of the ground becomes very high. But at night, up to 90 per cent of the accumulated heat escapes from the desert surface to the upper air because there are few or no clouds to deflect the radiation back to Earth. The result is a dramatic drop in temperature. In temperate regions also, the coldest nights in winter are those where there are few or no clouds in the sky.

Finish the lesson by showing the students a vacuum flask—ideally one of the older kinds, not a modern stainless steel version. Take the flask to pieces and discuss with the students how and why it was constructed of those materials and in that way.

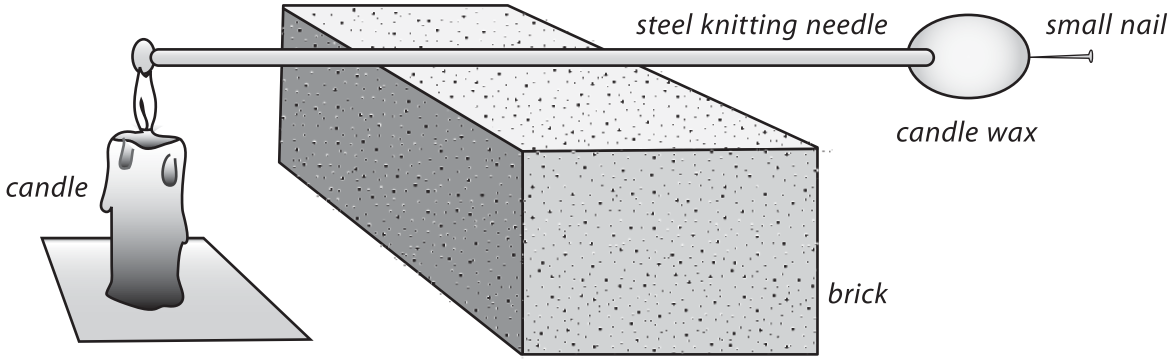
Ideas for investigation and extension work

Thermometers

Research the different types of thermometer available to measure body temperature. Explain the advantages and disadvantages of each type of thermometer.

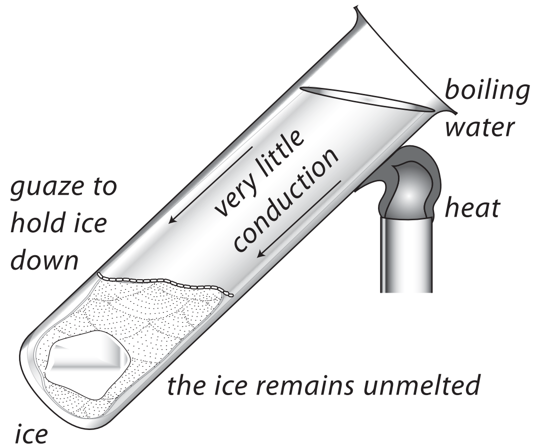
Comparing conductors of heat

Compare the rate at which different materials conduct heat. One method is to hold the tips of rods made of different materials in a beaker of hot water and to see how quickly the heat travels along the length of each to the fingers. An alternative method is shown in the diagram below, where a steel knitting needle is being tested. The time between the heat being applied to one end of the knitting needle and the small nail dropping from the molten wax is measured. To make comparisons fair, other materials tested should ideally be of the same length and diameter.



Is water a good conductor of heat?

Drop a few small chunks of ice into the bottom of a test-tube. Hold them in place at the bottom of the tube either with a paper clip bent and wedged against the sides of the tube or with a piece of gauze. Fill the tube with water and heat the upper part of the tube. The water there will begin to boil, while the ice at the bottom of the tube remains solid, proving that water is not a very good conductor of heat.

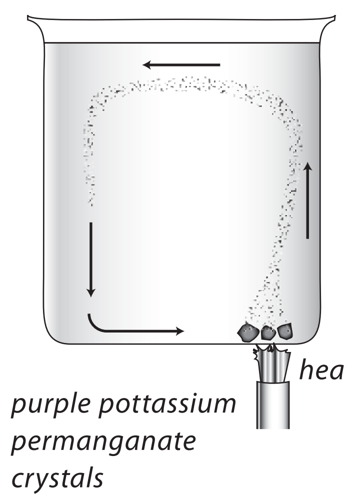


The best insulator

Present groups of students with four thermometers and cups or beakers made of paper, plastic, styrofoam, and glass. Each group will also need a stopwatch or access to a clock with a second hand, a measuring cylinder and a supply of hot water. Ask them to design, and then carry out, an experiment to see which cup is the best insulator. Ask them to draw a diagram of their experimental set-up, and to write down their procedure and details of the variables that they needed to control. They should present their results in a table and from their readings draw a conclusion.

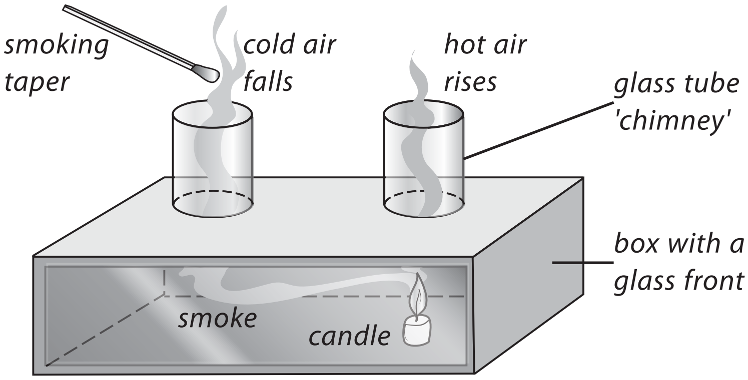
Observing convection currents in water

Stand a large beaker of cold water on a tripod. Drop one or two potassium permanganate crystals down a glass tube onto the edge of the bottom of the beaker. Hold your thumb tightly over the top of the tube and lift the tube out of the water. Use a spirit lamp or Bunsen burner to heat the water directly underneath the crystals. Observe what happens as the purple crystals dissolve.



Convection currents in gases

Place a small piece of candle under one of the chimneys of the smoke chimney apparatus and light it. After a few minutes, bring a smoking taper near to the top of the other chimney. Cold air will fall down this chimney, taking the place of the hot air which has risen above the lighted candle. In this way, a convection current will be created. Explain to the class that convection of air is used in many heating systems, and sea breezes are also caused by convection.



Convection currents and geography

Convection currents are very important in controlling our weather and ocean currents. Ask the students to research these aspects of convection currents so that they begin to appreciate some of the important links between science and geography.

Radiated heat

A small-scale alternative to the experiment described on Worksheet 4 is to stand two thermometers at an exactly equal distance from a heat source, such as a light bulb. The thermometers are identical except that the bulb of one is covered with silver foil or aluminium foil, while the bulb of the other is covered with an equal-sized piece of black paper. The temperatures shown by the two thermometers can be recorded on a graph at, say, one minute intervals from when the bulb is switched on and begins to radiate heat.

Wear a hat?

It is often said that wearing a hat can reduce heat loss from the body in cold weather. Ask the students to devise an experiment to see whether this is true. Ask them to imagine that they have two 250 ml beakers, two thermometers, and lids made from cork that will cover the beakers but have a central hole that a thermometer can pass through. They also have a kettle, a measuring cylinder and a stop clock as well as a small woolly hat. Ask them to draw a labelled diagram of the equipment that they would use. Ask them to write down what they will measure, how they will measure it, and what they will do to make sure that their experiment is a fair test. Ask them also to highlight any safety precautions that need to be taken. If possible, after discussion, let the students who devised the best plan carry out the actual experiment in front of the rest of the class.

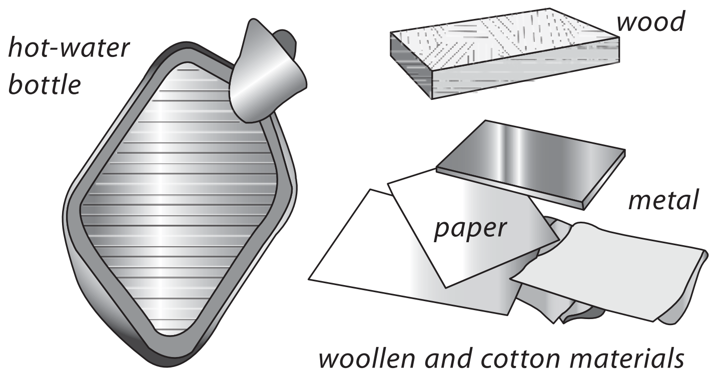
WORKSHEET 1

Which materials are good conductors of heat?

Materials needed: rubber hot-water bottle; piece of wood; plastic plate; metal baking tray; sheet of paper; cotton cloth; woollen cloth; hot water; clock or watch with a second hand

Safety: For this activity use hot but NOT boiling water.

1. Carefully fill the hot-water bottle with hot water.
2. Carefully lay the hot-water bottle on a flat surface. Quickly touch the outside of the bottle. Does it feel hot?
3. Lay the piece of wood on top of the bottle. Leave it there for four minutes.
4. Feel the top of the piece of wood. Does it feel hot, warm or cool now? ______
5. Now lay the metal baking tray on top of the hot-water bottle. Leave it there for four minutes. Is it hotter or colder than the wood was? ______
6. Test the other materials.



Which of the materials let heat through quickly? ______

These are the good conductors of heat.

Which of the materials let heat through slowly? ______

These are the good insulators of heat.

Which of the materials would be good for keeping a teapot hot? ______

Is the experiment a fair comparison of the materials? If not, explain why. ______

______

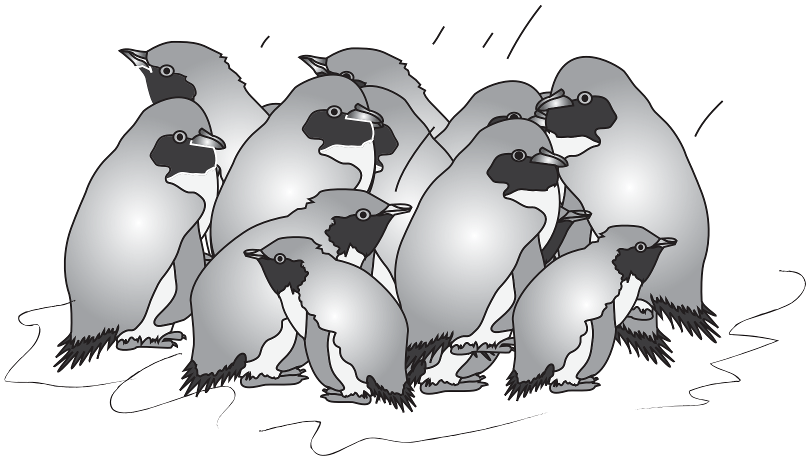
How could you improve the experiment? ______

______

WORKSHEET 2

Why do small animals huddle together in cold weather?

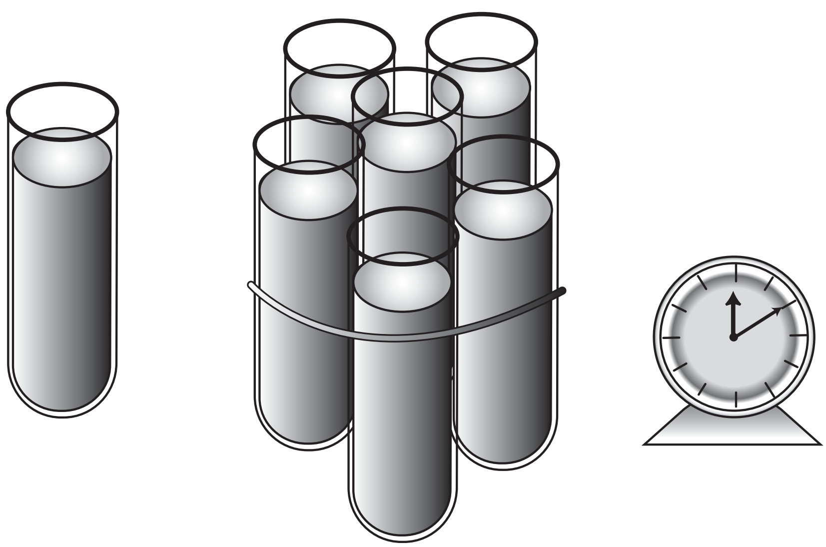
Have you ever noticed that in cold weather small mammals, such as mice, huddle together? In the Antarctic, penguins huddle together. Why do they do this?



Materials needed: seven test-tubes (instead of mice!); thermometers; a stopclock or watch with a second hand; elastic bands; hot water

Safety: use hot, but **NOT** boiling, water for this experiment.

The diagram below gives you a clue as to what you could do the answer the question.



You have to decide:

a) How much hot water to use.
b) How to measure the temperature.
c) How often to measure the temperature.
d) Which tubes you need to test.
e) How you will make sure that your experiment is a FAIR TEST.

Put your results in a table like this:

Time	**Temperature**	
	Single tube	**Huddled tubes**

Does huddling help to keep things warm? ______

Are all the huddled tubes equally warm? If not, why are some warmer than others?

______

______

Why do you think huddling works? ______

______

Explain how you made your experiments FAIR TESTS. ______

______

Draw a graph to explain your results to someone else.

If there were no other animals around, how could one animal try to keep warm? ______

______

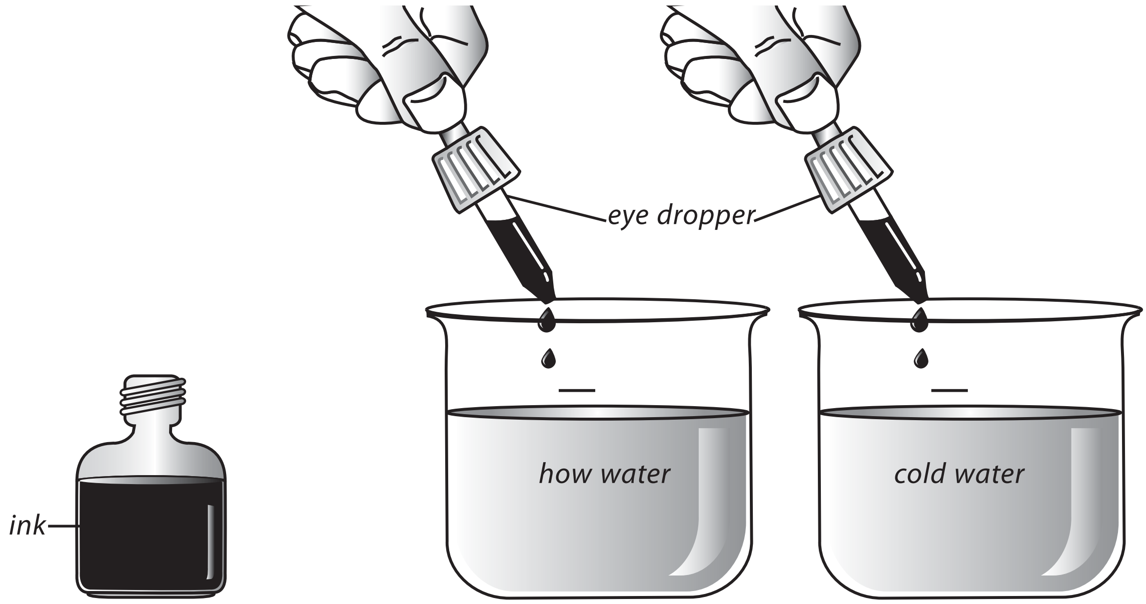
WORKSHEET 3

What happens to the molecules when water is heated?

Materials needed: 2 identical beakers; measuring cylinder; hot water; cold water; food colouring or ink; eye-dropper or teat pipette

Safety: Use hot, but NOT boiling water for this activity.

1. Pour equal amounts of hot water and cold water into two separate beakers.
2. Holding the eye-dropper or teat pipette about 1 cm above the surface, put two drops of colouring into each beaker.



3. Observe the beakers for about 5 minutes, and note any differences between them.

Describe how the movement of the molecules in hot water must be different from that in cold water to account for your observations. ____________________

____

____

State the general conclusions you can draw from this experiment. ____________________

____

Does this conclusion support the idea that heat is the movement of molecules? ____________________

____

WORKSHEET 4

Which kinds of surface tend to absorb radiant heat energy?

Materials needed: floodlamp, desk lamp or radiant electric heater; 2 identical empty cans; measuring cylinder; cardboard; black paint; 2 thermometers; watch or stopclock.

1. Remove the labels from both cans.
2. Paint one can black and leave the other shiny.
3. Fill both cans with exactly the same amount of cold tap water. Take the temperature as accurately as possible. Cover each can with a square of cardboard.
4. Place the two cans in bright sunlight or about 50 cm from a floodlamp, desk lamp or radiant electric heater. If you use a lamp or heater, make sure that both cans are exactly the same distance from the lamp or heater.
5. Take the temperature of the water in each can every 5 minutes for about half an hour.
6. Record your results for both cans in the table below.

Time (minutes)	Temperature	
	Black can (^{o}C)	Shiny can (^{o}C)
0		
5		
10		
15		
20		
25		
30		

Which can absorbed radiation more quickly? ______

What do you think would happen if you used a can painted another colour, such as green? ______

______

Would it make any difference whether you used a flat paint or a glossy paint? ______

______

What would happen if you did the experiment twice more, a) with the cans 25 cm from the lamp, and b) with the cans 1 metre from the lamp? ______

______

Why is a layer of aluminium foil sometimes included in the walls of a house when it is being insulated? Should the shiny side face in or out? Explain your answer. ______

______

______

Answers to questions in the Students' Book

1. The unit usually used to measure temperature is the degree Centigrade (°C).
2. The bath of water at 50°C has more heat than the cup of tea at a temperature of 80°C. The tea is at a higher temperature, but heat is a form of energy and it takes much more heat energy to raise the temperature of the bath to 50°C than it does to heat the cup of tea to 85°C.
3. A jacket potato cooks more quickly if you put a metal skewer through it because metal is a good conductor of heat. The skewer carries heat through into the middle of the potato and helps to cook that area more quickly than if the heat had to spread from the skin of the potato inwards.
4. A quilt keeps you less warm if it is flattened because it no longer traps such an effective insulating layer of air.
5. Birds fluff out their feathers in cold weather to trap a layer of air around their bodies. This keeps the bird warm by insulating it.
6. Air is a poor conductor of heat because its particles are spread out. Therefore the particles do not collide very much and are unable to pass heat energy to each other.
7. The three ways that heat can travel are by conduction, convection, and radiation. Heat travels through solids by conduction as, for example, when heat travels along a spoon placed in hot tea. Heat is transferred in liquids and gases by convection, and the movement of warm and cold gas or liquid produces a convection current, as for example, when air heated by a hot radiator circulates round a room. Radiation does not need particles to transfer heat energy from one place to another. The Earth, for example, is warmed by heat energy coming from the Sun as radiation.
8. Energy from the Sun cannot reach us by conduction or convection because both conduction and convection need particles to transfer heat. Heat from the Sun has to travel through space to reach the Earth, and space is almost a vacuum.
9. A tiled floor feels cold because your feet are warmer than the tiles, and heat flows easily from your feet into the tiles. A carpet is a poor conductor of heat, and heat does not flow easily from your feet into the carpet and your feet stay warm.
10. One of the radiators which is part of a central heating system is badly named because it gives out only a little heat by radiation. Most of the radiator's heat energy warms the room by creating a convection current in the air of the room.
11. If you found yourself in a smoke-filled room, it would be important to remember that the smoke is being circulated by a convection current. The hotter, smoke-laden air would be near the ceiling and the cooler air, containing fewer smoke particles would be near the floor.
12. The main disadvantage of using metal instead of glass in a vacuum flask is that metal is a good conductor of heat, whereas glass, a non-metal, is a poorer conductor of heat.
13. A thermograph is a special type of photograph taken by a thermal imaging camera. It uses different colours to show infrared rays coming from hot objects. Thermographs can be used to show warmer, diseased tissue in the human body, the heat being lost from a building, overheating electrical cables, or to locate people trapped in a smoke-filled room, or to show where a fire started.

14. We can make our houses cool in summer and warm in winter by insulating them. Windows that are double-glazed and wall and roof spaces that are filled with insulating material will help to reduce the movement of heat into the house in summer, and reduce heat loss from inside the house in winter.

Assessment

Question 1

In an eight-storey block of flats, the boilers for the central heating system should be:

(A) in the basement
(B) on the top floor
(C) on the fourth floor
(D) on any floor

Question 2

Which of the following will be the best conductor of heat?

(A) glass
(B) iron
(C) plastic
(D) cork

Question 3

The Innuit or Eskimo people in Greenland can keep warm inside igloos made of blocks of ice because ice is a good:

(A) convector
(B) conductor
(C) reflector of heat
(D) insulator

Question 4

A man builds a hut with a corrugated iron roof in a country which has hot days and cold nights. The hut will be:

(A) cool during the day
(B) hot during the day
(C) hot during the night
(D) cool day and night

Question 5

A coal fire gives out heat mainly by:

(A) conduction only
(B) convection only
(C) radiation only
(D) convection and radiation

Question 6

Winds form because air:

(A) which is cold is less dense than hot air
(B) is always cold over the sea
(C) allows radiation to pass through it
(D) is a better conductor than land

Question 7

Heat lost by convection currents in a stoppered flask is prevented by:

(A) silvering the inside surfaces of the walls
(B) silvering the outer surfaces of the walls
(C) making a vacuum between the walls
(D) making the stopper of insulating material

Question 8

On a hot, sunny day it will be coolest to wear a:

(A) loose, coloured shirt
(B) string vest
(C) loose black shirt
(D) loose white shirt

Question 9

A certain kind of pie needs as hot an oven as possible. The best place to bake it would be on:

(A) the top shelf
(B) the bottom shelf
(C) the middle shelf
(D) a thick metal baking tray

Question 10

On a hot day, which colour car will become hottest inside?

(A) shiny black
(B) dull black
(C) shiny white
(D) red

Question 11

Which one of the following statements is true? Conduction:

(A) takes place best in gases
(B) takes place best in liquids
(C) is fastest in a vacuum
(D) cannot take place in a vacuum

Question 12

Which one of the following statements is true? Convection:

(A) only takes place in liquids
(B) is faster than radiation
(C) is always slower than conduction
(D) is faster in gases than in liquids

Question 13

Which one of the following statements is true? Radiation:

(A) travels by movement of particles
(B) can only travel in air
(C) travels in straight lines
(D) can only travel in a vacuum

Question 14

Modern buildings often have a double pane of glass in the windows because:

(A) glass is a good conductor of heat
(B) air trapped between the panes prevents convection
(C) radiation cannot pass through trapped air
(D) air trapped between the panes reduces conduction

Question 15

Think about each of the statements below. State whether each is an example of conduction, convection, or radiation.

(i) A tiled floor feels cold when you walk on it with bare feet. ____________________

(ii) Heat from the Sun travels to the Earth. ____________________

(iii) Only the water at the bottom of an electric kettle is heated, but the heat travels all through the water until it boils. ____________________

(iv) The handle of a metal spoon left in hot coffee gets hot. ____________________

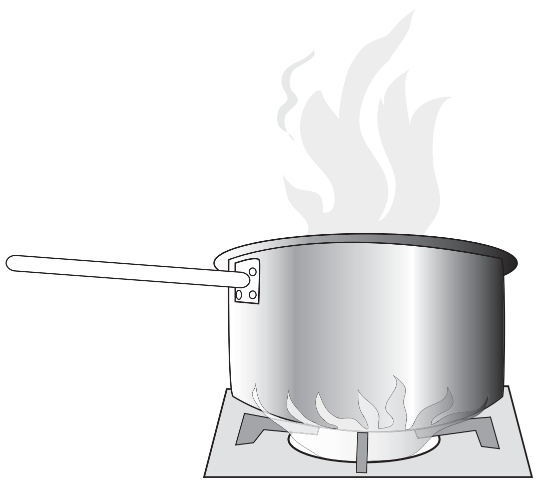
(v) A central heating radiator warms a room. ____________________

(vi) A grill in the top of the oven heats the food below it. ____________________

(vii) The air in a refrigerator is cooled throughout, even though the cooling element is at the top of the refrigerator. ____________________

Question 16

The picture below shows a saucepan of soup being heated on a stove.



(i) Name one part of the saucepan that should be a good conductor of heat. Explain why it is necessary for this part to be a good conductor.

____

(ii) Name one part of the saucepan that should be a good insulator of heat. Explain why it is necessary for this part to be a good insulator.

____

(iii) Suggest suitable materials for each of the parts of the saucepan you named in (i) and (ii) above.

____

Answers to assessment questions

Question 1 (A)	**Question 2** (B)	**Question 3** (D)	**Question 4** (B)	**Question 5** (D)
Question 6 (A)	**Question 7** (C)	**Question 8** (D)	**Question 9** (A)	**Question 10** (B)
Question 11 (D)	**Question 12** (D)	**Question 13** (C)	**Question 14** (D)	

Question 15

(i) A tiled floor feels cold when you walk on it with bare feet. conduction

(ii) Heat from the Sun travels to the Earth. radiation

(iii) Only the water at the bottom of an electric kettle is heated, but the heat travels all through the water until it boils. convection

(iv) The handle of a metal spoon left in hot coffee gets hot. conduction

(v) A central heating radiator warms a room. convection

(vi) A grill in the top of the oven heats the food below it. radiation

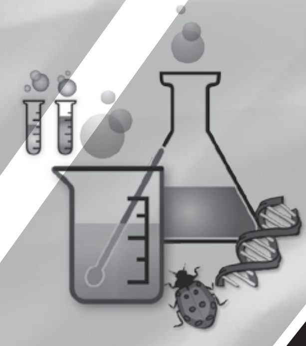
(vii) The air in a refrigerator is cooled throughout, even though the cooling element is at the top of the refrigerator. convection

Question 16

(i) The bottom of the saucepan needs to be a good conductor of heat so that it can conduct heat from the stove or hot-plate to the soup.

(ii) The handle of the saucepan should be a good insulator of heat to stop heat travelling up the handle and burning the cook's hand.

(iii) The base of the saucepan should be of a metal such as steel, stainless steel or copper, while the handle should be made of wood or plastic.



Disperson of light

CHAPTER 11

Teaching Objectives

- To explain the causes of the refraction of light and their effects
- To describe the dispersion of light by a prism and its effects
- To identify primary colours and to demonstrate how they are combined to form secondary colours
- To examine the uses of different coloured lights in the home, school, and wider environment
- To demonstrate, practically, how the colours of the rainbow can be recombined to form white
- To explain the absorption and reflection of light by different objects and materials

Learning Outcomes

After studying this chapter students should be able to:

- explain the refraction of light and its causes
- discuss the effects of refraction with examples
- list the colours of light using a prism
- describe the dispersion of light by a prism
- identify different uses of lights of different colours at home, school, and in the country and explain the relationship of the choice of colours to their purpose
- define the spectrum of light
- identify primary colours and show how they are combined to form secondary colours
- identify a device in their surroundings that uses different combinations of colours
- demonstrate how the spinning of a rainbow-coloured disc results in it appearing white
- explain why an opaque or non-luminous object appears to be of a certain colour

Introduction

No matter what its source, light always travels through a vacuum at a speed of about 300,000 kilometres per second. It also travels at very nearly the same speed in air, but when it encounters another medium, such as water or block of glass, it slows down. Different transparent substances slow light down by a different amount. The ratio of the speed of light in a vacuum to its speed in a particular transparent material is called the refractive index of that material. The refractive index of glass is about 1.5, which means that light travels through glass at two-thirds of its speed in a vacuum.

Refraction and lenses

When light passes from one material to another, the change of speed alters its wavelength, making the light bend, or refract, slightly. White light is split up into its separate colours on being refracted by a prism, because each colour is refracted by a different amount. Refraction is also important in lenses. When a ray of light passes through a lens it is bent, and this enables the lens to produce the image of a distant object. The first lenses were made for spectacles about 700 years ago, but it was not until about 1600 that scientists discovered that by looking through two lenses in a line, small objects could be greatly magnified and distant objects made to seem close. This led to the development of the microscope and telescope.

A convex lens, which curves outwards and it thicker at the centre than at the edges, causes light rays to converge when they pass through it. A concave lens, which is thinner at the centre than at the edges, makes the light rays diverge or spread out. Objects viewed through a concave lens always appear smaller. A simple magnifying glass is a double convex lens which causes a beam of light to converge to a focus (the point at which all the rays meet). When an object is fairly close to the lens, an upright magnified image is seen.

Objects seen through many cheap lenses show a fringe of colours around the object. This blurs the outline of the image because the lens acts as a prism to split the light into a spectrum. This defect, called chromatic aberration, can be corrected by constructing a lens of two special types of glass. The outer part of a cheap lens also bends light more than the central portion, and gives the image a fuzzy look. This defect is called spherical aberration and it is avoided in a camera by the use of an aperture that lets light enter only through the centre of the lens.

Colour

White light, or more accurately colourless light, from the Sun or the white-hot filament of an electric light, consists of a mixture of light of several colours. The spectrum of colours which makes up white light ranges from the short violet and blue waves, through the green, yellow and orange waves to the red waves, which are the longest that the human eye can detect. This was demonstrated by Newton in 1666. He allowed a narrow beam of sunlight to shine through a triangular glass prism. Newton found that when the light that had passed through prism fell onto a screen, it was split up into a rainbow-coloured band (a spectrum). Each component colour of the white light is bent, or refracted, through a different angle as it passes through the prism. In this way, the prism separates out the colours present in the white light.

To show that white light is a mixture of colours, it is necessary to combine all the coloured components to reform white light. Newton's colour disc does this; it is a circular disc divided into sectors, each of which is painted with a colour in the spectrum. When the disc is rotated rapidly, the colours are mixed by the eye and brain and produce the impression of white. Mixing coloured beams of light in the correct proportions of colours also produces a white effect. By changing the proportions, however, lights of many different colours can be produced.

Objects which are not themselves sources of light appear coloured because they reflect certain of the component colours of the light illuminating them to the eye. A red book, for example, absorbs the violet, blue, green, yellow and orange components of the light falling on it and reflects only the red component. If all the light is scattered or reflected, the object appears white. If an object absorbs all the light falling on it, and reflects none, it appears black.

Coloured lights and rainbows

Interesting effects can be produced by changing the colour of the light illuminating an object. A red book illuminated by a red light will appear red, but a red book illuminated by a pure blue light appears black. This is because the blue light is completely absorbed and no light is reflected. Similarly, a glass or cellophane filter that appears red, only allows red light to pass through it, and all the other wavelengths are absorbed. It is transparent to red light only.

The rainbow is a large-scale spectrum produced when the Sun's rays pass through raindrops in the atmosphere. Each drop splits up the light in the same way as the prism in the spectrum experiment.

Practical considerations

Ideally for the work in this chapter, ray boxes should be available. If they are not, then torches with black paper taped over the lens will work. Cut a narrow slit in the centre of the black paper over each torch lens. Torches have the disadvantage that they roll easily, but on the other hand they do not get hot in the way that ray boxes do. Only two lesson plans are included here. Many more are possible, depending upon the materials and equipment available to you. The topic could also be extended into drama, when dealing with theatrical lighting, and into art when dealing with the mixing of coloured paints and pigments.

Lesson suggestions

1. Bending light rays

Refer to page 132 of the Students' Book

Starter suggestions

Place a large transparent container in front of the students and ask a volunteer to hold a pencil or ruler inside it. Slowly add water to the container and ask the students to look carefully at the place where the pencil or ruler enters the water. What do they notice? (A 'break' appears in the pencil or ruler.)

Place a coin at the centre of an empty opaque bowl. Ask the students to move so that they can only just see the coin. Slowly and carefully pour water into the bowl. What happens? (The coin seems to disappear.)

Ask the students if they can explain what they have observed in these two simple activities. Explain the two tricks in terms of light changing direction as it slows down when it passes from air to water. Make sure the students understand that the light rays are making a sharp change of direction, not curving, as they pass from one material to another.

Main lesson

Carry out the experiment on refraction described on Worksheet 1 with the students. Glass blocks work better in this experiment than Perspex ones. If you use glass blocks and they have sharp edges, tape these with masking tape. It is important that the block does not move during the experiment and that the students mark the normal lines clearly and accurately. The refraction is most obvious at larger angles of incidence.

Discuss the results of the experiment and introduce the term 'refractive index' and refer the students to the table on page 134 of the Students' Book.

Explain that lenses also work because of refraction and let the students examine concave and convex lenses and also instruments which contain lenses.

2. Rainbow colours

Refer to page 139 of the Students' Book

Starter suggestions

Show the students a photograph of a rainbow. Ask them to name the colours in the rainbow. Can they make up a mnemonic to help them remember the colours? One such mnemonic is '**R**inse **O**ut **Y**our **G**reasy **B**ottles **I**n **V**inegar'.

Show the students a picture of a diamond or an ornament made of cut-glass or cut-crystal. The high refractive index of these materials, and their many different facets, disperse light strongly so that you see many colours.

Main lesson

Introduce the word *spectrum* to the students. Explain that the first person to split a beam of light into various colours to produce a spectrum was the British scientist Isaac Newton in 1672. Explain that electric lamps were unknown then, so he used sunlight. However, it is easier, and more convenient, to make a spectrum using an electric lamp.

Demonstrate the use of a prism first of all to make a spectrum, and then to recombine the colours to form white light again, as described in the **Ideas for investigation and extension work** section of this chapter. A certain amount of trial-and-improvement is necessary to get the second prism to recombine the colours. Then let the students experiment with the 'Make a rainbow' activity using mirrors, which is also in this section. Again, a certain amount of trial-and-improvement is necessary to make this activity work. The students can then carry out the activity on Worksheet 3, repeating Newton's discovery of a colour disc, to see the effects of combining different combinations of colours.

Move on to examine filters and how they work. A simple activity using filters is described on Worksheet 2. It is important for the students to understand that the filter does not 'change the colour' of the light, but instead absorbs some colours and transmits others.

If possible, finish the lesson by showing the effects that can be produced by changing the colour of the light illuminating objects.

Ideas for investigation and extension work

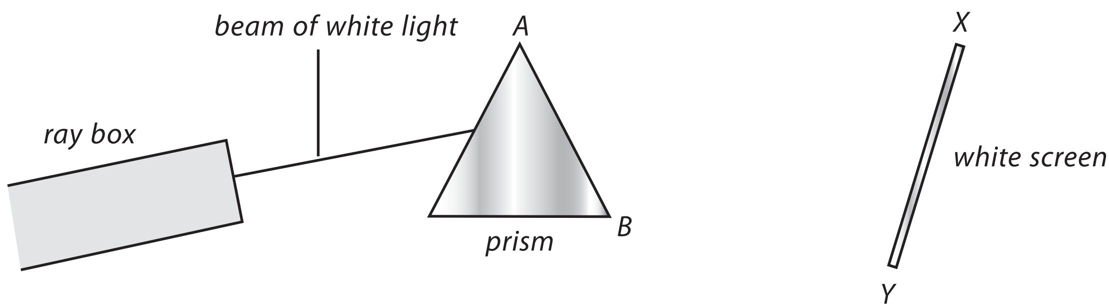
Make a rainbow

Fill a clear plastic box half full with water. Stand a small mirror at one end of the box so that it leans against the end of the box at an angle of about 30° from the base of the box. Next you need a torch fitted with a black cover over the lens, in which a narrow slit has been cut, or a ray box. Shine a narrow beam of light onto the mirror *through* the water. Ask a helper to hold up a piece of white card so that reflected light coming from the mirror can shine onto it. After a little trial-and-improvement you will see a rainbow on the card. As the light travels from the air to the water it slows down and bends. The seven colours of the spectrum or rainbow travel at different speeds, and therefore each colour bends at a slightly different angle. The mirror reflects the different colours so that you see a rainbow or spectrum of the seven colours.

Colours of the rainbow

Demonstrate the fact that white light is made up of many colours. For this activity you need two prisms, preferably of dense flint glass, a ray box or a powerful torch with the lens covered with black paper with a narrow slit in it, and a white screen.

Set up the apparatus as shown in the diagram below and produce a spectrum on the white screen. Ask the class to identify the colours, starting from the top of the spectrum. Invert a second prism between the first one and the screen. Ensure that one edge of the second prism is parallel to the lines AB of the first prism. Ask the students to say what colour is formed on the screen now. They can then draw the apparatus used and explain what they have seen.



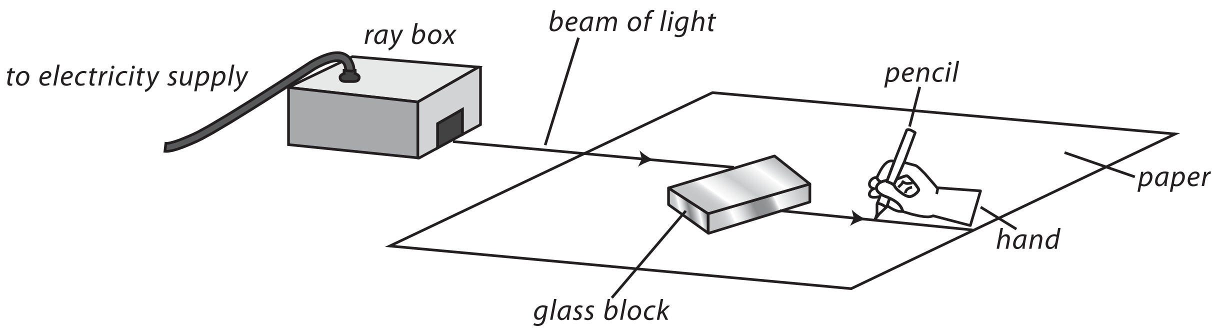
WORKSHEET 1

Refraction

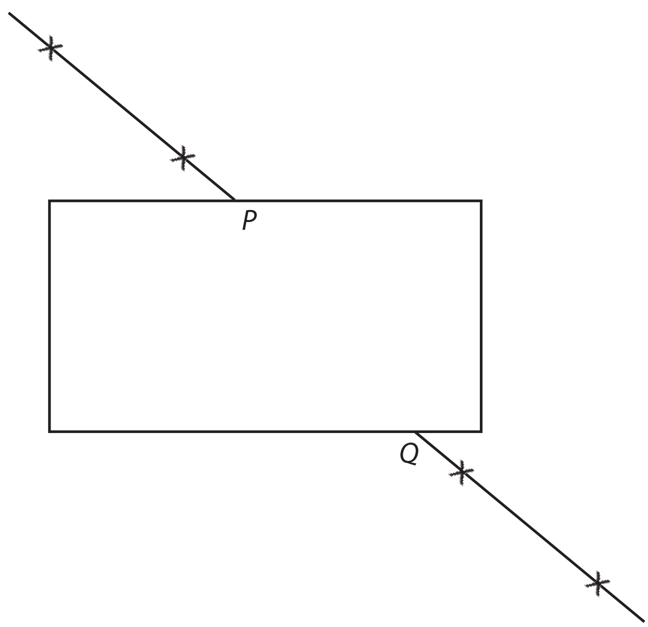
Materials needed: rectangular glass or Perspex block; ray box with electrical supply or a torch with black paper over the lens in which a slit has been cut; sheet of white paper; pencil

Safety: If you are using a glass block and it has sharp edges, ask your teacher to cover these with masking tape.

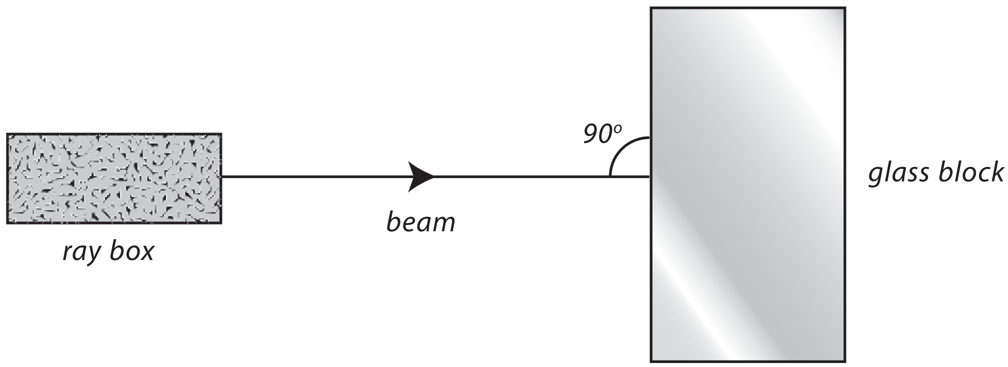
1. Place the glass or Perspex block on the sheet of white paper. Draw around the outline of the block.
2. Using the torch or ray box, direct a narrow beam of light **at an angle** to the edge of the block.



3. Mark two crosses on the paper to show the path of the beam going into the block and two more crosses to show the path of the beam leaving the block.
4. Remove the light source and glass or Perspex block. Draw a straight line through each of the two sets of crosses as shown in the diagram.



5. Join the points P and Q on your drawing.
6. Now direct a narrow beam of light at 90º to the glass or Perspex block.



a) What happens to the light ray as it passes through the block? ______________________

____

b) What happens when a light ray enters the glass or Perspex block at an angle? ______________________

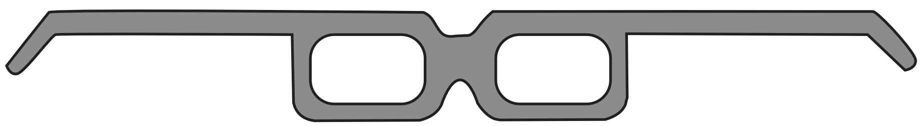
____

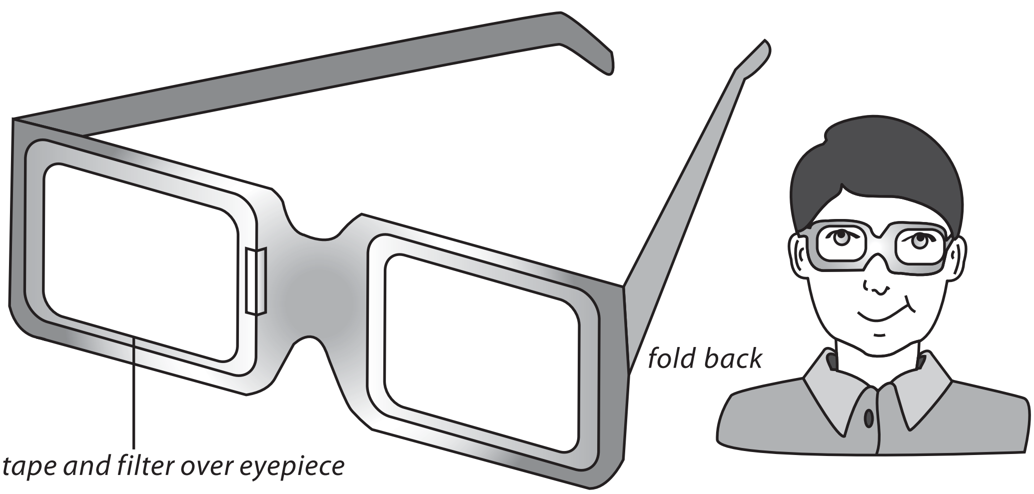
WORKSHEET 2

Make a pair of coloured spectacles

Materials needed: thin card; scissors; sticky tape; coloured filter or coloured cellophane.

1. Draw a pair of spectacles on the card, as shown below.
2. Fold back the two side pieces.





3. Tape a piece of red filter or red cellophane over both eye pieces. Predict how the different coloured objects around you will look when you are wearing these spectacles. ________________________________

4. Now put them on and see if you were right ________________________________

5. Now try with another colour, such as green. Record your results below.

WORKSHEET 3

Spinning colours

Materials needed: thin card; scissors; pencil; paper clips; masking tape; coloured pencils, crayons of felt-tipped pens in red, orange, yellow, green blue, and violet or purple.

1. Cut out several copies of the disc below.
2. Place one of the discs on the piece of card and trace round it. Cut out a circle of card the same size as the disc.
3. Colour sections A, C, and E with one colour, and use another colour for sections B, D, and F.
4. Fix the paper disc onto the circle of card with paper clips.
5. Carefully poke the pencil through the centre of the disc. See that the same length of pencil is sticking out on both sides of the disc. Use sticky tape to hold the disc and pencil in place.
6. Predict what colour the disc will appear when you spin it. Then spin the disc as fast as you can. Do this several times if necessary. Record what you see.

   ____

   ____

7. Clip a new copy of the disc onto the card, but this time use three different colours: one colour for sections A and D, one for B and E, and a different one for C and F. Again, predict your results and then see if you were correct when you spin the disc.

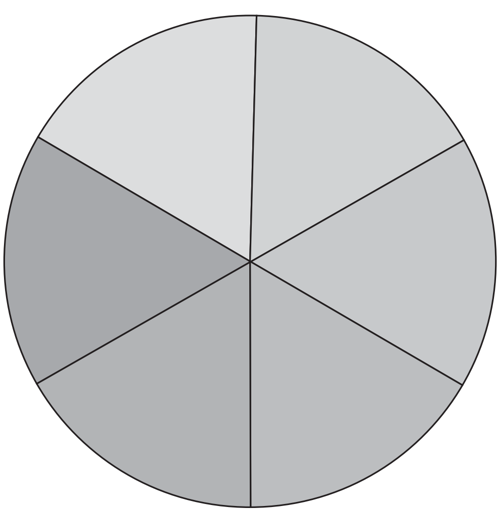
   ____

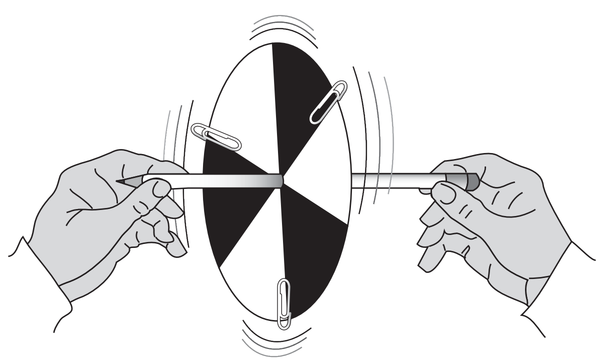
   ____

8. Now try other combinations of colours, including leaving some sections white. Record your results here:

   ____

   ____





Answers to questions in the Students' Book

1. Light travels in rays which bounce off, or are reflected by, mirrors and most other objects and materials. Refraction occurs when light rays move to a denser or less dense transparent material. The light rays then bend, or are refracted.
2. The refraction of light is caused when light rays change speed and bend as they go from one transparent material, such as air, glass of water, into another transparent material of different density.
3. When light rays travel from air into water they slow down from almost 300,000 kilometres per second to about 250,000 kilometres per second. This is because water is denser than air.
4. Refraction makes a straight stick appear to bend where it enters water, it makes the water in a swimming pool look less deep than it really is, and it produces mirages.
5. Uses of refraction include lenses, optical fibres, and prisms.
6. A man fishing with a spear would have to aim his spear a little way beyond the fish because refraction would make the fish appear nearer than it really was.
7. The colours in the spectrum of white light are red, orange, yellow, green, blue, indigo, and violet.
8. i) When red and blue lights are mixed, the result is magenta light. ii) When red and green lights are mixed the result is yellow light. iii) When green and blue lights are mixed they make cyan light.
9. Grass looks green because it reflects green light and absorbs all the other colours of the spectrum.
10. A colour filter works by removing unwanted light. A red filter for example, only allows red light to pass through. It stops the blue and green colours.
11. If you pass white light through a blue filter, only blue light will pass through. All the other colours will be absorbed by the filter. If that blue light was then shone onto a red filter, no light would pass through the red filter—the result would appear black.
12. The two sets of cells which make up the retina of the eye are called rods and cones. Rods respond to dim light, while cones are sensitive to bright light and to red, green, and blue lights.
13. When shopping for clothes, customers take items to the window to look at them, because the white light given out by fluorescent tubes and other artificial lights has slightly different wavelengths, and therefore produces slightly different colours from natural sunlight.
14. An optic fibre is an extremely thin flexible glass rod. Light rays reflect internally along the whole length of the fibre. The light emerges from the fibre almost as bright as it went in. Bundles of optical fibres, fixed to a special camera or eyepiece, are used to see inside machines or the human body. Optical fibres can also carry coded signals of light from a laser. These can be used to carry telephone messages.
15. We see rainbows when the Sun is shining behind us and it is raining in front of us. Sunlight shines through the millions of raindrops, each of which acts as a tiny prism. The light spreads out and is split into a band of seven colours—the colours of the rainbow—with the reddish colours at the top and bluish colours at the bottom.

16. A convex lens is thicker in the middle than at the edges. An object looked at close up with a convex lens is magnified. A convex lens converges (brings together) parallel rays of light after they have passed through the lens.

    A concave lens is thinner in the middle than at the edges. If you look through a concave lens, you see a lot of your surroundings, but the image appears smaller than normal. A distant object appears upside down or inverted. A concave lens diverges (spreads out) parallel rays of light so that they appear to come from a focal point on the other side of the lens.
17. If a light ray falls on a prism, the prism would disperse or spread out the colours in the light ray and form a spectrum. Red light is refracted least and appears at the top of the spectrum, while violet light is refracted most and appears at the bottom of the spectrum.

Assessment

Question 1

Which of the following is an example of a luminous object?

(A) a candle (B) a mirror (C) the Moon (D) a prism

Question 2

We see lightning before we hear the thunder because:

(A) light waves are stronger than sound waves (B) sound travels faster than light

(C) light travels faster than sound (D) sound waves are stronger than light waves

Question 3

When a ray of light enters a glass block it:

(A) speeds up (B) slows down

(C) goes at the same speed (D) spreads out

Question 4

When a ray of light enters a glass block at 90° it:

(A) speeds up (B) bends away from the normal

(C) is not refracted (D) bends towards the normal

Question 5

The splitting of white light into the colours of the rainbow is called:

(A) refraction (B) internal reflection (C) dispersion (D) separation

Question 6

The spectrum of white light consists of:

(A) three colours (B) five colours (C) seven colours (D) nine colours

Question 7

The primary colours of light are:

(A) red, blue, yellow (B) red, blue, green

(C) red, yellow, green (D) yellow, blue, green

Question 8

In white light, a blue car reflects the following colour(s):

(A) red (B) blue (C) green (D) all colours

Question 9

What colour light passes through a red filter?

(A) none (B) all (C) blue (D) red

Question 10

Afshan is wearing a blue dress with red flowers on it. She stands under a red lamp. The dress will appear:

(A) completely red (B) completely blue

(C) black with red flowers (D) blue with red flowers

Question 11

a) Which of the statements about light below are true? Tick the FOUR correct options.

(i) Light is a form of energy. ☐

(ii) Light is a form of radiation. ☐

(iii) Nothing else travels as fast as light. ☐

(iv) Light rays reflect off objects into our eyes. ☐

(v) Light rays reflect off your eyes onto objects. ☐

(vi) Light cannot travel in a vacuum. ☐

b) Why does a ray of light bend when it travels from air to water? ____________________

____

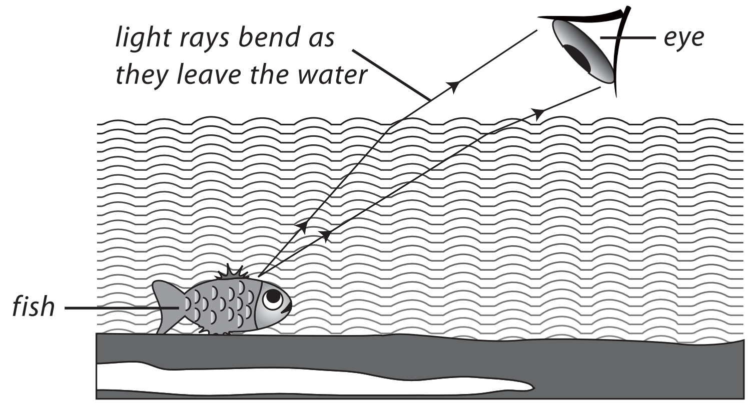
c) Why does a ray of light bend as it travels from water to air? ____________________

____

d) What is this bending effect called? ____________________

e) The diagram on page 192 shows how two light rays coming from a fish on the bottom of a pond are bent as they leave the water. How does this affect the way the fish appears to a person standing on the edge of the pond? ____________________

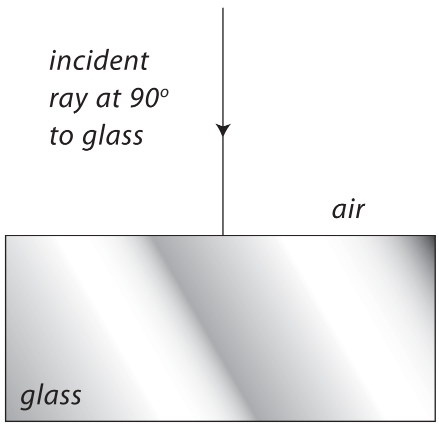
____



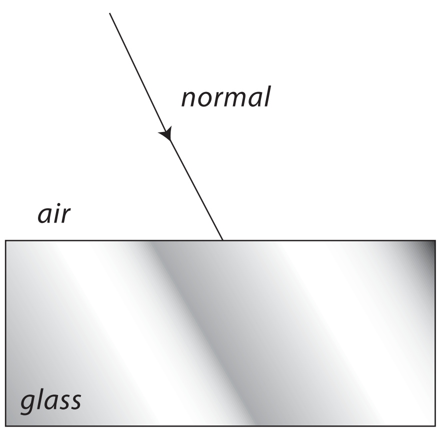
f) Put a cross on the diagram to show where the fish would appear to be.

Question 12

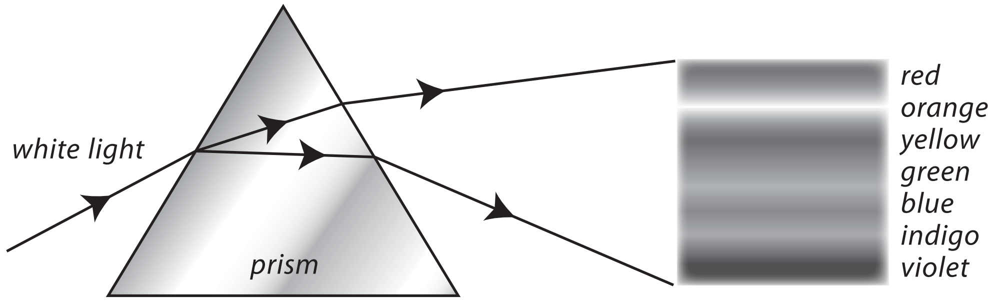
a) The diagram below shows a ray of light striking the surface of a glass block at an angle of 90° to the surface. Use a pencil and ruler to show what happens to the ray of light after it has struck the glass block.



b) This diagram shows a ray of light striking the surface of a glass block at an angle. Use a pencil and ruler to show what happens to the ray of light after it has struck the glass block.



c) The diagram below shows white light passing through a prism and producing a band of colours.



(i) What is the name given to this band of colours? ______

(ii) Where would you see such a band of colours produced in nature? ______

d) A filter was placed over a torch that produced white light. Only red light passed through the filter. The orange, yellow, green, blue, indigo, and violet colours were absorbed.

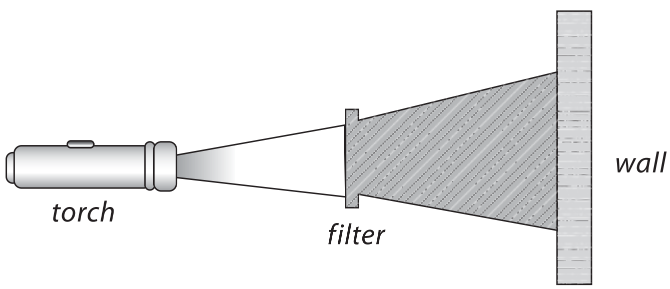
(i) What colour was the filter? ______

(ii) Explain your answer. ______

______

Question13

a) Nadir carried out an experiment with a torch and some green and red filters. He shone the torch onto a white wall.



(i) Nadir shone the torchlight through a green filter. What colour would the wall appear to be?

______

(ii) He then put a red filter behind the green filter and shone the torch onto the wall again. What happened to the light this time?

______

b) Nadir then shone the light through a green filter onto his red jumper.

(i) What colour did his jumper appear to be? ______

(ii) Explain why. ______

______

(iii) What colour will his red jumper appear to be if he shines light onto it through the red filter?

______

Answers to assessment questions

Question 1 (A) **Question 2** (C) **Question 3** (B) **Question 4** (C) **Question 5** (A)
Question 6 (C) **Question 7** (B) **Question 8** (B) **Question 9** (D) **Question 10** (C)

Question 11

a) The FOUR correct options are:
   (i) Light is a form of energy
   (ii) Light is a form of radiation
   (iii) Nothing else travels as fast as light
   (iv) Light rays reflect off objects into our eyes

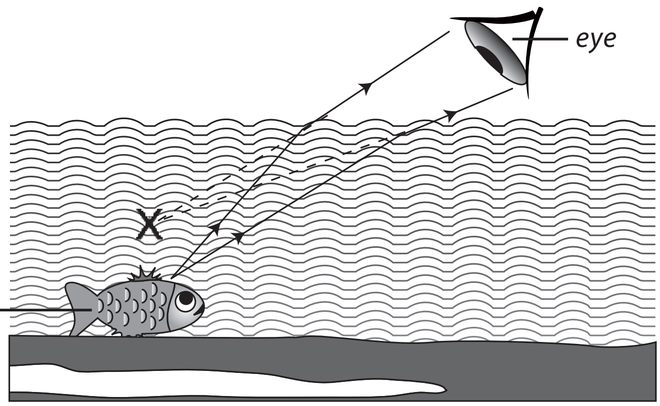
b) A ray of light bends when it travels from air to water because it slows down.

c) A light ray bends as it travels from water to air because it speeds up.

d) This bending effect is called refraction.

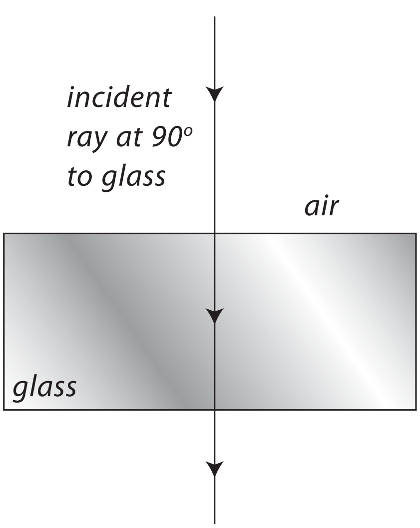
e) The bending of light rays as they leave the water makes the fish appear nearer to the surface/less deep than it really is.

f) The cross on the diagram below shows where the fish would appear to be.

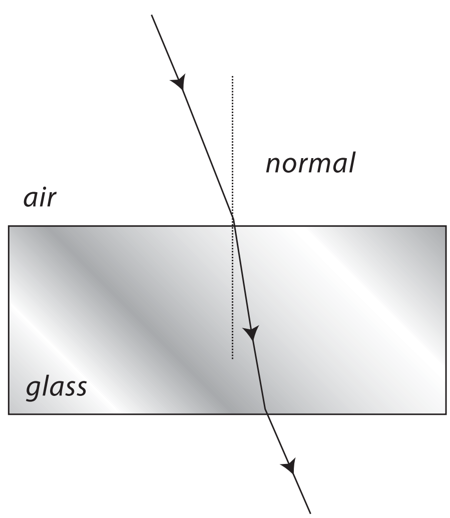


Question 12

a)



b)



c) (i) The band of colours is called a spectrum.

(ii) A rainbow is a natural spectrum.

d) (i) The filter is red.

(ii) A red filter absorbs all the colours of the spectrum, except for red.

Question 13

a) (i) green

(ii) No light will pass through the combination of filters.

b) (i) black

(ii) Only green light will fall onto Nadir's jumper and this will all be absorbed.

(iii) red

Sound waves

CHAPTER 12

Teaching Objectives

- To extend earlier learning on sound with an explanation of wavelength, frequency, and amplitude
- To examine examples of everyday objects that produce different sounds
- To compare and contrast the audible frequency range of humans and a range of other animals
- To identify the parts of musical instruments which vibrate and to explain the relationship between the shape of instruments and the sounds they produce
- To examine the production and uses of sounds in everyday life

Learning Outcomes

After studying this chapter students should be able to:

- explain the wavelength, frequency, and amplitude of sound and give their units
- state factors on which sound depends
- investigate objects in the home and surroundings that are designed and made to produce different sounds
- compare the audible frequency range of humans and different animals
- design a musical instrument and explain the relation between its sound and shape
- identify the applications of different sounds in daily life

Introduction

Sound is always caused by something moving—the slamming of a door, the running of a car engine, the wind rustling the leaves of a tree. Every movement sets up vibrations which cause changes of pressure in the surrounding air. Sound waves are created when these changes of pressure spread out in all directions, like the waves on the surface of a pond when a stone is thrown in.

Sound waves cannot travel through empty space because they need a solid, liquid or gas to pass through. Astronauts on the Moon are equipped with radios to speak to each other. Even if they were able to survive outside their space suits, it would be impossible for them to talk to each other as they do on Earth because the Moon has no atmosphere through which sound waves could travel.

Noise

As everything that vibrates at a frequency of between about 50 to 20,000 vibrations per second makes sound waves, not all sound waves are intentional. Accidental sounds that are loud and discordant are called noise.

Car engines, aircraft engines, road drills and factory machines all have vibrating parts and they all produce unwanted sound waves that serve no useful purpose. Apart from wasting valuable energy, this noise is one of the urgent problems of urban life, and a great deal of time and money is spent on the control and suppression of unnecessary noise.

Pitch and frequency

A shrill high note is produced by rapid vibrations; a deep low note is produced by slow vibrations. The highness or lowness of a note is called its pitch, and the pitch of a note depends only on the number of times the sound producer vibrates in one second. The number of vibrations in one second is called the frequency of the sound. When the key for middle C is struck on a piano, a hammer strikes two or three strings, each of which vibrates 256 times in one second. The SI unit of frequency is the hertz, and one hertz is equal to one vibration or cycle per second. The frequency of middle C is therefore 256 Hz.

Changing pitch and frequency

To obtain different musical notes, the frequency of the vibrations of the sound producer must be changed. This can usually be done by altering the size, the tightness or the weight of the object which is vibrating. If the length of an elastic band is altered while it is being plucked, there is a change in pitch. A violinist adjusts the tightness, or tension, of the strings of his instrument in order to tune them. Then he alters the length of each string by 'stopping' it with his fingers to play different notes. In wind instruments the length of the vibrating air column must be altered to change the pitch of the note produced.

Loudness and amplitude

The loudness of a sound is the effect it has on the human ear. It depends upon the size (amplitude) of the vibrations. The larger the vibration, the louder the sound. The amount of energy needed to produce the vibrations controls the intensity of the sound. Although the pitch of a sound can be judged very accurately, our ears are not very good at judging loudness.

The intensity or loudness of sounds is measured in units called decibels (dB). A whisper has an intensity of about 30 dB, normal conversation about 60 dB, and a jet aircraft 30 metres away has in intensity of 140 dB. This is the danger limit for the unprotected ear, and people exposed to this level of noise should wear some form of ear cover or ear defender.

Practical considerations

As in several previous chapters, it is possible to expand this topic to several lessons if the time, materials and equipment are available. Ideally, a signal generator, microphone and oscilloscope are needed. If they are not available, the students will have to look at second-hand examples of sound waves, either in books, including the Students' Book, or on television programmes, DVDs, and the Internet.

Lesson suggestions

1. Sound waves

Refer to page 146 of the Students' Book

Starter suggestions

Ask the students what they understand by the word 'wave'. How many examples of waves can they think of? Remind them how a stone thrown into a pond produces a series of waves in concentric circles.

Obtain a sheet of flexible material, such as thin hardboard or thin metal sheet, measuring about 80 cm x 50 cm. Hold the material by one end and shake it. If it is the right kind of material not only will a wave shape be visible but it will also make a 'wobbling' sound. Obviously it is best to test out different materials before you show the class how it works.

Main lesson

Remind the students that all sounds, and sound waves, are produced as a result of vibrations. Whenever we hear a sound, something is moving and causing the vibrations.

Carry out some of the activities described in the **Ideas for investigation and extension work** section of this chapter, and also as many as possible of Worksheets 1, 2, 3, and 4.

Some notes on three of the suggested activities are given below:

Make a roaring cup

The roaring cup is a popular toy found in Spain and other parts of Europe. The cup acts as a cavity which increases sound. A cup helps to amplify and prolong sound because sound waves inside the cavity hit the walls, bounce back and reinforce each other. This is called 'resonance'. Musical instruments such as bells have cavities; others, such as the violin and guitar have sound boxes. In a musical instrument, the walls of the sound box or cavity vibrate at the same frequency as the source of the sound (e.g. the strings of the violin or guitar). If this were not so, the sound wave would cause an echo when it bounced back instead of reinforcing the original sound.

Make elastic bands sing

Any tightly-stretched wire, string, or elastic band will vibrate when the wind blows over it. When you spin the elastic-band chain, the weight of the paper clips makes the elastic bands stretch. 'Wind' is created by the spinning motion of the chain (the air itself is still, but the chain is moving through it). The spinning chain produces eddy currents of the air behind it, much like a boat leaves a swirl of water behind as it travels. The small, irregular swirls of air make the elastic-band chain vibrate back and forth as it moves through the air. As the chain spins through the air faster, it vibrates more rapidly. Eventually the vibrations result in sound waves which you can hear.

Changing the pitch

We can change the pitch of a note produced by a string or elastic band by changing its length or the tension on it. The more weights that are applied to the elastic band (within reason), the higher the note it will produce. The greater the distance between the two pencils, the lower the note that will be produced.

If you have access to an oscilloscope and microphone or signal generator, demonstrate sound waves to the students so that they understand the relationship between the pitch, frequency and amplitude of sound waves. If this equipment is not available, show the students pictures or other 'second-hand' examples of sound waves.

2. How sound travels

Refer to page 148 of the Students' Book

Starter suggestions

If you have the equipment, demonstrate the electric bell in a bell-jar experiment illustrated on page 223 of this book. Use a safety screen if it is available and keep the students well back, just in case there is a flaw in the glass of the bell-jar which causes it to implode.

Use a length of rope or a 'slinky spring' to demonstrate longitudinal waves. Explain that it is a progressive wave in which the 'vibrations' travel in the direction of the wave. In the case of a sound wave moving through the air, as the vibrating object moves forward it squashes the particles in the air together, forming compressions. When the vibrating object moves backwards, the particles in the air become widely spaced (rarefactions). A sound wave produced by a loudspeaker, for example, consists of a whole train of compressions and rarefactions in the air.

Main lesson

Once the students have begun to understand the movement of sound through air, they can go on to investigate the movement of sounds through solids and liquids. The 'portable telephone' activity, finding out which materials conduct sound best, and Worksheet 5, will all help to develop the students' knowledge and understanding.

The lesson can be rounded off with a consideration of the audible frequency range of humans and other animals, and also the applications of different sounds in our daily life (including doorbells, sirens, telephones, smoke and security alarms, radios, TVs, and music systems). These can be discussed and, if possible, illustrated by the use of films, TV programmes, and DVDs.

Ideas for investigation and extension work

Vibrations

Ask the students to talk or shout (one at a time) with their mouth very close to an inflated balloon. Ask them to notice how the balloon vibrates. Compare the vibration of the skin of the balloon with the vibration of the eardrum. Observe how the stretched mouth of an inflated balloon vibrates when the air is released through it.

Jumping rice grains

Sprinkle rice grains on the speaker of a radio or CD player. Watch what happens to the rice grains as you alter the volume of the radio or CD player.

Sound waves and vibrations

You need a bowl about 25 cm in diameter. Cover the top with plastic film, such as Cling-film', and pull the film tight in all directions until it is smooth and flat. Sprinkle some salt grains on the plastic film.

Bring a small saucepan and a metal spoon right next to the bowl. Strike the bottom of the saucepan with the spoon to produce a short, loud sound. Notice how, when you strike the saucepan, the salt grains jump. If you can get near enough, shout and watch the salt grains jump.

What happens is this: when you strike the saucepan it vibrates. The vibrations are transmitted through the air to your ear and the plastic film. The film vibrates and sends the salt grains jumping in the air. When you shout, your vocal cords are doing the vibrating.

Recording sounds

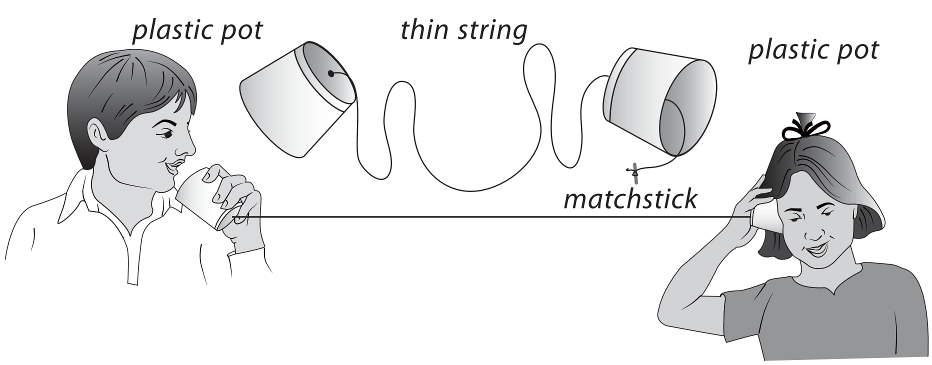
Use a mobile phone or a pocket digital recorder to make recordings of sounds of different pitch and loudness. Explain the differences between the recorded sounds in terms of frequency, amplitude and wavelength.

Which materials conduct sound best?

Lay a ticking clock or a small battery-operated radio on the table. Place a piece of wood gently on the clock or radio. Ask a volunteer to place one ear gently on the piece of wood and say whether he or she can hear the clock ticking. Now remove the wood and lay other materials, such as a cushion, a piece of carpet, or cotton wool, one at a time on the clock or radio. How well can the student hear the clock or radio? Pump up a balloon so that it is filled with air and lay that on the clock or radio. Can the student hear the clock or radio through the air in the balloon? Now carefully repeat the balloon part of the activity, this time with the balloon filled with water.

Make a portable 'telephone'

Use two or more plastic cups and a ball of thin string to make a portable 'telephone', as shown in the diagram below.



Which is best, tight string or slack string? Over what distance will the 'telephone' work? Will it work round corners? Will it work through closed doors or up and down stairs? Will it work if you add a third 'telephone'?

Make simple stringed instruments

Ask the students to design and make simple stringed instruments using boxes, plastic bottles, plastic pots, cardboard tubes, and elastic bands.

Bouncing sound waves

Sound waves bounce off objects that are obstructing them, producing an echo. To demonstrate this, roll up a piece of paper into a tube and hold one end to your ear. Have someone stand behind you and hit two spoons together behind your left ear, your right ear and above your head. The ear that has the paper tube held to it will not be able to pick up the sound from the spoons being tapped above your head, so you will think the sound is coming from behind the unobstructed ear.

Supersonic aircraft

Supersonic aircraft travel at speeds greater than Mach 1. Use the internet or reference books and encyclopedias to find out what the term 'Mach 1' means. Find out what happens to the speed of sound at high altitudes. Present your findings to the rest of the class.

Sounds in a vacuum

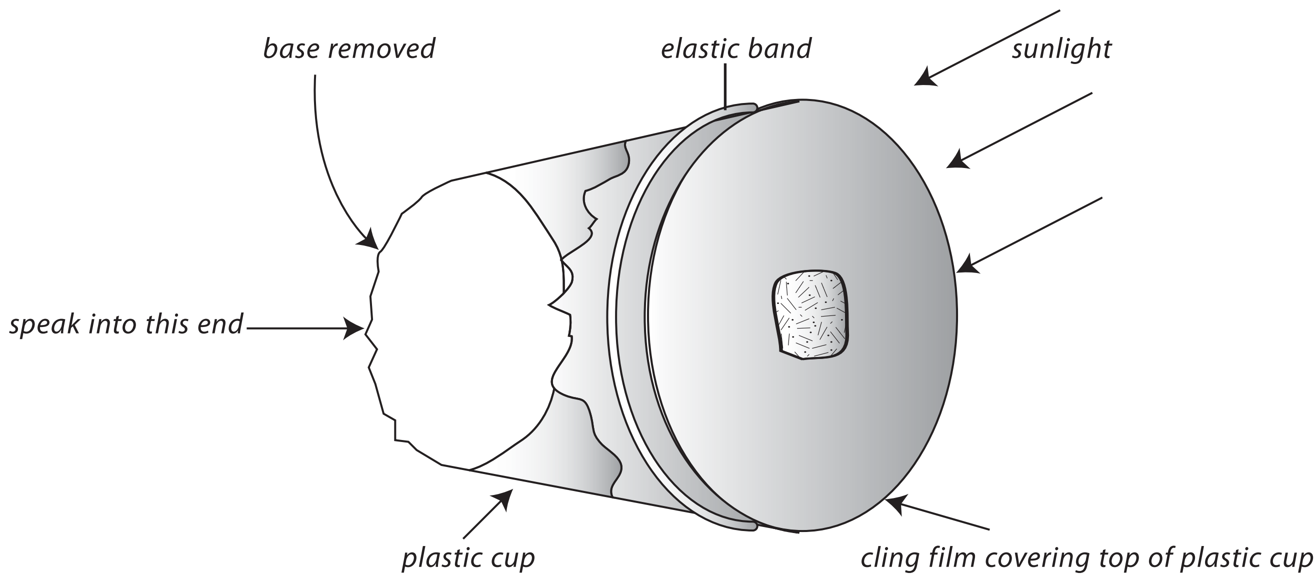
Demonstrate to the class that sounds cannot travel in a vacuum. There is a diagram of the apparatus on page 212.

WORKSHEET 1

How to see sound waves

Materials needed: a plastic cup; some plastic film such as Cling-film; scissors; an elastic band; a small piece of aluminium foil; glue; a sunny day.

1. Carefully cut the bottom from the cup and discard it.
2. Stretch a piece of plastic film over the mouth of the cup and hold it in place with an elastic band.
3. Cut a piece of aluminium foil about 0.5 cm square. Glue this to the plastic film approximately one-third of the way across the mouth of the cup.
4. Find a room that faces the Sun and draw the curtains to leave a gap about 5 cm wide for the Sun to stream through.



5. Sit in the sunlight, fairly close to the curtains, and hold the bottom of the cup close to your mouth. The end of the cup which has the plastic film on it should reflect the sunlight onto a wall or the back of the curtains. You should be able to see this reflection clearly.
6. Speak into the bottom of the cup and watch what happens to the reflection as you speak.

What happens to the reflection as you speak? ______________________________

____

Explain what you observed ______________________________

____

What is the purpose of the small square of aluminium foil? ______________________________

____

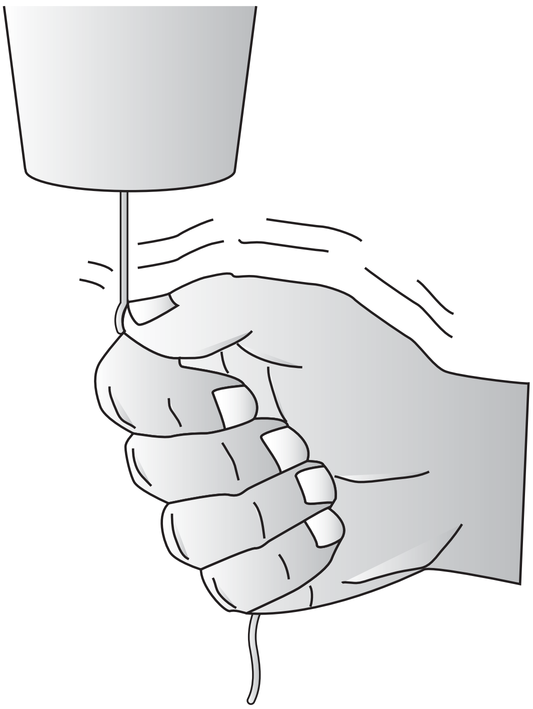
WORKSHEET 2

Make a roaring cup

Materials needed: a paper or foam cup; scissors; string

Science is important in music. This toy is based on the same principles used in making musical instruments.

1. Tie a large knot at one end of a piece of string about 35 cm long.
2. Make a tiny hole in the middle of the bottom of a paper or foam cup.
3. Run the end of the string without a knot through the inside of the cup and poke it through the hole in the bottom of the cup. The knot should stop the string from going completely through the hole.



4. Hold the cup in one hand and then rub the thumbnail of your other hand down the string, while squeezing and pulling the string tightly. You should hear a roaring sound. Why?

____

____

5. Try rubbing the string without the cup. Do you get the same effect? Why not?

____

____

WORKSHEET 3

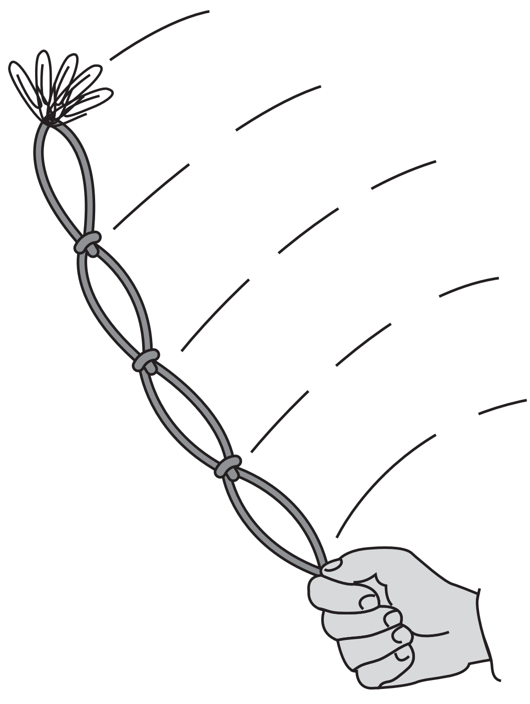
Make elastic bands sing

Materials needed: four elastic bands, each about 8 cm long; six paper clips

On certain days when the wind is blowing, telephone and electricity wires sometimes start to make whistling and singing sounds. In this activity we make elastic bands sing.

1. Loop four elastic bands together to form a chain.
2. Hook six paper clips onto one end of the chain.
3. Hold the other end of the elastic band chain in one hand and spin the chain round as fast as you can. You should begin to hear a shrill whistle.

Safety: Do not spin the chain near your face or near other people's faces. If the chain breaks it could cause injury.



4. Twirl the chain faster and then slower. Can you produce different sounds? What do they sound like?

____

____

5. Does it make a difference how many paper clips you fix onto the chain? ____________________

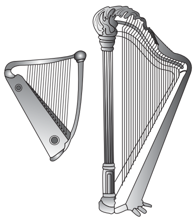
____

WORKSHEET 4

Musical instruments

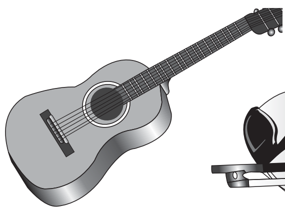
Materials needed: pen or pencil

Look at the pictures below of musical instruments. Then fill in the table. In the last two rows add musical instruments of your choice.

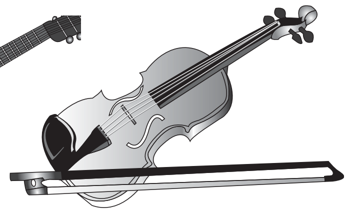


harp

drum kit



guitar



violin and bow

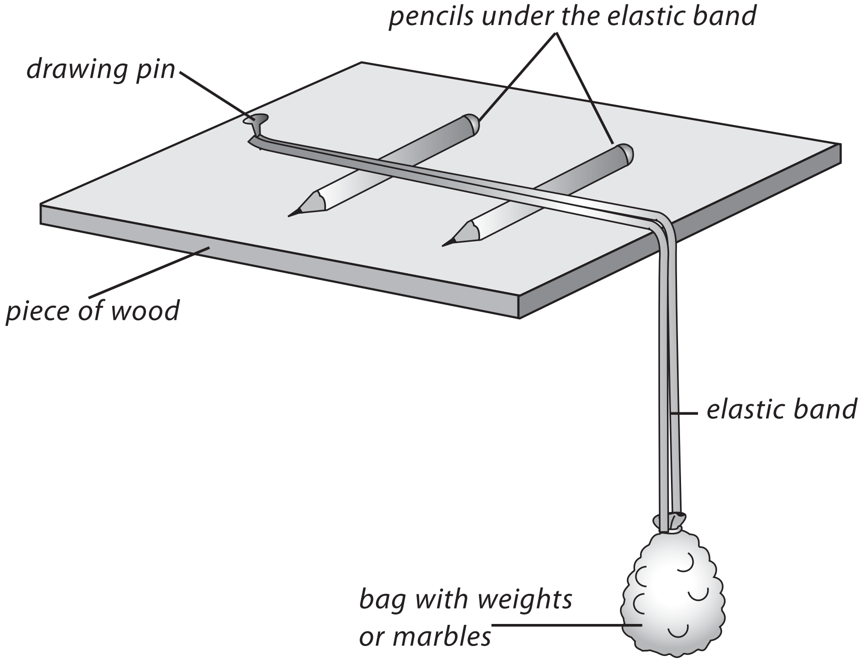
clarinet

Instrument	**How are vibrations produced?**	**How is amplitude (loudness) changed?**	**How is frequency or pitch changed?**
harp			
drum kit			
guitar			
violin			
clarinet			

WORKSHEET 5

Changing the pitch

Materials needed: piece of wood; two pencils; small bag; thread; drawing pin; large elastic band; small weights or marbles



1. Push a drawing pin into the piece of wood near one end.
2. Hook one end of the elastic band around the drawing pin.
3. Use the thread to tie the small bag to the other end of the elastic band.
4. Lay the apparatus on a table so that the bag hangs over the edge of the table.
5. Place two pencils under the elastic band.
6. Put one small weight or marble in the bag. Pluck the elastic band in the middle between the two pencils. Listen carefully to the kind of note the elastic band makes.
7. Add more weights, one at a time, to the bag. Each time, pluck the elastic band.

How does the pitch of the note change as you add more weights to the bag? ______________________

____

Do the experiment again. This time find out what happens if you vary the distance between the two pencils.

Summarize what you have discovered about the pitch of a note. ______________________

____

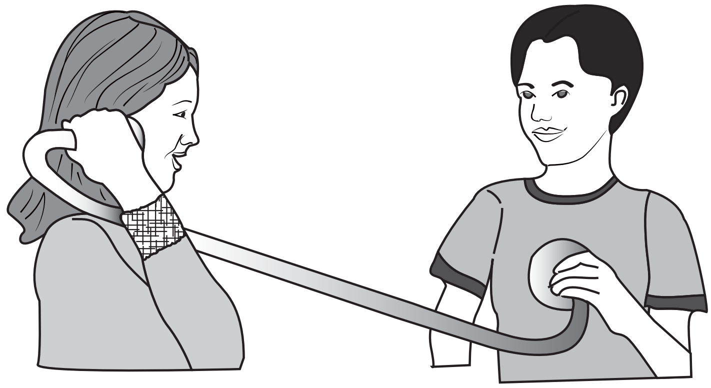
WORKSHEET 6

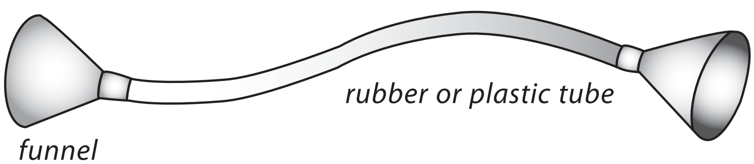
Make a model stethoscope

Materials needed: two plastic funnels; rubber or plastic tubing

The doctor uses a stethoscope to listen to the sounds made by your heart and lungs. But it can also be used to listen to other soft sounds.

1. Join the two funnels to the tube, as shown in the picture.





2. Put one funnel to your chest and the other against your ear.

   Can you hear the beat of your own heart? The sound travels along the tube to your ear.
3. Now stand one side of a wall and ask a friend to tap on the other side of the wall with a spoon or pencil. Can you hear the sound? Ask your friend to tap again, but this time listen with the model stethoscope pressed against the wall. Can you hear the tapping sound better now?
4. Work with a friend again and measure the distance over which you can hear a sound carried by a wall or by iron railings when you listen without and with the stethoscope.

Describe what your beating heart sounded like. ____________________

____

What did you discover when you listened to the tapping sound through the wall with and without the stethoscope? ____________________

____

Write down what you discovered when you listened to the tapping sound along the wall or fence with and without the stethoscope. ____________________

____

Answers to questions in the Students' Book

1. Sound and light are both forms of energy that travel in waves.
2. Sounds are made when something moves or vibrates. The rapid backwards and forwards movements cause changes of pressure in the surrounding air. These sound waves spread out until they reach the ears of a listener.
3. When a drum is beaten it vibrates. It causes small changes in the pressure of the surrounding air. These sound waves travel through the air and, when they reach your ears, they make your eardrums vibrate.
4. We often see a flash of lightning before we hear thunder because light travels much faster than sound. In air the speed of light is 300,000 kilometres per second, whereas sound travels through the air at 300 kilometres per second.
5. Amplitude is the height of a sound wave from its peak to its mean rest position. The size of the amplitude shows how much energy is carried by the wave and how loud the sound is.

   The frequency of sound is the number of complete waves that pass a point in a second. It is a measure of the pitch of the sound.

   Wavelength is the distance between two identical points on a sound wave.

   Pitch is the sensation of how high or how low a sound is.

   A longitudinal wave is a wave in which the vibrations move along the line of the wave in the direction in which the sound wave is travelling. A transverse wave is a wave in which the vibrations are at right angles to the direction in which the wave is travelling.
6. If there was an explosion in space near you, you would hear nothing. This is because sound cannot travel through a vacuum, and there is no air in space to carry the sound waves.
7. All musical instruments produce vibrations. They do this in one of three main ways—with vibrating strings of different lengths and thickness, by allowing air to vibrate in a tube, while percussion instruments have to be struck to make a sound. In stringed instruments and some percussion instruments such as drums, the sound is amplified by a box-like structure. In wind instruments, sounds are made by allowing air to vibrate in tubes of different lengths.
8. An echo is a reflection of sound waves made by an object so that a weaker version of the original sound is heard.
9. There are fewer echoes in a hall which is full of people than when it is empty because the bodies of the people absorb many of the sound waves that would otherwise bounce off the walls and ceiling as echoes.
10. We cannot hear all sounds, only those within a certain range of frequencies. We can only hear sounds within about 0 and 20,000 hertz. Dogs, bats, and dolphins can hear sounds with much higher frequencies than this. These sounds which are too high for people to hear are called ultrasounds.
11. Theatres and cinemas have thick curtains lining the walls to absorb the sound waves so that echoes are not formed.

12. A ship searching for a sunken ship carrying treasure might use echolocation to find the sunken ship. The ship would send pulses of sound down to the sea bed and a detector on the bottom of the ship would measure how long it takes for the echo to come back. A microchip would work out the depth and display it on a screen. A sunken ship would show up because the depth of the sea where it was located would be less. Only a diver could tell whether or not the sunken ship carried treasure.
13. Noise is unwanted or unpleasant sounds. Noise can disturb our sleep, cause stress and ill-health and, if it is loud, it can damage our ears and hearing.
14. Some jobs where people should wear ear protectors include working near aircraft, drilling or cutting metal, concrete, or tarmac, and using pile drivers or other noisy machinery.
15. It can be harmful to live near the part of an airport where aircraft take off because that is where the noise of the aircraft engines is loudest. It can cause loss of sleep, stress and ill-health, and damage the ears and hearing.

Assessment

Question 1

The hammer, anvil, and stirrup bones are found in the:

(A) outer ear (B) middle ear (C) inner ear (D) ear drum

Question 2

When sound travels through the air, the air particles vibrate:

(A) along the direction of the sound wave (B) but not in any fixed direction

(C) perpendicular to the direction of the sound wave (D) in a random motion

Question 3

When large objects vibrate, what kinds of notes do they produce?

(A) low pitched (B) high pitched (C) loud (D) quiet

Question 4

What kind of sounds do objects that vibrate with large amplitudes produce?

(A) high pitched (B) low pitched (C) quiet (D) loud

Question 5

What units do we use to measure the frequency of a wave?

(A) metres (B) metres per second (C) Hertz (D) Hertz per second

Question 6

Through which of these materials can sound NOT travel?

(A) wood (B) water (C) vacuum (D) air

Question 7

Which part of our body is made to vibrate by sound waves?

(A) nerve cells (B) brain (C) vocal cords (D) eardrum

Question 8

Which of the following is NOT a characteristic of a musical sound?

(A) pitch (B) wavelength (C) quality (D) loudness

Question 9

Loudness of sounds is measured in:

(A) Hertz (B) centimetres (C) cycles per second (D) decibels

Question 10

The speed of sound in air is about:

(A) 130 m/s (B) 230 m/s (C) 330 m/s (D) 430 m/s

Question 11

Sound waves used for measuring the distance of an object are called:

(A) RADAR (B) ECHOAR (C) SONAR (D) GOCAR

Question 12

Ultrasound is sound we cannot hear because it:

(A) has too high a frequency (B) is too quiet

(C) has too low a frequency (D) is travelling too fast

Question 13

The hearing range of an average person is:

(A) 20 to 20,000 Hz (B) 0 to 25,000 Hz (C) 20 to 2000 Hz (D) 25 to 2500 Hz

Question 14

The level on the decibel scale reached by a nearby aircraft taking off is likely to be:

(A) 20 dB (B) 80 dB (C) 100 dB (D) 120 dB

Question 15

a) What is meant by the word *vibration*? ____________________

____

b) Describe how a violin produces sound. ____________________

____

c) How does the sound from a violin travel through the air? ______

______

d) What is meant by the term *frequency* when used in connection with sound? ______

______

e) What is the unit of frequency? ______

f) Explain how the frequency of a note affects the pitch of a sound. ______

______

g) Bats and dolphins navigate using ultrasound. What is ultrasound? ______

______

h) Explain how ships can use ultrasound to find out the depth of water beneath them.

______

Question 16

Sounds are made by something vibrating. Match each object to the part that vibrates to make a sound. For example, in a flute, air in a tube vibrates to make a sound.

Object	**Part which vibrates**
guitar	vocal cords
drum	paper cone
piano	wings
flute	prongs
voice	skin
tuning fork	wires
loudspeaker	air tube
bumble bee	strings

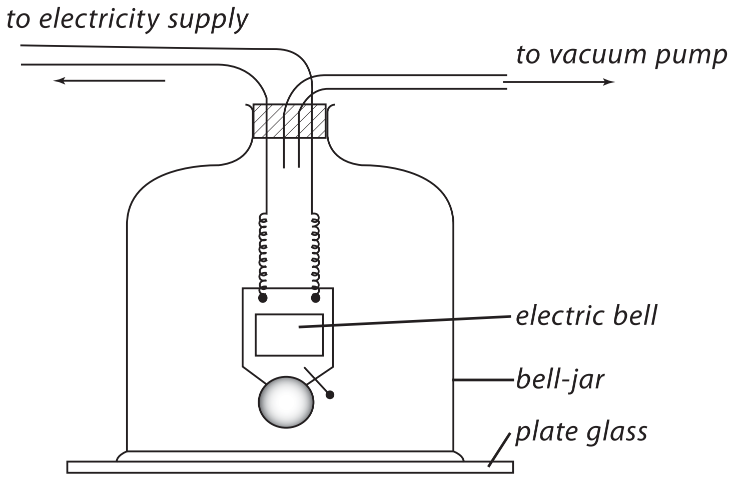
Question 17

The loudness of sound is measured in **decibels**: the louder the sound, the greater the number of decibels (dB). Match each sound to the correct loudness. For example, normal talking has a loudness of about 60 dB.

Sound	**Loudness in decibels (dB)**
whisper	160
normal talking	110
loud rock band	70
silence	80
vacuum cleaner	0
traffic	90
close thunder	120
pneumatic drill	20
space rocket taking off	60

Question 18

The electric bell below is in an airtight jar. At first the bell can be heard ringing. But when the air is pumped out of the jar and there is a vacuum inside, the bell can no longer be heard.



a) What is a vacuum? ______

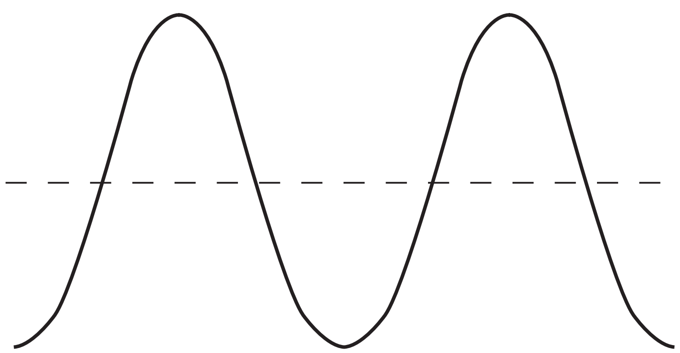
b) Why can the bell not be heard when the air is pumped from the jar? ______

c) How can your ears tell which direction sound is coming from? ______

d) Why is it more difficult to tell where sound is coming from in water? ______

e) What is meant by 'wavelength' when referring to sound? ______

f) The diagram below shows the shape of a sound wave as it appears on the screen of an oscilloscope. What other piece of equipment would you need in order to display a sound wave on the screen of an oscilloscope? ______



g) What is the image of the wave on the screen called? ______

h) Mark on the diagram the wavelength and amplitude of the sound wave.

i) Draw a second sound wave on the diagram that has a smaller amplitude than that of the sound wave in the diagram.

j) How would the sound produced by the wave with smaller amplitude differ from the sound produced by the wave with a larger amplitude? ______

______

Question 19

a) What is meant by *ultrasound*?

______

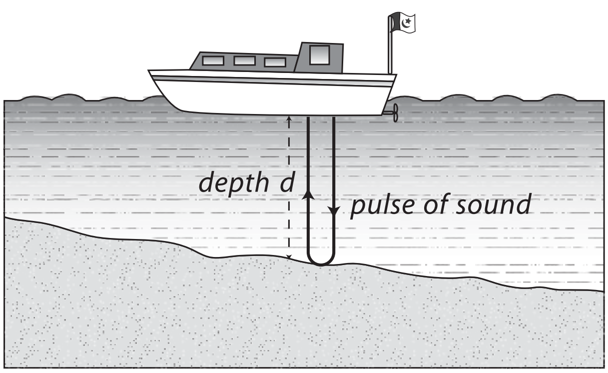
b) Name TWO animals that use ultrasound for communication, navigation, or to find their food.

i) ______ ii) ______

The table shows the speed of sound in metres per second in three different materials:

Material	**Speed of sound (m/s)**
air	330
fresh water	1497
sea water	1560

Some ships and fishing boats use ultrasound to measure the depth of water or to find shoals of fish.



c) A survey ship sends down a pulse of ultrasound to the sea bed and detects the echo 2 seconds later. How deep is the sea at that point? ______

d) If the ship was in a lake and the echo came back in 4 seconds, how deep would the lake be?

______

e) Why is it important for the echo-locating machine on the ship to know what kind of water the ship is in? ______

f) Name ONE medical use of ultrasound. ______

Answers to assessment questions

Question 1 (B)	**Question 2** (A)	**Question 3** (A)	**Question 4** (D)	**Question 5** (C)
Question 6 (C)	**Question 7** (D)	**Question 8** (B)	**Question 9** (D)	**Question 10** (C)
Question 11 (C)	**Question 12** (A)	**Question 13** (A)	**Question 14** (D)	

Question 15

a) A *vibration* is a backwards and forwards movement.

b) A violin produces sound when its strings vibrate. The vibrating strings and the surrounding wooden body of the violin make the air around vibrate and so create sound waves.

c) The sound from a violin travels through the air in the form of sound waves, created by the vibrating strings and wooden body of the violin.

d) The term ***frequency*** refers to the number of complete sound waves produced in one second.

e) The unit of frequency is the hertz (Hz).

f) The higher the frequency of a note, the higher the pitch of the sound.

g) Ultrasound is high-frequency sounds. These have a frequency too high for human ears to detect.

h) Ships use ultrasound to find out the depth of water beneath them by sending down pulses of ultrasound. The longer it takes for the echo to come back, the deeper the sea bed.

Question 16

guitar—strings; drum—skin; piano—wires; flute—air tube; voice—vocal cords; tuning fork—prongs; loudspeaker—paper cone; bumble bee—wings

Question 17

whisper—20; normal talking—60; loud rock band—110; silence—0; vacuum cleaner—70; traffic—80; close thunder—90; pneumatic drill—110; rocket taking off—160

Question 18

a) A vacuum is a completely empty space. It lacks even air.

b) The bell cannot be heard when the air is pumped from the jar because there are no particles to vibrate and create sound waves.

c) Your ears tell which direction sound is coming from because they can sense which ear is nearer the sound.

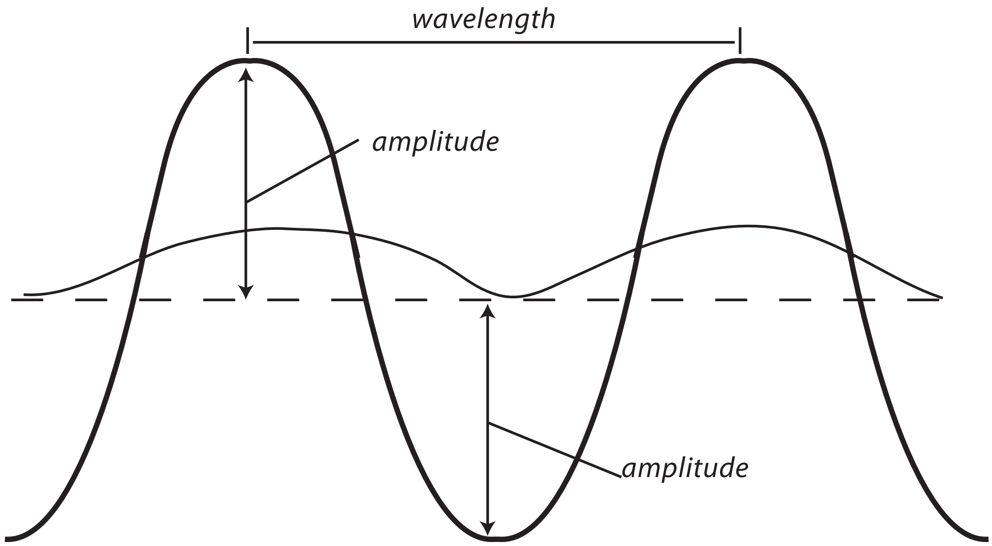
d) It is more difficult to tell where sound is coming from in water because there are more particles to vibrate and the sound waves travel faster.

e) The *wavelength* of a sound is the length of one complete sound wave, or the distance from a point on a wave to the exact same point on the next wave.

f) The other piece of equipment you would need in order to display a sound wave on the screen of an oscilloscope is a microphone.

g) The image of the wave on the screen is called a waveform.

h) The diagram below shows the wavelength and amplitude of the wave.



i) The diagram above also shows a wave that has a smaller amplitude than the sound wave in the diagram. Any reasonable drawing in which the two crests of the wave are below those of the one in the diagram is correct.

j) The sound produced by the wave with smaller amplitude would be less loud/quieter/have a lower volume than the wave with the larger amplitude.

Question 19

a) Ultrasound is sound that is above the hearing range of humans (above about 20,000 Hz).

b) Animals that use ultrasound for communication, navigation or to find their food include bats, dolphins, and mice. Dogs can also detect ultrasounds.

c) The sea is 1560 metres deep at that point (Remember the 2 seconds is the time taken for the pulse of sound to go down to the sea bed and be reflected back as an echo).

d) If the ship was in a lake and the echo came back in 4 seconds, the lake would be 2 x 1497 = 2994 metres deep.

e) It is important for the echo-locating machine on the ship to know what kind of water the ship is in because the speed of sound varies in different types of water, and therefore the time taken for an echo to return will vary.

f) Medical uses of ultrasound include scanning pregnant mothers to check the development of the unborn baby, cleaning badly coated teeth, and breaking up kidney stones.

Circuits and electric currents

CHAPTER 13

Teaching Objectives

- To extend earlier learning, with an explanation of current and a comparison of the construction and uses of parallel and series circuits
- To explain the differences between current and energy and to examine methods of measuring both
- To explain the relationship between
- voltage and resistance and the advantages and disadvantages of resistance
- To examine the effects of current in some everyday appliances
- To examine the major uses of electricity in the home
- To discuss potential hazards in the transmission and use of electricity, and to examine the safe use of electricity in the home, school, and wider environment

Learning Outcomes

After studying this chapter students should be able to:

- define current
- make parallel and series circuits
- investigate types of circuits used for different purposes
- identify a disadvantage of a series circuit
- differentiate between current and energy
- explain the effects of electric current in daily use appliances
- describe voltage
- explain resistance as opposition to the flow of current
- describe the relationship between voltage and resistance
- measure current by using different devices
- list the major uses of electricity in homes
- list electrical hazards and precautionary measures to ensure the safe use of electricity at home
- describe why electricity is dangerous to humans

Introduction

An electric current is a flow of electrons. The path along which electrons flow is called a circuit. For an electric current to flow, there must be a complete circuit without gaps. A simple circuit might consist of a battery, a switch and a bulb in a bulb holder. When the switch is pressed, the circuit is completed and the bulb lights up as the current flows through the circuit. A series circuit is formed when the components are arranged so that there is a single path for the current to take, and the current passes through each component one after another, as in the example given above. A parallel circuit is formed when the components are arranged so that there is more than one path for the current to take. The current splits up and passes through each branch of the circuit at the same time.

An electric current is a flow of electric charge, and a flow has direction. Before the discovery of electrons at the end of the 19th century, scientists decided to say that the current flowed from the positive terminal around the circuit to the negative terminal. This is still the convention shown on some circuit diagrams and is known as the conventional current. The real electron flow, called the electron current, is in the opposite direction. The negative terminal is the source from which electrons (which are negatively charged) enter a circuit. They leave by the positive terminal.

Conductors and insulators

Substances which allow an electric current to flow through them easily are called conductors. Metals are good conductors, so too is the non-metal graphite. Solutions of some chemicals (acids, bases and salts) will also conduct, but not as well as metals. Substances that will not allow a current to pass through them are called insulators. They include rubber, china, plastics and most non-metallic substances. Wires carrying an electric current almost always have an insulating covering to prevent the current leaking away. If two bare wires touch a short circuit causes a spark or even a fire.

Semiconductors

Semiconductors can conduct electricity better than insulators, but not as well as metals. Germanium, silicon and selenium are semiconductors. Their particular feature is that their electrical resistance decreases as the temperature rises. In the pure state, semiconductors have

very few free electrons, but the number can be increased by adding a small number of special impurity atoms. Transistors consist of different types of semiconductors joined together, often in the form of a sandwich. Diodes and other electronic components are also made from semiconductors.

Measuring electricity

The flow of electricity through a wire is often compared with the flow of water through a pipe. Since the pipe offers resistance to the flow, a pressure is needed to drive the water along. This pressure can be produced by a pump, as it is in some central heating systems. Similarly, with an electric circuit there has to be an electric pressure to cause the electrons to flow. This is provided by the cell, battery or generator, which acts as a kind of electron pump.

The electrical pressure, or electromotive force, is measured in volts. The current, or rate of flow of electricity, is measured in amperes. One ampere is equivalent to about six million million million electrons each second. The resistance of the conductor to the electron flow is measured in ohms. The names (volts, amperes and ohms) of these units commemorate famous scientists. A very simple relationship exists between the three quantities:

$$\text{current} = \frac{\text{voltage}}{\text{resistance}} \quad \text{or amperes} = \frac{\text{volts}}{\text{ohms}}$$

The relationship was discovered by George Ohm, a German physicist, in 1826 and is known as Ohm's Law. All simple electrical calculations are based on this law. If two of the three values are known, the third can be calculated.

Electrical power

Electrical power (rate of working) is measured in watts or the larger unit, the kilowatt (1kW= 1000w). The power used depends on both the current and the voltage and, in fact, watts = volts x amperes. This is another useful relationship for calculations. For example, a 2kW electric heater connected to a mains supply of 240V will use 2000/240 = 8.3 amperes. This is why two such heaters could not be connected to a plug containing a 13 amperes fuse. The double current of 16.6 amperes would blow the fuse.

The electricity meter records both the power and the time for which it is used. It therefore measures electrical energy, usually in units of kilowatt-hours. This is the amount of energy used when an appliance rated at 1kW is used for one hour. A 100W lamp running for 10 hours uses one unit of electricity; a 2kW heater working for 10 hours uses 20 units. Our electricity bills tell us how many units we have used.

Heat and light

When an electric current flows through a conductor, the atoms or molecules of the conductor offer a resistance to the flow of electrons. Some substances, such as silver and copper, offer very little resistance and are good conductors. Others substances, such as glass and polythene, offer a great deal of resistance and are bad conductors but excellent insulators. Resistance also depends on other factors: the longer and thinner a piece of wire, the greater will be its resistance. Its resistance also increases when it is heated.

When a current is forced through a conductor against its resistance, the electrons collide with atoms of the conductor and make them move about faster. This causes the temperature of the conductor to rise. A practical use of this is in electric heaters. If the temperature rise is great enough, light is produced and this is used in electric lamps.

Teaching considerations

Undoubtedly the best way for students to understand the construction of circuits and the use of resistors and devices for measuring current is for them to build their own circuits and to incorporate the appropriate devices for measuring current in them. Of course, this all depends on having the right materials and equipment available. If it is not possible to carry out the activities individually, it may be possible for them to be carried out using a 'stations' or 'circus' technique, with the experiments set up around the room, so that the students circulate from one to the next until they have completed them all. Failing that, it will be necessary for the teacher to demonstrate the experiments and activities.

Lesson suggestions

1. Series and parallel circuits

Refer to page 165 of the Students' Book

Starter suggestions

Ask the students to list all of the electrical devices in the room that can be turned on and off using a switch. Discuss what the different devices are used for.

Ask the students to make a table of all the electrical devices they can think of which use mains electricity and those which are powered by batteries. Compile a class table on the board from the students' suggestions and let them copy out the finished version.

Main lesson

Let the students carry out the practical activity described on Worksheet 1, or demonstrate it for them. Discuss the advantages and disadvantages of series and parallel circuits.

Take the students into the school hall or outside where there is plenty of room and carry out the model series circuit activity described in the Ideas for investigation and extension work section of this chapter.

If time permits, return to the classroom or laboratory and investigate what effect different numbers of bulbs and cells have on the brightness of the bulbs in a circuit, as described in Worksheet 2.

Finally, give the students a chart of the common electrical symbols and ask them to draw circuit diagrams of the circuits they have seen or made.

2. Electric current and resistance

Refer to page 167 of the Students' Book

Starter suggestions

Ask the students to think about watering some window boxes of flowering plants some distance away from a tap using a watering can. You have a length of hose but no spray attachment. In any case you do not want to spray the windows with water. Why would it take longer to fill the watering can using the hose near to the window boxes than it would filling the can straight from the tap. Introduce the idea of resistance, in this case due to the friction of the water against the sides of the hose, and the longer the hose, the greater the resistance.

Set up and use the fun experiment described in Worksheet 3.

Main lesson

Ask the students to think about an ornamental fountain in the park. A pump circulates the water, but the same water is used over and over again. Alternatively, ask them to think about their blood system. The heart acts as a pump and the blood goes round and round the closed system. In both examples, neither the water nor the blood gets used up. In an electrical circuit, the mains or the cell or battery act as a pump, pushing electrons along the wire or some other conductor. But the important point is, like the water and blood, the electrons do not get used up when they travel round the circuit. Many students believe that electrons are used up when they light up a bulb or turn an electric motor.

Let the students carry out the experiment described on Worksheet 4, or demonstrate it for them. If one is available, demonstrate the working of a variable resistor, perhaps salvaged from an old radio, or purchased ready-made. Using the circuit with a bulb in it, and either the home-made or ready-made resistor, add an ammeter to the circuit and see how the brightness of the bulb is related to the current.

Examine a variety of electric heaters, electric kettles, hair driers and electric irons (all unplugged!) and also conventional light bulbs. Explain to the students how we use resistance to produce heat and light.

If time and resources permit, the students could try to make a model light bulb or electric fire using only cells or batteries to produce the electric current.

Give the students a chart of the common electrical symbols and ask them to draw circuit diagrams of the circuits they have seen or made.

3. Electrical safety at home

Refer to page 179 of the Students' Book

Starter suggestions

Ask the students to devise a slogan which emphasizes some aspect of electrical safety, e.g. 'Electricity can kill!' or 'Electricity and water do not mix!' or 'Electricity—a very helpful servant but a dangerous master!' Ask them to design posters to go with their slogans.

Place some wire wool on a heat resistant mat. Touch it with two bare wires, one coming from each of the terminals of a 1.5V battery. Each strand will glow, or even burn. This demonstrates that even a low voltage of electricity is sufficient to cause a fire.

Main lesson

Show the students a selection of electrical fuses and describe how they work.

Demonstrate the 'Making and testing a fuse' activity described in the **Ideas for investigation and extension work** section of this chapter.

Show the students a miniature circuit-breaker, earth wires, and earth leakage circuit-breaker and explain how they are used, and why.

Discuss how bathrooms need to have electric lights and sockets for electric razors and how these are made safe for people to use (pull cords for switches and extra earthing). Discuss other aspects of electrical safety in the home and round off the lesson by compiling, with the students, a list of things not to do with electricity, e.g. 'Don't touch plugs and cables with wet hands'; 'Don't overload sockets', etc.

Ideas for investigation and extension work

A model series circuit

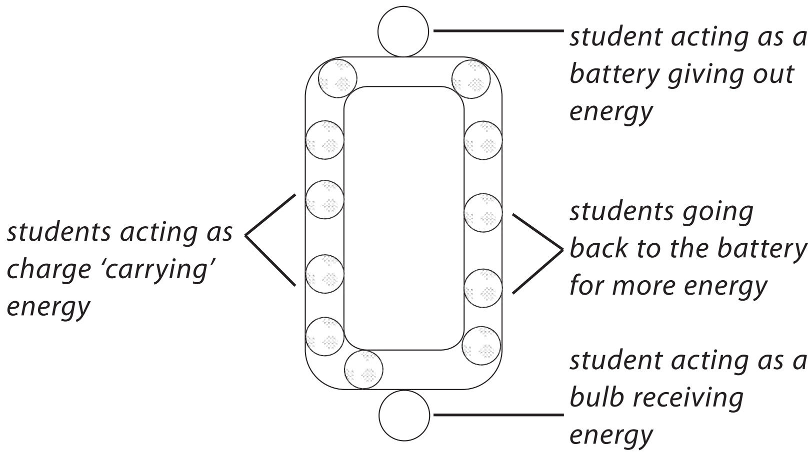
The students should already know that a bulb needs energy in order for it to light up. This human model helps them to understand where the energy comes from and how it travels around a simple circuit.

Mark a circuit out around the classroom. One student acts as the battery and one as the bulb. They stand at opposite ends of the classroom or hall. The other students are the electrons in the circuit and they stand spread out around the circuit. The teacher starts the flow of electrons by announcing that the switch is down. The students start walking around the circuit. As they pass the battery, the battery gives them some energy by gentle patting each of them on the head. The students show that they have this energy by holding their hands out in front, as if carrying a parcel. When they get to the bulb, they hand the imaginary parcel over and the bulb waves a book or flag in the air to show that he or she is being lit.

While this is going on, the teacher can explain that the amount of current in the circuit is not changing. In other words, it is not being used up, although the energy is. The teacher can also discuss the direction of the current and ask if it is flowing from the positive terminal or the battery to the negative, or vice versa. Explain that the electrons are flowing because they are being attracted to the positive terminal.

The demonstration ends when the teacher announces that the switch has been lifted. Again, the teacher can explain that a current is needed for energy to flow, and in a broken circuit there is no current and so the bulb will not light up.

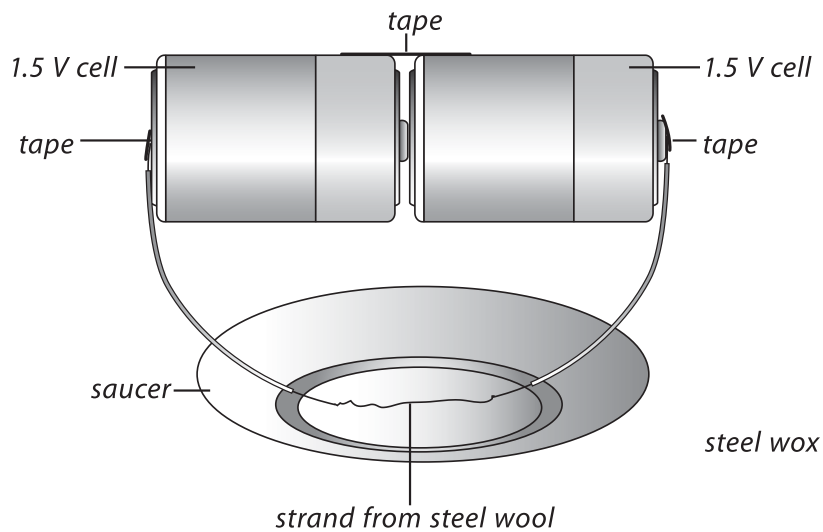
If time permits, branches can be added to the original circuit so that the students can see what happens in a parallel circuit.



Making and testing a fuse

Materials needed: two 1.5V cells, two connecting wires, masking tape, a small saucer or a heat-proof mat, and some steel wool

Pull a short strand from the steel wool and explain that this is to be a fuse. Connect the cells and wires as shown in the diagram below. If you do not have holders for the cells, masking tape can be used to hold them together. You can also use masking tape to fix the wires to the two terminals of the cells. Place the strand of steel wool on the saucer or heat-proof mat and cause a short circuit by touching one wire to each end of the strand of steel wool. Ask the students to record what happened to the fuse when you caused the short circuit. Discuss the safety implications of short circuits and overloading electrical appliances.

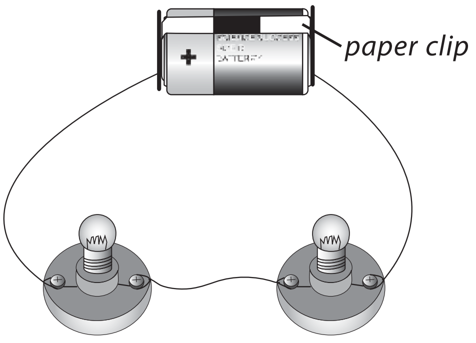


WORKSHEET 1

Series and parallel circuits

Materials needed: 1.5V cell; six pieces of wire; sticky tape; paper clips; three torch bulbs in holders; small screwdriver

1. Make a circuit like the one shown in the diagram. This is called a series circuit because the bulbs are in a series or row.



2. Now add an extra bulb to the circuit, using one more piece of wire. Are the bulbs brighter or dimmer than before?

____

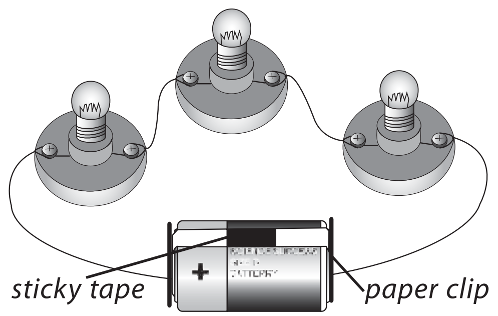
____

3. Carefully unscrew one of the bulbs. What happens to the other bulbs? ____________________________

____

____

4. Now wire up three bulbs, as shown. This is called a parallel circuit. Are the bulbs brighter or dimmer than they were with the series circuit?



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5. Carefully unscrew one of the bulbs. What happens to the other bulbs? ____________________________

____

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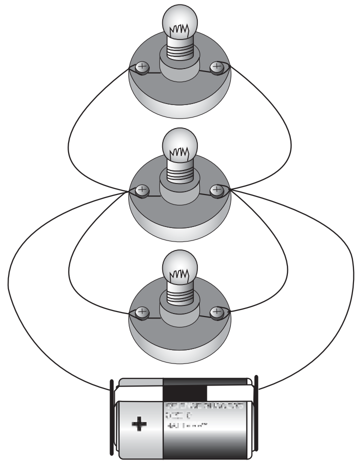

Draw circuit diagrams of your circuits on a separate piece of paper.

What have you learned about series and parallel circuits?

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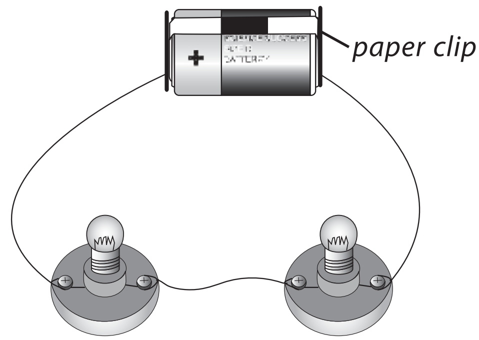
WORKSHEET 2

How bright is the light?

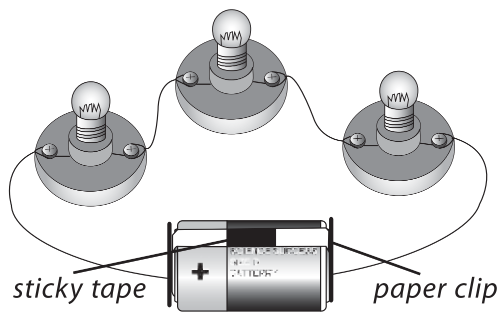
Materials needed: three 1.5V cells; four pieces of wire; three torch bulbs (4.5V) in bulb holders; crocodile clips or paper clips; small screwdriver

Investigate what effect different numbers of bulbs and cells have on the brightness of the bulbs in a circuit.

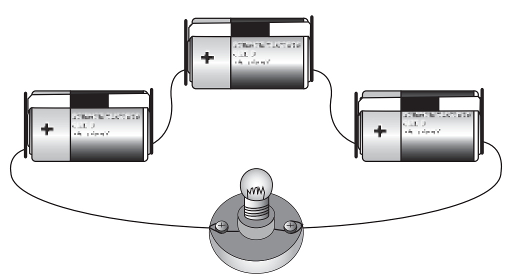
1. Wire the bulbs and cells in series like this:



2. Now add another bulb like this:



3. Add extra cells like this:



Record your results for each circuit in the table below.

Say how bright the bulbs were (dim, bright, or very bright).

Number of cells	Number of bulbs	Brightness of bulbs
1	1	
1	2	
1	3	
2	1	
2	2	
2	3	
3	1	
3	2	
3	3	

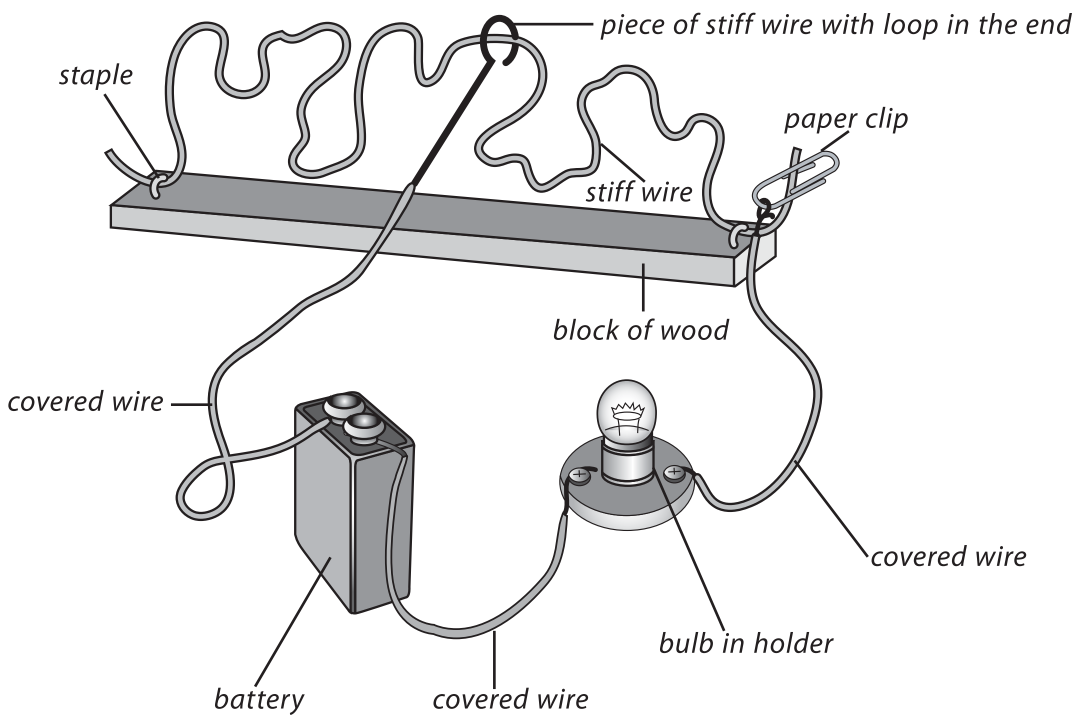
What affects the brightness of the bulbs?

WORKSHEET 3

How steady is your hand?

Materials needed: long block of wood; torch bulb in holder; piece of fairly stiff wire (e.g. cut from a wire coat hanger; two staples; paper clips; three pieces of covered wire; battery; pliers or wire cutters.

1. Make an obstacle course, like the one in the diagram below.



2. Test each member of your group.
3. Who can move the wire loop from one end of the obstacle course to the other without making the bulb light up?

Complete the table:

Name	Did the bulb light up?

Describe what happens to make the bulb light up. ______________________________

____

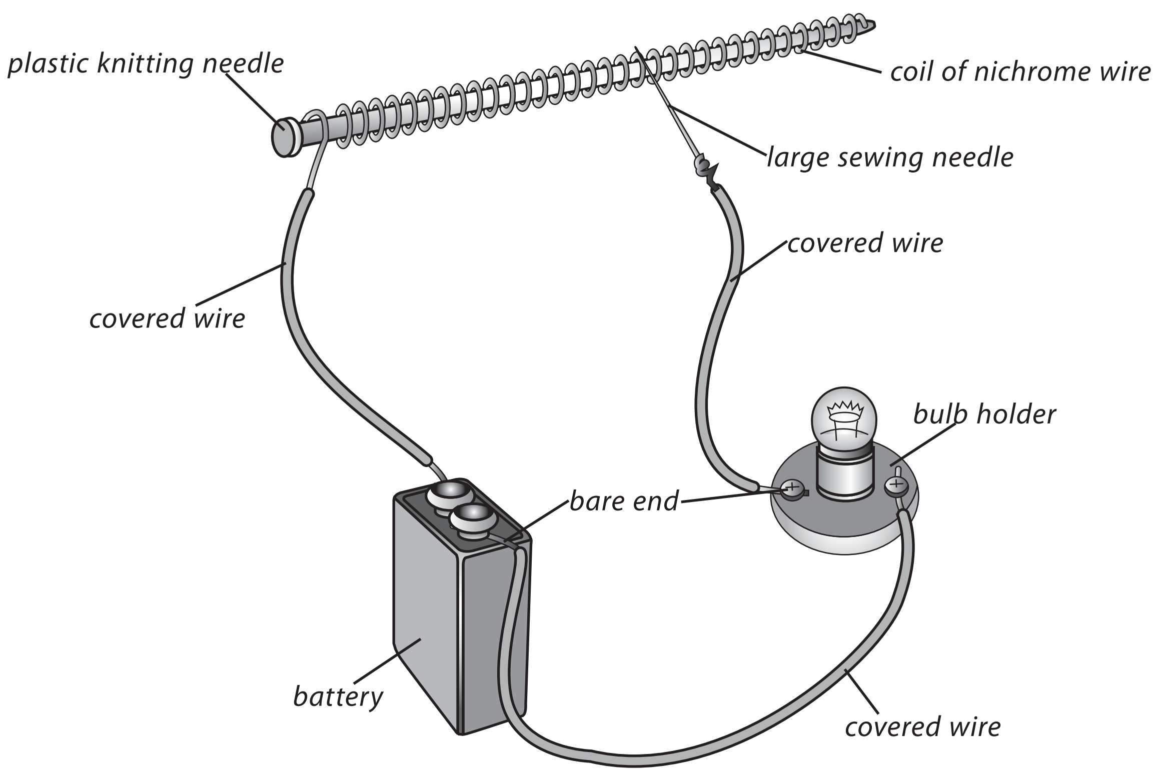
____

WORKSHEET 4

Making use of resistance

Materials needed: thick plastic knitting needle; nichrome wire or fuse wire; 9V battery, 6V torch bulb in holder; three pieces of covered wire with bare ends; large, blunt sewing needle (bodkin).

1. Carefully coil the nichrome wire or fuse wire neatly and evenly around the plastic knitting needle. The more turns of the wire you can put into the coil (without them overlapping or crossing), the better.
2. Connect the coil to the battery and bulb as shown in the diagram.



3. Fix the large sewing needle to the end of one of the wires.
4. Watch what happens when you touch different parts of the coil with the sewing needle.

When does the bulb light up? ______________________________

What differences do you see? ______________________________

Explain what the coil does. ______________________________

____

Where in the home would a coil like this be useful? ______________________________

____

Answers to questions in the Students' Book

1. A circuit is the complete path along which an electric current (or electrons) can flow from a cell, battery, or generator, to where the electricity is changed to other forms of energy, and back to the cell, battery, or generator.
2. In a circuit, a cell or battery pushes the electrons around the circuit.
3. Energy is not used up in a circuit. Electrical energy is simple changed to other forms of energy such as heat, light, sound, or movement.
4. Good conductors of electricity include metals such as silver, copper, and aluminium, and the non-metal carbon and graphite. Non-conductors or insulators include glass, rubber, and plastics such as PVC, polystyrene, Perspex, and Bakelite.
5.

Series circuit	**Parallel circuit**
Bulbs become dimmer when you add more bulbs to the circuit.	Bulbs stay at the same brightness when you add more bulbs.
The electrical energy in each bulb gets less when you add more bulbs.	The electrical energy in each bulb stays the same when you add more bulbs.
You can use only one switch for the whole circuit.	You can use a separate switch for each bulb.
If one bulb 'blows' they all go out.	If one bulb 'blows' the others stay alight.

6. A circuit diagram is a shorthand way of showing how to connect the components in a circuit. It is quicker to draw and does not depend upon artistic ability. The symbols used are standard ones that can be understood everywhere without the need for language.
7. The gases used in a light bulb are usually the inert gases argon or nitrogen. If air or oxygen was used, the filament of the bulb would burn out very quickly.
8. The instrument used to measure current is an ammeter and the units used are amperes (A).
9. A doorbell or electric bell uses an electromagnet. When the bell push is pressed, an electric current passes through the electromagnet. An iron bar linked to a small hammer is attracted by the electromagnet, and the bell is struck. The circuit is now broken and the magnet is switched off. A spring pulls the iron bar back to its original position. The whole process is repeated over and over again, and the bell rings, until the bell push is released.
10. Maglev trains do not run on rails, but instead they 'float' above the rails because of electromagnetism. An electric current passes through electromagnets in both the track and the train. The two sets of magnets repel each other, lifting the train upwards.
11. An electric current can be used to decompose (split) certain chemical compounds. The process is called electrolysis. For electrolysis to work, the compound has to conduct electricity. Water, for example, can be broken down into hydrogen and oxygen, while caustic soda (sodium hydroxide), chlorine, and hydrogen can be produced from salt solution. Electricity can also be used to plate metals (a process called electroplating) and to purify metals such as copper.

12. Resistance is the degree to which a substance resists electricity or reduces the flow of electrons. We use resistors to control the resistance of a circuit, because each type of resistor has a particular resistance.
13. Voltage is a measure of how much energy is provided by a cell, battery, or the mains to push an electric current around a circuit. Voltage is measured in volts. The higher the voltage of a cell or battery, the more energy each electron is given, and the more energy it has to be converted as it flows around the circuit.
14. It would take six 1.5V cells to provide a voltage of 9V.
15. A fuse is an electrical safety device. It consists of a short, thin piece of wire which heats up and melts when the current flowing through it exceeds a certain amount.
16. Fuses differ from circuit-breakers in that fuses can only be used once, then they have to be replaced. Circuit-breakers can be reset simply by pressing a switch or lever.
17. To increase the strength of an electromagnet, you could either increase the number of turns of wire in the coil around it, or increase the current in the coil.
18. The paper cone of a loudspeaker is fixed to a heavy metal frame so that only the cone vibrates, not the whole loudspeaker.
19. a) The cable of the iron has a frayed lead. If it touches something made of metal the woman could be electrocuted.
    b) Water can conduct electricity and could touch the terminals of the plug and electrocute or badly burn the person with wet hands.
    c) The socket is overloaded and could start a fire.
    d) The prongs of the metal fork could touch the heating element of the toaster, conducting electricity into the person's body.
    e) The stove burner could melt the insulation on the cable leading to the electric appliance. Electricity could then pass into the metal parts of the cooker, making the whole thing 'live' and dangerous.

Assessment

Question 1

Which one of the following is NOT a source of electrical energy?

(A) battery (B) dry cell (C) dynamo (D) resistor

Question 2

An electric current in a metal wire in a circuit is a flow of:

(A) atoms (B) neutrons (C) volts (D) electrons

Question 3

Which one of the following is an insulator?

(A) knife blade (B) plastic ruler (C) silver spoon (D) cooking foil

Question 4

To measure the current in an electrical component, we use:

(A) an ammeter connected in parallel
(B) an ammeter connected in series
(C) a voltmeter connected in series
(D) a voltmeter connected in parallel

Question 5

A switch turns a circuit on or off by making it:

(A) hot or cold
(B) conductor or insulator
(C) complete or incomplete
(D) positive or negative

Question 6

To vary the brightness of a bulb in a circuit we could use:

(A) a switch
(B) a variable resistor
(C) a connecting wire
(D) an insulator

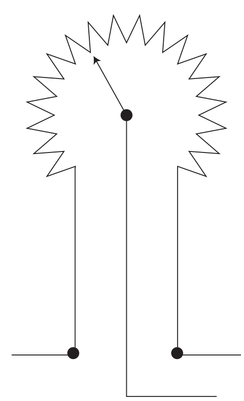
Question 7

To measure the voltage across a circuit, we would use:

(A) an ammeter connected in parallel
(B) an ammeter connected in series
(C) a voltmeter connected in series
(D) a voltmeter connected in parallel

Question 8

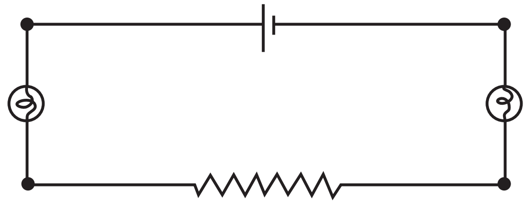
The diagram below shows part of an electrical circuit. The pointer P can be turned to make contact anywhere on the resistance wire R. This idea is used in:



(A) changing the programme on a television set
(B) in a thermostat to change the temperature setting
(C) in a motor car to switch off the engine
(D) in a radio to change the volume

Question 9

The diagram below shows two identical lamps, L1 and L2, on either side of a resistor R. The electrons flow from the battery through L2, R, and then L1. Which of the following statements is TRUE?



(A) Lamp L2 will be brighter than L1

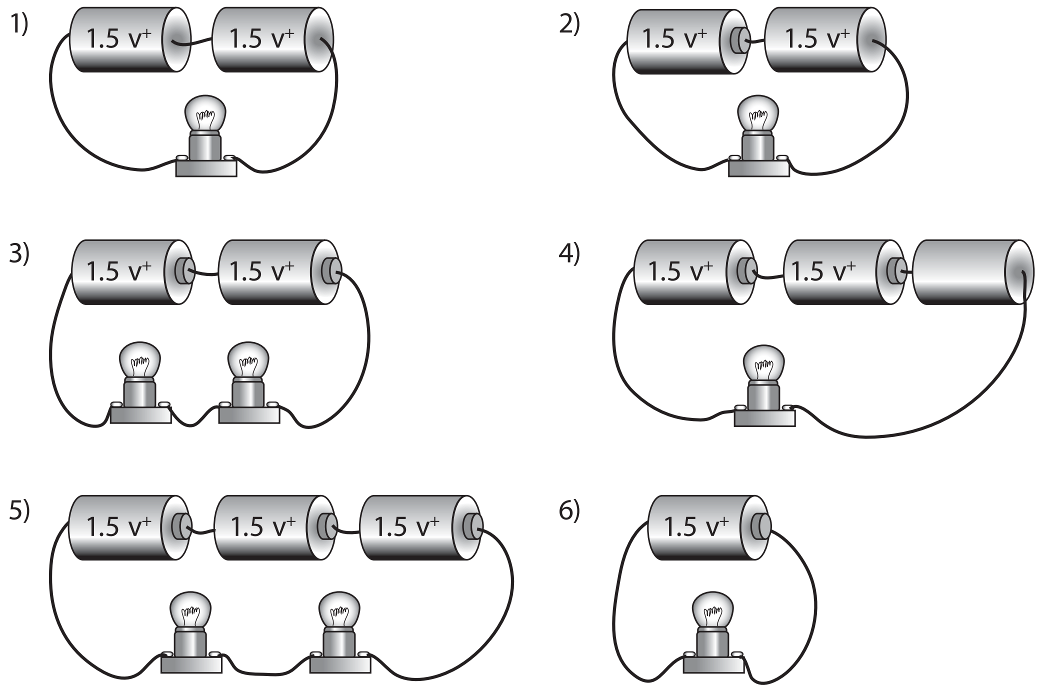
(B) Lamp L2 will be the same brightness as L1

(C) Lamp L2 will be less bright than L1

(D) No current will flow through the resistor R

Question 10

Look carefully at each of these pictures of circuits. The bulbs are all exactly the same and the batteries all have the same voltage. Now answer these questions.



a) Which circuit's bulb would have the BRIGHTEST light? ____________________

b) Which bulbs circuit would not light at all? ____________________

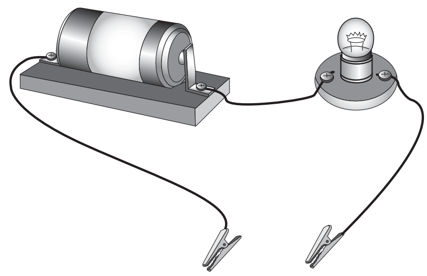
c) In which THREE circuits would the bulbs light with the same brightness. Explain your answer.

____

____

Question 11

Tanya and Myra made the circuit shown below. They used it to test different materials in order to discover whether they were conductors or insulators.



a) Explain how Tanya and Myra used the circuit to test the different materials.

____

____

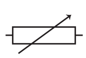
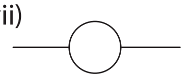
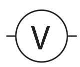
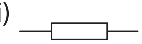
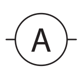
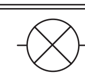
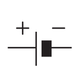
The table below shows some of the materials the two girls tested.

Material	Conductor	Insulator
copper	✓	
iron		
paper		
plastic		
tin		
graphite		
mercury		

b) Put a tick in the second column if you think the material is a conductor. Put a tick in the third column if you think the material is an insulator. The first one has been done for you.

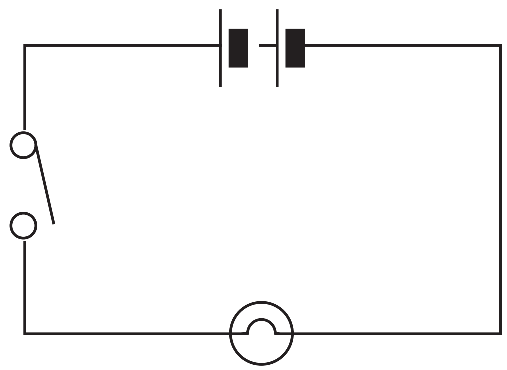
Question 12

Match the symbol to the electrical component it represents.

Symbol	Component	Symbol
i) 	ammeter	vi) 
	battery	
ii) 	cell	vii) 
	voltmeter	
iii) 	variable resistor	viii) 
iv) 	motor	ix) 
	bulb	
v) 	switch	
	resistor	

Question 13

Abbas made the simple circuit shown in the diagram below.



a) What must Abbas do in order to turn the bulb on?

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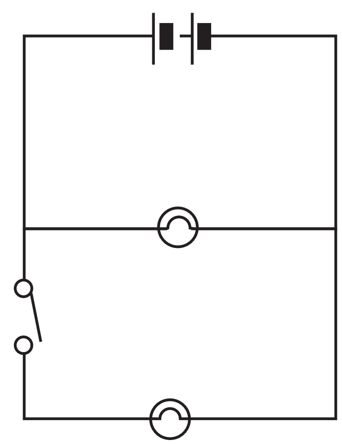
b) Abbas puts another bulb in the circuit, as shown in the diagram below.



(i) Is the new circuit a series or a parallel circuit?

(ii) Put a tick in the boxes next to the statements that are true for this circuit.

Both bulbs will be on at the same time. ☐

Bulb A will be on all the time. ☐

Bulb B will be on all the time. ☐

Bulb B will be on only when the switch is closed. ☐

Both bulbs will be off at the same time. ☐

(iii) Electric current is measured in amps. If 0.4 amps flows from the cell in the circuit in part (b), how many amps would flow through each of the two bulbs, assuming the two bulbs were identical?

Answers to assessment questions

Question 1 (D) **Question 2** (D) **Question 3** (B) **Question 4** (B) **Question 5** (C)
Question 6 (B) **Question 7** (D) **Question 8** (D) **Question 9** (B)

Question 10

a) The bulb of circuit 1 would have the brightest light.

b) The bulb in circuit 2 would not light at all.

c) The three circuits where the bulbs would light with the same brightness are 3, 4, and 6, because all three have 1.5 volts per bulb.

Question 11

a) Tanya and Myra put each test material between the two crocodile clips. If the bulb lit up, the material was a conductor. If the bulb did not light up, the material was an insulator.

b)

Material	Conductor	Insulator
copper	✓	
iron	✓	
paper		✓
plastic		✓
tin	✓	
graphite	✓	
mercury	✓	

Question 12

i)= switch; ii) = variable resistor; iii) = voltmeter; iv) = ammeter; v) = cell; vi) = battery; vii) = motor; viii) = resistor; ix) = bulb

Question 13

a) In order to turn the bulb on Abbas must close the switch.

b) (i) The circuit is a parallel circuit.

(ii) Bulb A will be on all the time. Bulb B will be on only when the switch is closed (the second and fourth boxes should be ticked).

(iii) 0.2 amps

Investigating space

CHAPTER 14

Teaching Objectives

- To provide a simple explanation of the Big Bang Theory of the origin of the Universe
- To examine the evidence for the Big Bang Theory
- To compare and contrast stars and other bodies in space that emit and reflect light
- To examine the structure and function of the Sun and ways of studying the Sun
- To explain galaxies and constellations and to identify the major constellations visible in the night sky
- To explain black holes and their formation
- To explain the structure and uses of telescopes in astronomy

Learning Outcomes

After studying this chapter students should be able to:

- explain the Big Bang Theory of the origin of the Universe
- describe a star using properties such as brightness and colour
- identify bodies in space that emit and reflect light
- suggest safety methods to use when observing the Sun
- define the terms star, galaxy, Milky Way, and black holes
- explain the types of galaxy
- explain the birth and death of our Sun
- evaluate the evidence that supports scientific theories of the origin of the universe
- identify major constellations visible at night in the sky
- describe the formation of black holes
- explain the working of a telescope

Introduction

The stars and planets you see on a clear, dark night are millions of miles away and it takes many years for their light to reach your eyes. Our Earth is in fact just a tiny speck in a vast Universe. From the earliest times, people have tried to understand how we on Earth fit into our local part of space and into the wider Universe.

Our place in the Universe

We now know that the Earth is part of the Solar System, a family of eight planets and their moons, plus countless asteroids, comets and other objects, all circling the Sun. On a very clear, dark night you can see about 2000 stars in the sky. If you were to study the sky regularly for a whole year, you would see some different stars each season. Your view of space keeps changing because the Earth orbits around the Sun, a journey which takes a whole year to complete.

The Milky Way galaxy

The stars we see with the naked eye are just a small proportion of the total number that exists in our part of space. This is because our Solar System belongs to a great spiral-shaped system of over 500,000 million widely-separated stars called the Milky Way galaxy. A galaxy is a gigantic collection of stars, gas and dust all held together by the pull of gravity. The Sun, Earth, and all the stars in the galaxy race around its centre. The Milky Way galaxy is so huge that it would take you at least 100,000 years to cross it if you could travel at the speed of light.

The Milky Way has most of its stars at the centre. This gives the galaxy a central bulge, from which arms spread out, like a gigantic starfish. We live in one of these arms. Like all galaxies, the whole Milky Way is travelling through space, while the stars within it are continuously moving around the centre of the galaxy. The stars in the Milky Way galaxy are far apart from each other. On average the distance between each is five light-years. A light-year is the distance that light travels in one year—almost 9.5 billion kilometres. Our Sun is situated in one of the spiral arms of the Milky Way, about two-thirds of the way from the centre.

Other galaxies

Until the 20th century, astronomers thought that the Milky Way was the only galaxy in the Universe. We now know that beyond the Milky Way there are millions of other galaxies, each containing millions of stars. These galaxies are extremely far apart from each other. Galaxies come in three basic shapes: spiral, like the Milky Way, elliptical, and irregular. Spiral galaxies are made up of young, middle-aged, and old stars, together with huge quantities of gas and dust. Elliptical galaxies are flattened ball-shaped collections of old stars that are near the end of their lives. Elliptical galaxies are the most common type of galaxy in the Universe. Irregular galaxies are those that have not formed into a specific shape. They mostly contain bright young stars, some old stars, and large amounts of gas and dust. Irregular galaxies are the rarest type of galaxy in the Universe.

The Sun

The Sun is at the centre of our Solar System. Indeed, without the Sun the Solar System would not exist. All the planets and their moons, asteroids, comets, and other bodies in our Solar System orbit around the Sun. The Sun is a medium-sized star, which means it creates its own light and heat. It is the closest star to the Earth, which is why it looks so large. All the other stars are much further away.

Sun Facts

- Diameter at equator: 1.4 million km
- Mass: 333,000 times Earth's mass
- Temperature (surface) 5500°C
- (centre) 15 million°C
- Weight of hydrogen fuel used: about 600 million tonnes a second
- Average distance from Earth: 150 million km
- Time taken for sunlight to reach Earth: just over 8 minutes

The Sun is a tremendous ball of hot, glowing gases which rotates in space. It is bigger than a million Earths in volume. The centre of the Sun is mainly made of hydrogen gas, with some helium and tiny amounts of other elements. Hydrogen is the Sun's fuel. Within the Sun, nuclear fusion continuously produces massive amounts of energy as light and heat, while helium gas is released as a waste product. At the centre of the Sun the temperature is about 15 million°C. Even at the Sun's surface the temperature is about 5500°C.

The Sun sometimes has dark spots on its surface. These sunspots are areas where the temperature is lower. Sunspots are not always in the same place on the Sun. Scientists have discovered that every eleven years, the Sun has more sunspots than usual. Sometimes a blazing burst of gas comes from the surface of the Sun, shoots up hundreds or even thousands of kilometres into space, and then loops back down. This is a called a prominence. From time to time there are huge explosions on the Sun and extremely hot gas particles are hurled into space. These solar flares seem to be associated with sunspots. By observing the movement of sunspots, scientists found that different parts of the Sun take different lengths of time to rotate. The Sun's middle, or equator, takes about twenty-five days to rotate completely, whereas its top takes around thirty days.

The birth and life of the Sun

Scientists believe the Sun began its life about five billion years ago. A great cloud of dust and gas formed in space. This cloud of gas and dust began to form a spinning disc with a huge bulge in the middle. The disc started spinning faster and faster. The huge bulge kept heating up until it began turning hydrogen gas into helium gas. Slowly the great bulge was turning into the Sun. At the same time, the planets, including our Earth, were formed from the rest of the gassy disc.

The Sun is about five billion years old and, like living things, it will have a lifetime and then die. As we have seen, the Sun's fuel is hydrogen gas, which it turns into helium gas, creating huge quantities of heat and light and many other kinds of radiation. Almost half of the Sun's hydrogen has now been turned into helium. It will take about 5 billion more years for all the hydrogen to be used up. When the last of the hydrogen has been turned into helium, the Sun will start to enlarge. It will grow up to one hundred times its present size and be a thousand times brighter than it is now. Then it will be called a red giant star. The next stage is that the Sun's outer layers will start turning into a cloud of gas. This gas will slowly disappear and leave only the Sun's centre. The Sun will start to cool down, although this will take millions more years. Stars like this are called white dwarf stars. Finally the Sun will cool down completely and end its life as a cold, dark body called a black dwarf.

Studying the Sun

Our atmosphere makes it very difficult to study the Sun. This is because it filters out many of the Sun's rays. The best way to study the Sun is to send space probes and satellites into space.

The American space probe Ulysses was launched in 1990, and reached the Sun in 1994. It has been sending back information about the Sun's outer layers and solar winds (particles that pour out of the Sun at high speed) ever since. Ulysses was only expected to last for five years, but in 2009 it was still sending back information about the Sun. Unfortunately Ulysses' orbit is taking it further and further away from the Earth, and the information it is sending back is becoming less valuable. The American space probe SOHO (short for Solar and Heliospheric Observatory) has been studying the Sun since 1995, while in February 2010, the American Space Agency NASA launched the Solar Dynamics Laboratory (SDO). This spacecraft will study the inner workings of the Sun and take pictures of the Sun every 0.75 seconds and send them back to Earth.

Constellations

Stars appear in groups called constellations in the night sky. In ancient times people divided the bright stars they saw into constellations which were named after things they knew. Often the names were those of animals, or of heroes and heroines in their myths. They drew imaginary pictures around the constellations so they were easy to remember.

Forty-eight constellations had been named by the time of the famous Egyptian astronomer Ptolemy, who lived from AD85 to about AD165. More constellations were described later, as people produced new maps of the night sky. In 1930, astronomers decided to divide the whole sky into 88 areas. The old constellation names now refer to these eighty-eight areas, instead of the mythical figures. You can find a star by knowing which constellation it appears in. For example, knowing that Sirius is in Canis Major, or Betelgeuse is in Orion, helps you to find these stars more quickly.

The constellations you see depend on where you live on the Earth. If you live in Pakistan or somewhere else in the northern hemisphere, there are constellations you will never see unless you travel to the southern hemisphere.

You can observe that the Sun, Moon and planets seem to move through twelve constellations during the year. These twelve are called the constellations of the zodiac. Ancient people believed that these constellations were special. They developed astrology—the study of these bodies and their movements—in order to predict how they thought the constellations would affect human behaviour. Today this belt of constellations is still called the zodiac, but scientists say that there is no proof that astrology can be used to predict the future.

Some constellations can be seen on very clear nights all year round. They circle around the sky without ever sinking below the horizon. These are called circumpolar constellations. Look for them around Polaris, the North Star or Pole Star. As the Earth turns on its axis during the night, you can see these stars move anticlockwise around Polaris. Other constellations rise and set overnight and change with the seasons.

It is important to remember that although the stars in a constellation look as if they are close together, there are, in fact, immense distances between them.

Starlight

Every one of the stars you see in the night sky is, like our Sun, a violent spinning ball of hot, burning gases. Like our Sun, they produce their own light by nuclear fusion reactions in their centres. You cannot tell just by looking at the stars which ones are shining the most starlight into space. The Sun, for example, looks many times brighter than the other stars, but it is not. How bright a star looks depends not only on how much light it sends out, but also on how far away it is from the Earth. The Sun looks so very bright because it is hundreds of thousands of times closer to us than any other star.

These enormous distances prevent us seeing the stars up close, even with the most powerful telescopes. Fortunately we can learn about the stars by studying the starlight that comes to Earth. The light we see coming from a star is only a small part of the electromagnetic radiation coming from space. We cannot see the ultra-violet, X-rays, gamma rays, and infra-red rays. Each kind of star radiates a different mixture of visible and invisible light waves into space. The waves travel through space at the speed of light—almost 300,000 km per second. Sirius is the brightest and closest star that can be seen from mid-northern latitudes. It is almost nine light-years from the Earth. This means that if you could travel in a spacecraft at the speed of light, it would take you almost nine years to reach Sirius. At the same speed it would take only eight minutes to reach the Sun.

From red giants to white dwarfs, stars come in a variety of colours and a huge range of sizes. The colour of a star gives us some idea of its surface temperature. Blue or white stars are hot and they give off the most light; red stars are cooler and their surfaces shine dimly. Astronomers use special equipment to collect and separate the light from a star into a spectrum. This tells them such things as what the star is made of and how hot it is. Many stars give out more infrared light than visible light.

The end of a star's life

Smaller stars live much longer than large ones and, whether large or small, for most of their lifetime, stars shine without much change. When a star's fuel begins to run out, the star starts to enlarge until it becomes a giant or a supergiant. Stars that are less than one and a half times the Sun's mass then blow off their outer layers, leaving a tiny, cooling star called a white dwarf. Stripped bare of its outer layers, the star then collapses on itself and becomes extremely dense. A white dwarf star, although similar in size to the Earth, has as much mass as the whole Sun. A single teaspoon of it would weigh many tonnes.

If a very large star, with a mass more than eight times that of the Sun, dies, its core collapses so quickly that it explodes. The explosion is called a supernova. The core may remain as either a neutron star or a black hole. Neutron stars are much denser than white dwarfs. A neutron star weighs more than our Sun, even though all this mass is packed into a ball just 10 kilometres or so across. A black hole is denser than a neutron star. The gravity around it is so strong that not even light can escape. This makes it impossible to see a black hole. Astronomers look for black holes indirectly. A black hole may pull in matter from a nearby visible star, or gas disappearing over the edge of a black hole may send out a burst of X-rays that can be detected.

Practical matters

It is not easy to find investigations of the Sun and stars that can be carried out by younger students. Only two lessons are suggested here, although other lessons could be prompted by some new event in space exploration, such as the launch of a space shuttle, space probe, space telescope or manned spacecraft.

SAFETY: Never look at the Sun directly with your eyes, even with sunglasses, and do not look at it through binoculars or through a telescope. You could seriously damage your eyes or even become blind.

Lesson suggestions

1. The Sun

Refer to page 186 of the Students' Book

Starter suggestions

Ask the students to make a list of all the details they know about the Sun and sunlight. Collate their answers and make a list on the board for them to copy.

Demonstrate to the students the dangers of looking directly at the Sun with naked eyes or through an optical instrument. Use a magnifying glass and a piece of tissue paper. Ask the students to imagine that the piece of tissue paper is the delicate retina of the eye. Then use the magnifying glass (a convex lens like the lens in the eye) to focus the Sun's rays on the tissue paper until it begins to smoulder and burn.

Main lesson

With the aid of photographs, PowerPoint diagrams, or films or DVDs, describe to the students how large the Sun is, how it formed, what its fuel is, and how long it is expected to last. Emphasize the importance of the Sun in maintaining temperatures on Earth and in providing the energy for the process of photosynthesis.

Investigate sunlight with the aid of a prism or mirror, as described on page 194 of Chapter 11 of this book.

Carry out the activities to 'Measure the inclination or 'height' of the Sun', and the 'Surface temperatures and height of the 'Sun', described in the **Ideas for investigation and extension work** section of this chapter.

1. Stars and constellations

Refer to page 188 of the Students' Book

Starter suggestions

Ask the students what the fastest thing they know of is. How long would it take an aircraft to reach the Sun? Explain that light travels at 300,000 kilometres a second, and yet it takes the Sun's light just over eight minutes to reach Earth.

Discuss the difference between an astronomer and an astrologer.

How many stars can the students name?

Main lesson

Explain to the students that our local star (the Sun) and its Solar System are part of a galaxy called the Milky Way. We cannot count the stars in the Milky Way, but a rough estimate is 500 thousand million.

Scientists estimate that there are more than one hundred thousand million galaxies in the Universe.

Tell the students that the nearest star to our Sun is called Proxima Centauri. It was discovered in 1915 and is only visible with a telescope. Proxima Centauri star is usually only visible in the southern hemisphere. Distances in space are so large that it becomes impossible to use kilometres as a unit of distance. Instead, astronomers use light-years. A light-year is the distance light travels in a year.

Light from Proxima Centauri takes 4.22 years to reach us (at a speed of 300,000 km/s), so it is 4.22 light-years away. However, light from some stars takes over 12 billion light-years to reach us.

Go on to talk about constellations—a group of stars in the sky which form a fixed pattern in relation to each other, as viewed from Earth. Show the students photographs or diagrams of some of the major constellations visible in the night sky. If possible, take the students out in the evening to look at, and identify, some of the main constellations in the night sky, or visit one of the planetariums in Pakistan.

Finish the lesson by explaining the birth, life, and death of a star.

Ideas for investigation and extension work

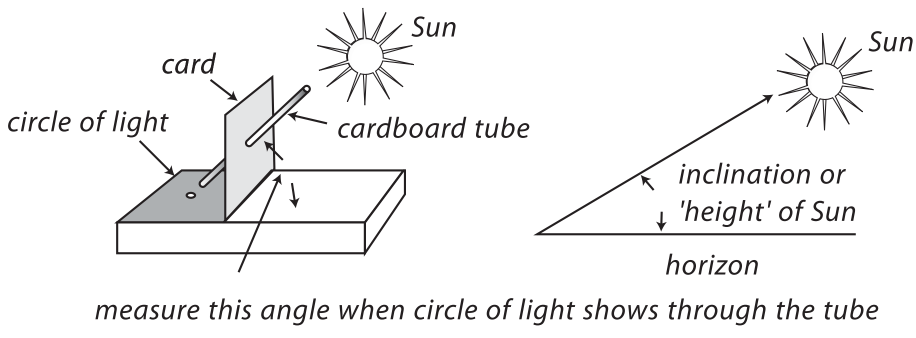
The International Space Station

The International Space Station (ISS) can be viewed from Earth if you know where to look. Since it has little or no light of its own, you can see it only when the ISS is in sunlight and it is dark on the ground where you are. The best viewing times are just before or after sunrise and sunset while the station is passing overhead. The ISS appears as a bright, fast-moving star. Normally you have only about two minutes to see it—four minutes at most. Telescopes are no help because of the speed at which the ISS is travelling. Binoculars may let you see some details of the station as long as you know exactly where to look with them, but most times naked eyes are best. Details of when the ISS and other spacecraft are passing over where you live can be found on the National Aeronautics and Space Administration's website at: www.spaceflight.nasa.gov/realdata/sightings .

Safety: Any observations of the daytime sky must avoid looking directly at the Sun. Under no circumstances should the Sun be viewed through binoculars or telescopes, or even using sunglasses, smoked glass or old photographic negatives.

Measure the inclination or 'height' of the Sun

Make the device shown in the diagram below to measure the 'height' of the Sun in the sky or the angle it forms with the horizon. The base is a rectangle of wood and the square of card is held in place by sticky tape.

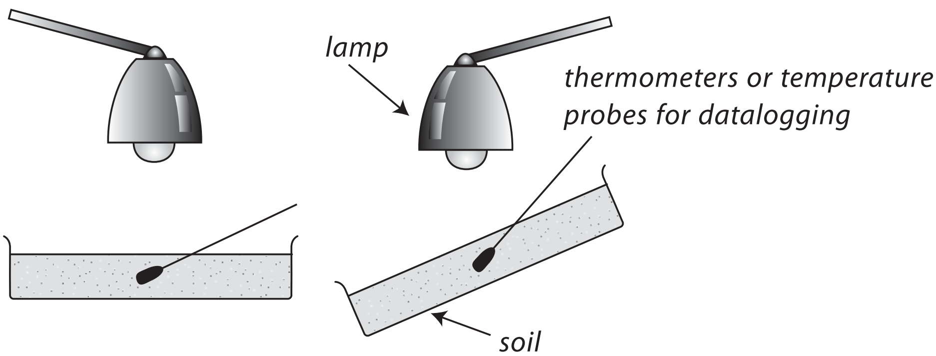


Relate the seasons and day length to the maximum 'height' of the Sun in the sky. Relate the time of maximum height of the Sun (or shortest shadow length) to the times of sunrise and sunset. Construct tables, charts, or graphs of results over a period of time.

Surface temperatures and the height of the Sun

Measure the outside temperatures over a period of several weeks or even months. Record these temperatures in tables, graphs or charts and relate them to day length and the height of the Sun. Relate the way in which plants and animals respond to the changing seasons.

Investigate the way in which soil is heated by a heat source (imitating the Sun) at varying angles. Set up the trays of soil at varying angles. Make sure it is a fair test by keeping other facts, such as the amount of soil and distance of the lamp from the soil, constant. Investigate how the angle of tilt affects the heating of the soil



Shine a torch beam on paper at different angles and draw around the pools of light produced. Relate the way the Sun's light is spread over a larger area when it is at a smaller angle to the heating effect.

Photographing the Pole Star

Study (and take) long exposure photographs of the Pole Star to show the rotation of the stars. Any photographs should be taken well away from street lights and other forms of light pollution. The shutter of the camera will need to be left open for several hours to obtain a useful photograph.

Centripetal force

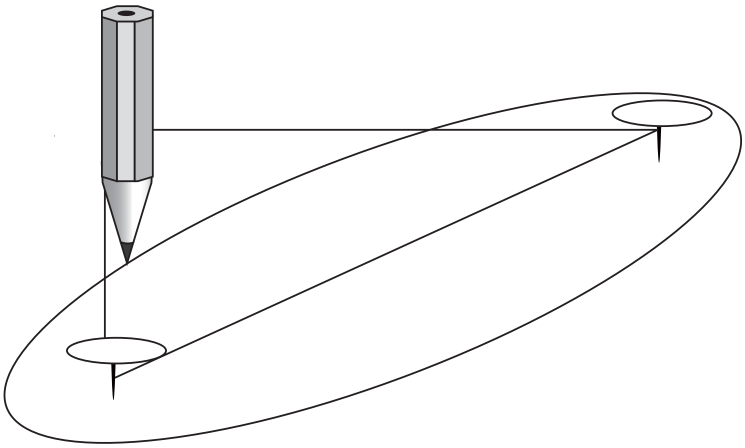
Natural and artificial satellites and all other heavenly bodies are attracted to one another by gravity. The bigger the bodies involved, the stronger the force of attraction. The closer the bodies involved, the stronger the force of attraction. Orbiting occurs when one body wants to go in one direction but is attracted by another body, such as a star or planet. This causes it to be continually pulled off course into a circular path or orbit. This force towards the centre is called the centripetal force.

Demonstrate the effect of centripetal force by putting a little water in a plastic bucket. Tie a strong string firmly to the handle, and then swing the bucket in a vertical circle. As long as the rate of rotation is great enough, the water stays in the bucket, held there by centripetal force.

Safety: This activity is best done outside away from buildings. Keep onlookers well clear!

Drawing an ellipse

The orbits of the Moon and planets are ellipses. Draw an ellipse as follows. Push two drawing pins through a sheet of drawing paper placed on a board. Loop some thin string between the two drawing pins. A pencil drawn around the perimeter of the loop will describe an ellipse.



A map of the night sky

Every month certain newspapers publish notes and maps of the night sky. Cut out one of these maps and mount it on a sheet of card. Hold the chart in front of you and make sure that 'North' on the chart is pointing towards the north. Use a compass if you are not sure which direction north is. Use the chart to help you identify the positions of the stars and planets.

Keep a 'Space Diary'

Keep a 'Space Diary'. In it place newspaper and magazine reports and photographs of important space discoveries as they occur. Write against each article and picture the date when it was published.

Website research

Visit the NASA website to find out more about such subjects as the International Space Station, the Space Shuttle, space probes, details of rockets and space suits used in space research, and information on future missions into space.

WORKSHEET 1

A journey into space

Materials needed: access to the NASA website (www.spaceflight.nasa.gov/mars) or reference books and encyclopedia.

Work with a group of friends. Imagine you are preparing for a mission to Mars. Discuss what preparations you would need to make including:

- The objectives of the mission. What scientific investigations will you carry out, what instruments and equipment will you need, what data will you collect?
- Research how long the journey to Mars will take, what the physical conditions on Mars are like, how long the mission will take.
- Details of the launch rocket, including its fuel, landing craft, and arrangements for the return journey to Earth.
- What dangers, such as harmful radiation, will the members of the mission be exposed to? How will they cope with zero gravity and the inability to speak to each other without the use of a radio? How will any illness amongst the members be dealt with?
- What kind of space suit will the members of the mission need?
- What will the members of the mission need on the journey, in terms of food, water, oxygen supplies and medical supplies?
- How will bodily waste and litter be dealt with?

Divide different aspects of the mission amongst the members of your group. These could include:

- Making a model of the launch rocket and any vehicles to be used on the surface of Mars.
- Design and make a model of the space suit.
- Produce a chart detailing the physical conditions on Mars.
- Design experiments to be carried out on the surface of Mars.
- Produce lists of the equipment and supplies needed during the mission.

Answers to questions in the Students' Book

1. A light-year is the distance travelled by light in one year. Astronomers use light-years rather than kilometres as units of distance, because the distances in space are so vast.
2. A galaxy is a giant collection of many millions of stars.
3. The galaxy to which our Sun belongs is called the Milky Way.
4. The light and high temperatures on the Sun and other stars are produced by the process of nuclear fusion.
5. Sunspots are areas of the Sun's surface where the temperature is lower. Scientists have discovered that sunspots are not always in the same place and that every eleven years there are more sunspots than usual. By observing sunspots, scientists have discovered that different parts of the Sun take different lengths of time to rotate.
6. Some of the stars we see in the night sky may no longer exist because they are so far away and it takes thousands, or even millions, of years for their light to reach us.
7. A constellation is a group of stars in the sky which form a fixed shape or pattern in relation to each other, as viewed from Earth.
8. The constellations you see in the night sky depend on where you live on the Earth. If you live in Pakistan or somewhere else in the northern hemisphere, there are some constellations you will never see unless you travel to the southern hemisphere.
9. A space probe is an unmanned spacecraft that leaves the gravity of Earth to carry out scientific exploration of the Moon, a planet, or some other body in space. Famous space probes include Mars Exploration Rover, Viking 1 and Viking 2, Voyager 1 and Voyager 2, and Pioneer 1 and Pioneer 2.
10. We should not look directly at the Sun because the lens in each eye focuses the Sun's rays on the retina of the eye, and this could damage the retina permanently.
11. The constellations we can see on clear nights all the year round are the circumpolar constellations, which occur around Polaris, the North Star or Pole Star.
12. All of the world's really large telescopes that are used for studying space use mirrors rather than lenses—they are refracting telescopes. This is because it is easier (and cheaper) to make really large mirrors than it is to make large lenses.
13. If light travels at 300,000 km in a second, it travels 300,000 x 60 x 60 km = 1080 billion km in an hour. Light also travels 300,000 x 60 x 60 x 24 x 365 = approx 9.5 trillion km in a year.
14. The 'Big Bang' theory says that about 15 billion years ago, all the matter in the Universe was packed together tightly into a small mass that was extremely hot and dense. There was a gigantic explosion and bits of matter, heat waves, and light shot out into space. About one billion years after the Big Bang, huge gas clouds started to move together under the action of gravity. Eventually these formed the first star and then, much later, the Sun and Solar System. A big piece of evidence for the Big Bang theory is that our Universe is still spreading out.

15. Radio telescopes are huge bowl-shaped dishes, or groups of smaller dishes, which collect radio waves from distant galaxies. The radio waves are changed into electrical signals that can be used to make radio images or pictures of these distant galaxies.

Assessment

Question 1

What forces hold the Solar System together?

(A) frictional (B) electrical (C) magnetic (D) gravitational

Question 2

We can see stars like the Sun because they:

(A) are not far away (B) reflect light (C) emit light (D) are big

Question 3

Ninety-nine per cent of the mass of our Solar System is contained in:

(A) the planets (B) the Sun (C) the asteroid belt (D) The moons of the planets

Question 4

What shape is an elliptical orbit?

(A) a slightly squashed circle (B) circular

(C) one that goes clockwise (D) one that is larger than the Sun

Question 5

Telescopes which use lenses to study the stars are called:

(A) reflective (B) refractive (C) refluxive (D) refectory

Question 6

On a clear night, roughly how many stars can we see in the sky?

(A) 1000 (B) 2000 (C) 4000 (D) 8000

Question 7

A galaxy is a giant collection of many millions of:

(A) meteors (B) planets (C) stars (D) comets

Question 8

The galaxy to which our Sun belongs is called the:

(A) Milky Way (B) Solar System (C) Milky Bar (D) Universe

Question 9

The light and high temperatures on the Sun and other stars are produced by the process of:

(A) combustion (B) confusion (C) molecular reaction (D) nuclear fusion

Question 10
The temperature on the surface of the Sun is about:

(A) 1500°C (B) 3000°C (C) 5500°C (D) 7500°C

Question 11
The Sun's fuel is:

(A) oxygen (B) hydrogen (C) nitrogen (D) helium

Question 12
A star the size of our Sun will eventually expand to form a:

(A) black hole (B) neutron star (C) red giant (D) supernova

Question 13
Stars larger than our Sun become red supergiants, which collapse and explode as spectacular:

(A) black holes (B) neutron stars (C) red giants (D) supernovas

Question 14
After a large star has collapsed and exploded, the core remains as an extremely dense:

(A) black hole (B) neutron star (C) red giant (D) supernova

Question 15
Scientists believe that the Universe began with a huge explosion called the:

(A) black hole (B) nebula (C) supernova (D) big bang

Question 16
An unmanned spacecraft that leaves the gravity of Earth to carry out scientific exploration of the Moon, a planet, or some other body in space is called a:

(A) satellite (B) space probe (C) space shuttle (D) space explorer

Question 17
Distances in space are measured in:

(A) kilometres (B) radio waves (C) light waves (D) light years

Question 18
Match each key word with its meaning.

Big Bang	The gravity of this is so strong that not even light can escape.
black hole	the fuel of a star
helium	A massive star dies in a big explosion known as this.
hydrogen	how scientists believe the Universe began
nebula	A star that has run out of fuel becomes this.
neutron star	the hot, dense core of a dying star

red giant	the dense core of a star left after a super nova
supernova	a cloud of dust and gas
white dwarf	the product of a nuclear reaction inside a burning star

Question 19

Complete the sentences below using the words from the box. You may need to use some words more than once.

hole	red	light	temperature	nuclear	explode
energy	core	white	gravity	helium	gravity

Inside a star, the force of ________________ pulls gases together until the ________________ and pressure are so great in the core that ________________ reactions occur. Vast amounts of ________________ are released as the star changes hydrogen into ________________. When a star's ________________ has used up all the available hydrogen, the star's outer layer cools to a huge red ball called a ________________ giant. Eventually the outer layer drifts away, leaving a hot, dense core called a ________________ dwarf. Much later, this will also fade away as the star dies. Some stars are massive and instead of becoming a red giant, they ________________. This is known as a super nova. If an even larger star explodes, the ________________ can be so strong that a black ________________ is formed and not even ________________ can escape.

Question 20

a) The Mars Pathfinder spacecraft was launched on 4th December 1996 on board a Delta II rocket. After a seven-month voyage, a lander from it touched down on the surface of Mars, aided by a parachute, rockets and air-bags. Once the lander had reached Mars, it opened and a robotic vehicle moved out to carry out experiments on the rocks and soils on Mars. The lander itself contained a stereoscopic camera and instruments to measure the air pressure, temperature and wind speeds on Mars. A great deal of valuable information about Mars was collected, including rocks which appeared to have been deposited by a flood and others which had been shaped by the wind. The average temperature on Mars was -63°C, with a maximum of 20°C and a minimum of –140°C. The air pressure was very low.

i) Suggest why the surface temperatures on Mars are much lower than those on Earth.

____

____

ii) Why do you think there is such a big temperature range on Mars?

____

____

iii) The lander used parachutes for much of its descent, but had to fire rocket engines for its final stage. Explain this.

____

____

iv) Why do you think the lander was surrounded by air-bags as it touched down?

____

____

b) The first Space Shuttle was launched in April 1981. It was the world's first reusable spacecraft. Since then, there have been 129 more Space Shuttle missions, with four more planned.

i) Give ONE advantage that the Space Shuttle has over a rocket such as the one that launched the Mars Pathfinder spacecraft.

____

____

ii) What fuel does the Space Shuttle use? ____________________

iii) Why is the Space Shuttle covered in heat-resistant tiles?

____

____

iv) Suggest TWO uses for the Space Shuttle.

____

____

Answers to assessment questions

Question 1 (D) **Question 2** (C) **Question 3** (B) **Question 4** (A) **Question 5** (B)

Question 6 (B) **Question 7** (C) **Question 8** (A) **Question 9** (D) **Question 10** (C)

Question 11 (B) **Question 12** (C) **Question 13** (A) **Question 14** (D) **Question 15** (D)

Question 16 (B) **Question 17** (D)

Question 18

Big Bang	how scientists believe the Universe began
black hole	The gravity of this is so strong that not even light can escape.
helium	the product of a nuclear reaction inside a burning star
hydrogen	the fuel of a star
nebula	a cloud of dust and gas
neutron star	the dense core of a star left after a super nova
red giant	A star that has run out of fuel becomes this.
supernova	A massive star dies in a big explosion known as this.
white dwarf	the hot, dense core of a dying star

Question 19

hole	red	light	temperature	nuclear	explode
energy	core	white	gravity	helium	gravity

Inside a star, the force of **gravity** pulls gases together until the **temperature** and pressure are so great in the core that **nuclear** reactions occur. Vast amounts of **energy** are released as the star changes hydrogen into **helium**. When a star's **core** has used up all the available **hydrogen**, the star's outer layer cools to huge red ball called a **red** giant. Eventually the outer layer drifts away, leaving a hot, dense core called a **white** dwarf. Much later, this will also fade away as the star dies. Some stars are massive and instead of becoming a red giant, they **explode**. This is known as a super nova. If an even larger star explodes, the **gravity** can be so strong that a black **hole** is formed and not even **light** can escape.

Question 20

a) i) The surface temperatures on Mars are much lower than those on Earth because Mars is further from the Sun and so less heat reaches the planet.

ii) There is such a big temperature range on Mars because it has little atmosphere.

iii) The lander used parachutes for much of its descent, but had to fire rocket engines for its final stage. This is because although Mars has an atmosphere, it is not dense enough to slow down the lander sufficiently for it to make a safe landing.

iv) The lander was surrounded by air-bags as it touched down to protect the delicate instruments it contained.

b) i) The big advantage that the Space Shuttle has over a rocket such as the one that launched the Mars Pathfinder spacecraft is that it can be used over and over again, so saving money.

ii) The Space Shuttle's fuel is liquid hydrogen.

iii) The Space Shuttle is covered in heat-resistant tiles to withstand the heat generated by friction as the craft re-enters the Earth's atmosphere.

iv) Uses for the Space Shuttle include launching and retrieving satellites, launching spacecraft into outer space, studying the weather, carrying out experiments, transporting crew or spare parts to space stations, etc.