MYP *by Concept*
1

Sciences

Paul Morris
Patricia Deo

DYNAMIC LEARNING

HODDER EDUCATION

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1

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Series editor: Paul Morris

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AN HACHETTE UK COMPANY

Dedication

Paul Morris dedicates this book to Peter.

Patricia Deo – For my parents – thank you for all that you have done, and continue to do, for me.

Author acknowledgements

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Contents

How to use this book

Each chapter is framed with a *Key concept* and a *Related concept* and is set in a *Global context*.

Welcome to Hodder Education's *MYP by Concept* series! Each chapter is designed to lead you through an *inquiry* into the concepts of science, and how they interact in real-life global contexts.

The *Statement of Inquiry* provides the framework for this inquiry, and the *Inquiry questions* then lead us through the exploration as they are developed through each chapter.

KEY WORDS

Key words are included to give you access to vocabulary for the topic. Glossary terms are highlighted and, where applicable, search terms are given to encourage independent learning and research skills.

As you explore, activities suggest ways to learn through *action*.

ATL

Activities are designed to develop your *Approaches to Learning* (ATL) skills.

EXTENSION

Extension activities allow you to explore a topic further.

Assessment opportunities in this chapter:

Some activities are *formative* as they allow you to practise certain parts of the MYP Sciences *Assessment Criteria*. Other activities can be used by you or your teachers to assess your achievement *summatively* against all parts of a learning objective.

Key *Approaches to Learning* skills for MYP Sciences are highlighted whenever we encounter them.

Hint

In some of the activities, we provide hints to help you work on the assignment. This also introduces you to the new Hint feature in the on-screen assessment.

Information boxes are included to give background information, more detail and explanation.


At the end of this chapter, we will be carrying out tests on eggs to find out what makes them strong, look at naturally-occuring examples of egg-carriers, and suggest how to design a super-rugged egg-carrier.

In your MYP Sciences course you will explore not only what scientists have contributed to our understanding of the natural world, but also how they gained that knowledge. You will have the opportunity to make your own scientific questions and then to carry out your own scientific inquiry to find the answers to them. You will learn how to work collaboratively to achieve your aims as well as how to think independently.

To be a scientist is to be a world-changer!

These Approaches to Learning (ATL) skills will be useful …

- Critical-thinking skills
- Creative-thinking skills
- Collaboration skills
- Media and information literacy skills

1 What do scientists do? 3

● We will reflect on this learner profile attribute …

Each chapter has an *IB learner profile* attribute as its theme, and you are encouraged to reflect on these too.

Finally, at the end of the chapter you are asked to reflect back on what you have learnt with our *Reflection table* and maybe to think of new questions brought to light by your learning.

Use this table to evaluate and reflect on your own learning in this chapter.

Questions we asked	Answers we found	Any further questions now?			
Factual					
Conceptual					
Debatable					
Approaches to learning you used in this chapter	Description – what new skills did you learn?	How well did you master the skills?			
		Novice	Learner	Practitioner	Expert
Learner profile attribute(s)	Reflect on the importance of the attribute for your learning in this chapter.				

You are prompted to consider your conceptual understanding in a variety of activities throughout each chapter.

We have incorporated Visible Thinking – ideas, framework, protocol and thinking routines – from Project Zero at the Harvard Graduate School of Education into many of our activities.

! Take action

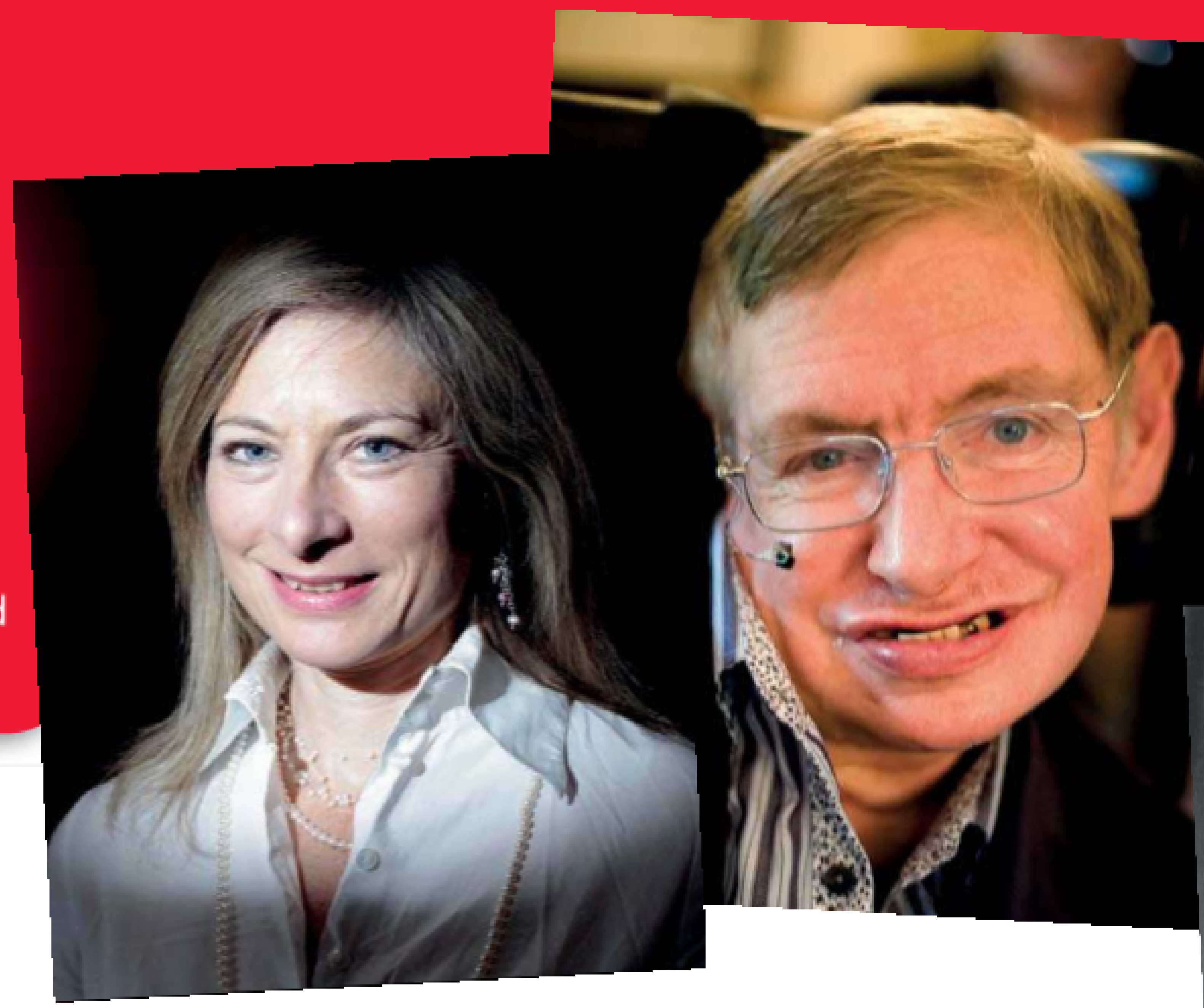
! Guidance is given throughout the book about how to apply your knowledge of the scientific process to real-life situations. While the book provides many opportunities to apply the knowledge you have learnt in practical ways, you must be an active part in this process. Activities help you explain the ways in which science can be applied and used, and also to discuss and evaluate the implications of using scientific principles to address specific issues. This should give you a better understanding of the issues facing scientists in the twenty-first century. By engaging in these activities, you will also learn the value of consistently applying scientific language to communicate understanding clearly and precisely.

▼ Links to:

Like any other subject, Sciences is just one part of our bigger picture of the world. Links to other subjects are discussed.

1 What do scientists do?

To be a scientist means to gather **evidence** about **similarity and difference** in nature to understand how things are **related**.



■ **Figure 1.1** clockwise from top left: Harvard theoretical physicist Lisa Randall (1962–), cosmologist Stephen Hawking (1942–), botanist George Washington Carver (1860–1943), astronomer Jocelyn Bell Burnell (1943–), physicist Chandrasekhara Venkata Raman (1888–1970), crystallographer Rosalind Franklin (1920–1958)

CONSIDER THESE QUESTIONS:

Factual: How do scientists behave? How is a laboratory different? What is an experiment?

Conceptual: How are scientific theories made?

Debatable: Can science tell us everything we need to know?

Now **share and compare** your thoughts and ideas with your partner, or with the whole class.

IN THIS CHAPTER WE WILL …

- **Find out** what scientists do, the way they ask questions, and how we can start to be scientists.
- **Explore** the working environment of scientists.
- **Take action** to help others think scientifically about media information.

KEY WORDS

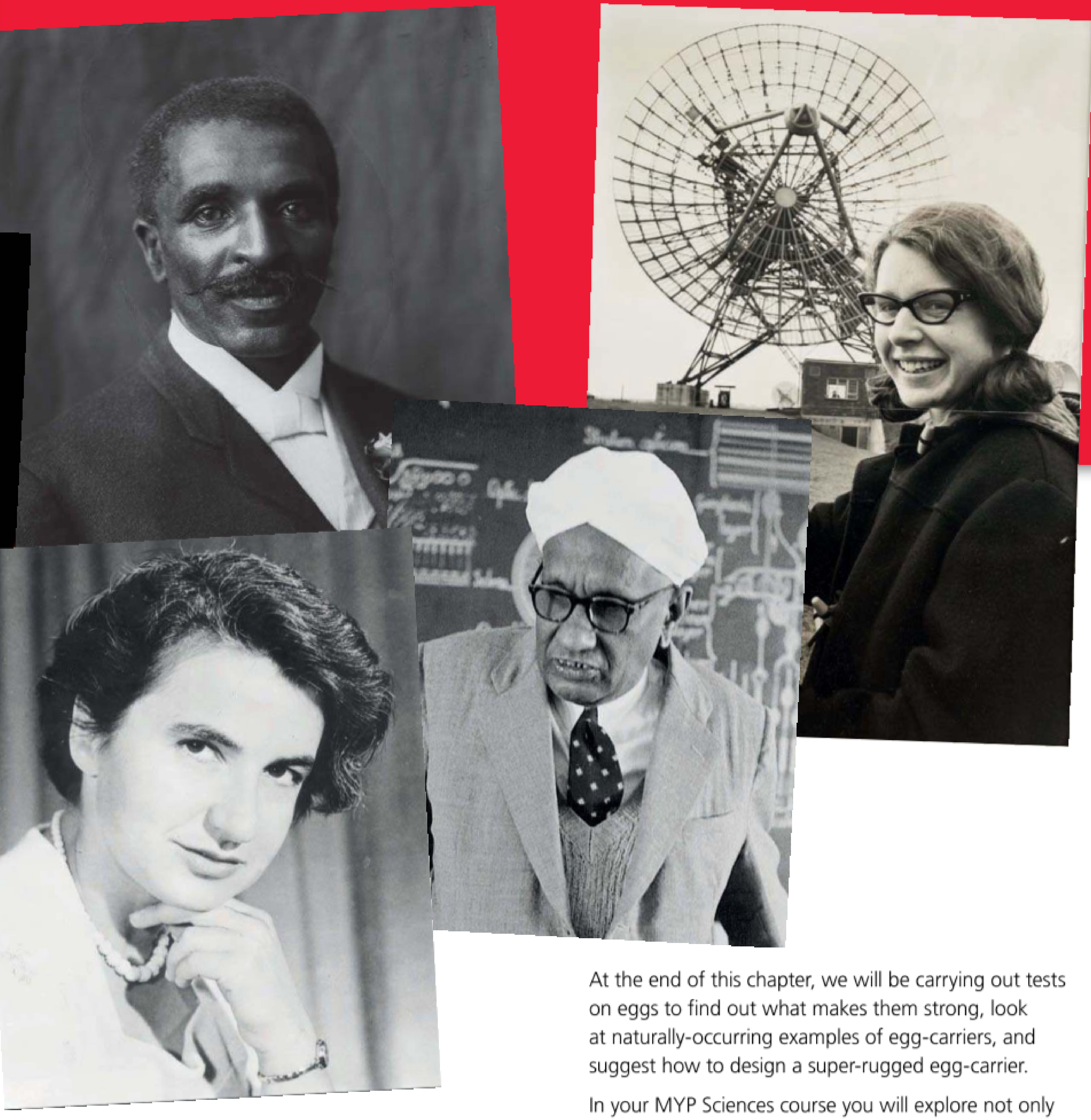
apparatus
control
experiment
laboratory
prediction

We will reflect on this learner profile attribute …

- Inquirers – we will be inquiring into the work of scientists and formulating our own questions for scientific inquiry.

Assessment opportunities in this chapter:

- **Criterion B:** Inquiring and designing
- **Criterion C:** Processing and evaluating



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To be a scientist is to be a world-changer!

These Approaches to Learning (ATL) skills will be useful …

- Critical-thinking skills
- Creative-thinking skills
- Collaboration skills
- Media and information literacy skills

How do scientists behave?

■ **Figure 1.2** From the moment we are born we begin to inquire about the natural world around us

ACTIVITY: What do scientists look like?

ATL

- Media literacy skills: Demonstrate awareness of media interpretation of ideas

Individually, using a small piece of card, or a miniature whiteboard, draw a picture of what a scientist looks like.

As a class, hold up your pictures so that everybody can see them.

Identify any similarities between the pictures you have drawn.

Discuss and then **summarize:** what does your class think a scientist looks like?

Look at the photographs in Figure 1.1 on pages 2–3 and read the caption underneath. All of these people are scientists. How many of your class pictures looked like them?

Of course, anyone can be a scientist – but first, you need to know how to do science.

ASK THE QUESTION!

The first step in being a scientist is sometimes the hardest: asking the right question! Scientists have to think **analytically**, be **rational** and **methodical**, but they also have to be creative and imaginative in knowing what questions to ask. The inquiry often begins with a simple **observation** of something in nature.

ACTIVITY: Scientists like me

ATL

- Information literacy skills: Access information to be informed and inform others

- Individually, research and identify a scientist who is like you in some way. Perhaps they are from your home country, or they speak the same language as you.
- Find out what their work was about. What kind of science did they do? Did they win any prizes? How did they start out as a scientist? Where did they study?
- **Present** your research in one of the following ways:
  - a monologue 'in character' – pretending to be the scientist!
  - a poster card that could form part of a mosaic wall of scientists made by the whole class
  - an interactive online 'guide' summarizing all the research from your class.
- Reflect on your research. As a class or in pairs, **discuss** and compare the lives of the scientists you researched. What did they have in common? What made them scientists? **Summarize** your discussion using this starter: 'To be a scientist, one should be …'.

ACTIVITY: What's the question?

ATL

- Critical-thinking skills: Formulate questions

While scientific inquiry may begin with wonder, scientific questions need to be a little more focussed than speculation. As scientists, we have to make questions that can be tested in some way such that we can find an answer or explanation for what we observe. Often a problem in nature will turn out to be much more complicated than it seems at first, and we will only be able to answer a big question by first identifying a number of smaller questions and finding the answers to those.

SEE–THINK–WONDER

To help us to think creatively and make up questions, we can use techniques like 'See–Think–Wonder'.

Individually, watch these videos. BUT the first time, watch with the volume MUTED (turned down).

www.youtube.com/watch?v=BleCJJAKkgw

www.youtube.com/watch?v=XJSZsgTaRAQ

www.telegraph.co.uk/news/science/space/10899919/Hubble-captures-star-explosion-over-four-years.html

www.youtube.com/watch?v=7MLWHGRnqfI

For each video, make notes using these guiding questions:

- **What do you see?**
- **What do you think?**
- **What does it make you wonder?**

Now watch the videos again with the volume on so that you can hear the science behind the weirdness!

ACTIVITY: Big and small questions – super foods!

ATL

- Critical-thinking skills: Formulate questions

As the saying in English goes, 'you are what you eat'. The media are often full of stories about diet and what are the best foods. Find out about some of these claims using the search term: super foods.

If we want to test the claims in the media scientifically, we need to ask the right questions.

Individually or in pairs, look at the list of questions in the box. The questions are mixed up randomly.

Organize them into a list showing the order from the 'biggest' question to the 'smallest' – from the most general, to the most specific.

Hint

If you think some questions are equally important, put them on the same line in your list.

What does our body need to work?

How much energy do different foods contain?

Which is the best food to eat?

How much mineral content do different foods have?

What kinds of food are there?

How much protein do different foods contain?

Now use the search term: super foods NHS choices and read one or two of the articles on the site.

Discuss: How scientific are the claims made for super foods? Are they valid?

Outline what is meant by a 'super food' in your own words. **Summarize** the evidence you found for the existence of super foods.

WHAT IS AN EXPERIMENT?

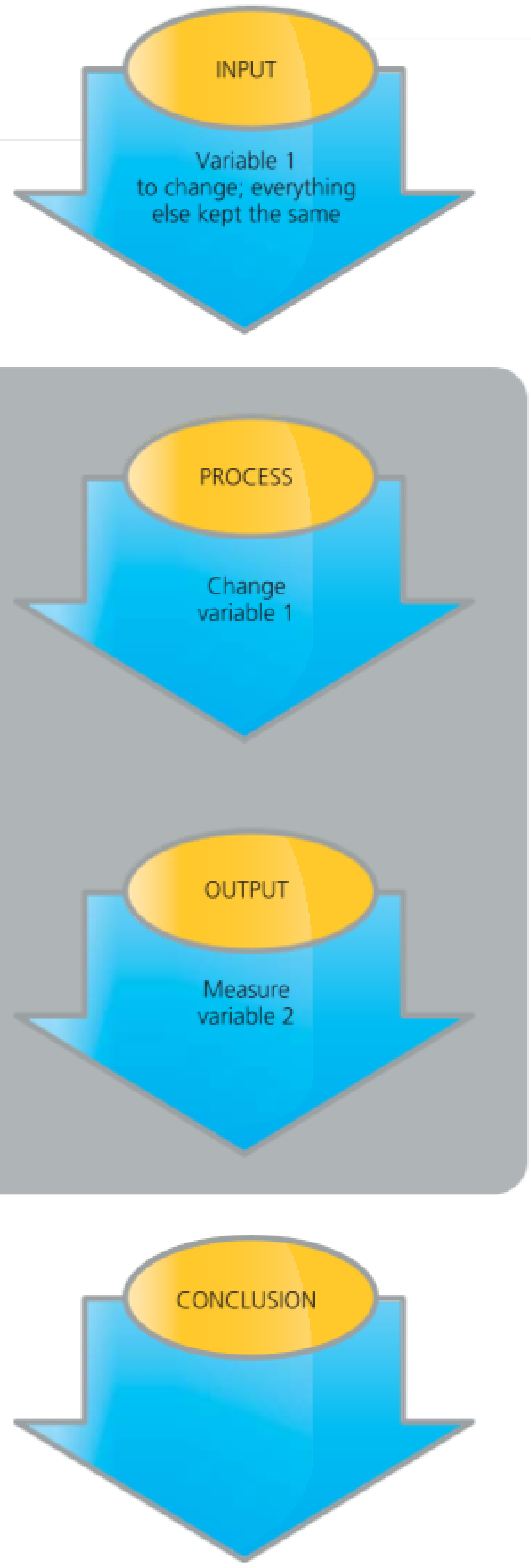
Once we have identified some suitably small, focussed questions we can then begin to figure out how to find the answers to them. Scientists do this in many ways, but one of the most important ways is by carrying out an **experiment**.

We can think of an experiment as a process where we control certain things, and find out what effect is caused by changing them. Anything that can be changed in an experiment is called a **variable**.

The variable to change in the experiment is called the **independent variable**, because it doesn't – or shouldn't – depend on anything else.

The variable to measure in the experiment is called the **dependent variable**, because we think it will depend on the thing we are changing.

The other variables – things which may affect the dependent variable, but that we do not want to test, are said to be **controlled variables**. By controlling these variables we make sure that our experiment really is showing us the effect we want to find – that it will be a valid experiment.



■ **Figure 1.3** Experiment machine

ACTIVITY: What's changing?

ATL

- Critical-thinking skills: Organize relevant information to formulate an argument

Table 1.1 shows some experiments that some MYP 1 scientists want to carry out. It also gives some variables that they have 'brainstormed' together for each experiment.

Individually or in pairs, help out the MYP 1 scientists by **organizing** the variables into the different columns as dependent, independent, or controlled.

Watch out! In each experiment, the MYP 1 scientists have identified one variable which is not really important to the experiment. **Identify** the 'irrelevant' variable in each case.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion B: Inquiring and designing.

Inquiry question	Variables	Independent (to change)	Dependent (to measure)	Controlled (to keep the same, for a valid experiment)
Which material for the sole of a shoe squashes the most?	Material Thickness Weight (mass) of person Colour of shoe			
Which method keeps food fresh the longest?	Kind of food Amount of salt Cost of food Temperature of room Time to go rotten			
How does exercise affect our bodies?	Number of stairs climbed Pulse (heartbeat) rate Weight (mass) of person Time taken to climb stairs Hairstyle of person Sex (male or female) of person Age of person			

Table 1.1

ACTIVITY: Choosing the right question

■ ATL

■ Critical-thinking skills: Organize relevant information to formulate an argument

Go back to the questions about 'super foods' in the activity *Big and small questions – super foods!*, on page 5.

In pairs, compare your lists of questions and the order you chose for them. Did you agree? If not, why not?

Thinking about what you have learnt about writing experimental inquiry questions, now **select** the questions from the list that you think would be best to use for an experimental inquiry.

Outline why you choose these questions, and not the others.

◆ Assessment opportunities

◆ In this activity you have practised skills that are assessed using Criterion B: Inquiring and designing.

Asking the right question

In the experiment, the first thing we did was select our variables and figure out which variables we were going to change, and which we were going to measure.

To do this, we had to have an idea what problem we were trying to solve. This is why the first stage in the scientific investigation cycle is to write an 'inquiry question' for the experiment. A good inquiry question should include the variables that you are going to control, for example:

How does variable 1 affect variable 2?

or

What is the relationship between variable 1 and variable 2?

How is a laboratory different?

IN THE LABORATORY

Scientists carry out their experiments in a special environment: the laboratory. A laboratory is a specially equipped room where all the equipment and **apparatus** the scientists require is available. It is kept very clean and tidy, so as to ensure that nothing can affect the experiments carried out other than the intended independent variable.

School laboratories are different to regular classrooms, and the way we behave in them has to be different too.

Sometimes we will be carrying out experiments using materials or techniques that could be dangerous, if we do not use them in the correct way. This is why it is essential that before beginning any laboratory experiment:

- you listen to instructions carefully
- you familiarize yourself with the equipment before you begin
- you keep workspaces clean and tidy.

When conducting experiments, it is important that we operate in a clean and tidy environment. It is also important to consider the effect of our actions on the environment – both inside the laboratory and outside.

We should consider the way we dispose of waste materials, especially if we are using chemicals or other 'special' materials – remembering though that in a laboratory, everything we use is scientific apparatus, even if it is something we might consider quite usual at home. This is why we never put anything in our mouths during experiments, and we must clean any apparatus and surfaces, and wash our hands after we have finished.

ACTIVITY: The scientist's environment

ATL

- Critical-thinking skills: Practise observing carefully in order to recognize problems

Individually or in pairs, carry out a survey of everything in your school laboratory that seems different to the classrooms you use for other MYP subjects. Your teacher may help out by labelling the items in the laboratory. Copy and complete Table 1.2 to **summarize** your findings.

Item that is different to a regular classroom	Scientific name	What it does

Table 1.2

Figure 1.4 A laboratory is a controlled environment

■ **Figure 1.5** Some chemicals have labels like this to show that they may be harmful

ACTIVITY: Making up the rules

■ ATL

■ Collaboration skills: Take responsibility for one's own actions

Every laboratory needs a 'code' to make sure that all experiments are carried out safely and scientifically.

In pairs, **discuss**, copy and complete Table 1.3 by **explaining** why it is important to take the safety measures listed in the first column.

Safety measure	Reason
Keep bags, coats and books in a safe place, out of the way	
Wear protective clothing and safety glasses when instructed	
Walk, do not run	
Do not put anything in your mouth	
Do not listen to music while working	
Wash hands carefully after using chemicals or organic substances	
Tie back long hair	

■ **Table 1.3**

As a class, brainstorm any other safety measures that you think might be important in the laboratory.

When you have finished:

- **design and make a safety poster illustrating any of the safety measures so that other MYP 1 students will understand**
- **design and make a 'safety checklist' to use before you begin any experiment.**

Another useful preparation is to write an **environment impact evaluation** of our experiment, where we consider the effect of our experiment on the living and non-living environment.

ACTIVITY: Thinking about environmental impact

ATL

- Collaboration skills: Take responsibility for one's own actions

In pairs, brainstorm as many ways as possible that a scientific experiment might affect the environment – both in the laboratory and outside it.

Share your ideas with the class and collect all the class ideas together.

Discuss what action you should take to minimize the impact of each of the environmental impact factors you have identified.

Organize the impact factors and the actions in the form of an easy-to-use checklist similar to the one you designed in the activity *Making up the rules*.

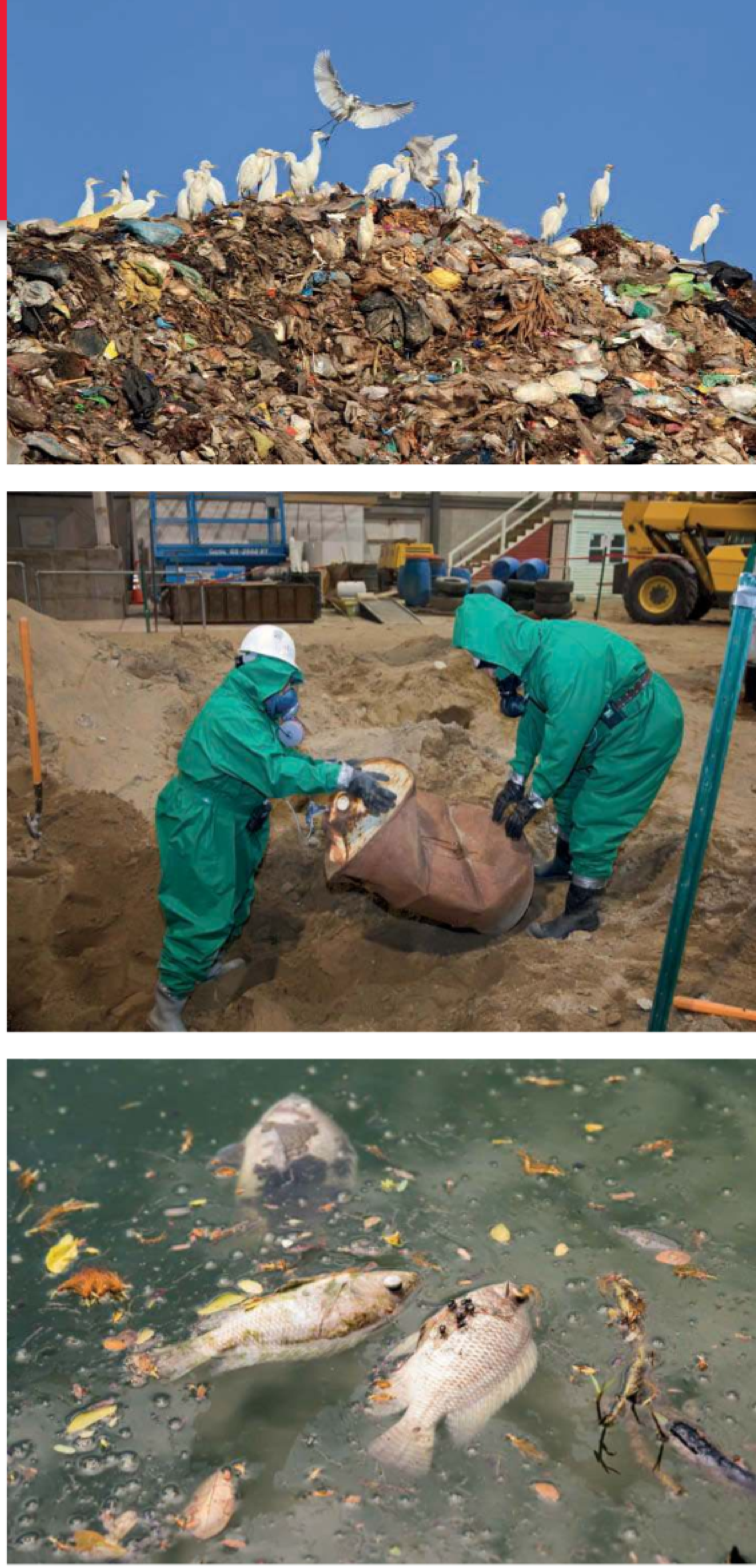


Figure 1.6 Think about your environmental impact

ACTIVITY: How strong is an egg?

ATL

- Creative-thinking skills: Use brainstorming to generate new ideas and inquiries
- Critical-thinking skills: Evaluate evidence and arguments

Figure 1.7 Eggs in the wild

After all this preparation, now we are ready to try an experiment! Eggs are fragile, right? This is why they have to be kept in a strong container like an egg box. In fact, bird and reptile eggs are adapted perfectly to survive in nature and they are stronger than you think.

In this task, your role is to work as a consultant for a food packaging company and your goal is to find out the best way to carry an egg safely. You must make recommendations to the engineers who are going to design the boxes used to carry the eggs safely! The company wants to collect free range eggs from farmers in rural places without access to good roads, so that they can be delivered safely. The product of your experiment will be a report for the engineers that gives them detailed scientific information about the best kind of carrier for eggs.

As a class:

> **Hint**
> *What shape is an egg? Is it equally strong whichever way up it is?*

1. **Brainstorm all the ways that the strength of an egg could be tested.**
2. **Now brainstorm all the variables you might need to consider when testing your egg.**
3. **Select the variables that you will investigate in your experiment.**
4. **Write your experiment aim in the form of a scientific inquiry question.**
5. **Categorize your variables as independent, dependent, or controlled.**
6. **Now make a prediction about how the independent variable in your experiment will affect the dependent variable. Apply what you know about strong shapes, collisions and forces to give an explanation with scientific reasoning.**

Now you will need to **design** your experiment before you carry it out. The scientific investigation cycle in Figure 1.8 is designed to guide you through the stages in carrying out your experiment.

> **SAFETY:** Use your safety checklist to check that you are ready to inquire scientifically and safely! Carry out an environment impact evaluation using your checklist.

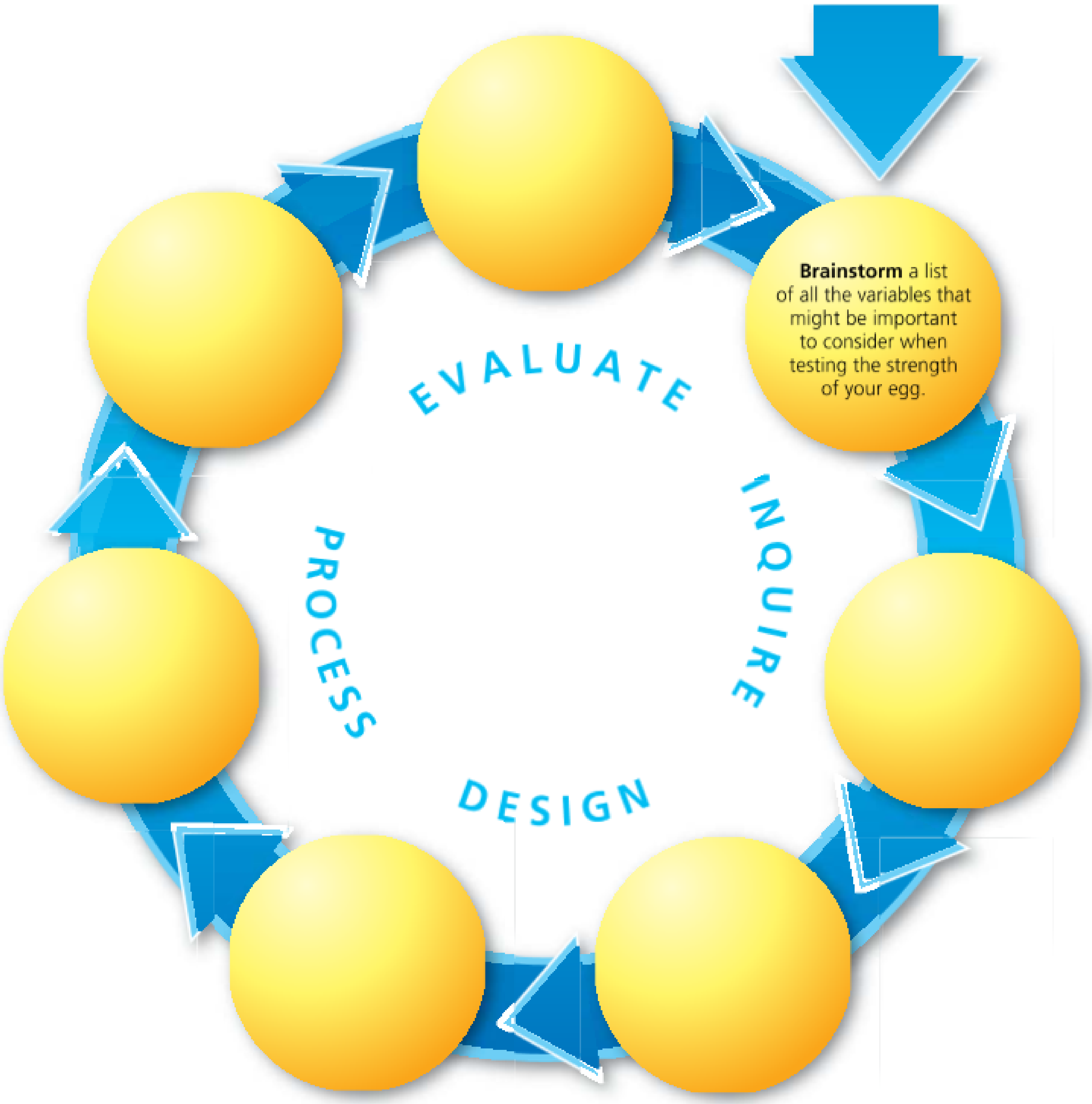
Before you begin, make sure that your teacher checks your design for safety.

Make note of any measurements or observations you take. **Organize** your measurements or observations in a way that makes them easy to **interpret**, for example in a table.

When you have finished taking measurements, **summarize** your experimental conclusions in the form of a report for the engineers who are going to design the egg-carrier. What did your measurements tell you about the strength of the egg?

State whether your prediction was correct and **discuss** why this was, referring to your results.

Evaluate your experiment. How well did it work? Was it valid – did it answer the inquiry question you wrote? How could it have been improved? **Describe** the validity of your experiment and **describe** any improvements you think you could have made.



■ **Figure 1.8** Scientific investigation cycle for the egg experiment

Now **research** how eggs are kept safe in nature using an image search with the search term: **nests**.

Compare and **analyse** the images – consider these questions:

- **What do the nests have in common?**
- **How are some of them different?**
- **What shapes are they?**
- **What materials are they made from?**
- **How might your design be different?**

In your final report to the engineers, **suggest** what the egg-carrier should look like, and **apply** your results and conclusions to show how it should be designed.

◆ Assessment opportunities

- This activity can be assessed using Criterion B: Inquiring and designing and Criterion C: Processing and evaluating.

Doing science is inquiry

In the egg experiment, we carried out our inquiry in different stages. We will return to these stages in more detail and depth throughout this book and others.

The MYP Sciences Inquiry Cycle helps us to structure our inquiry so that we always carry out scientifically valid experiments that enable us not only to **describe** but also to **explain** the science behind the questions we have.

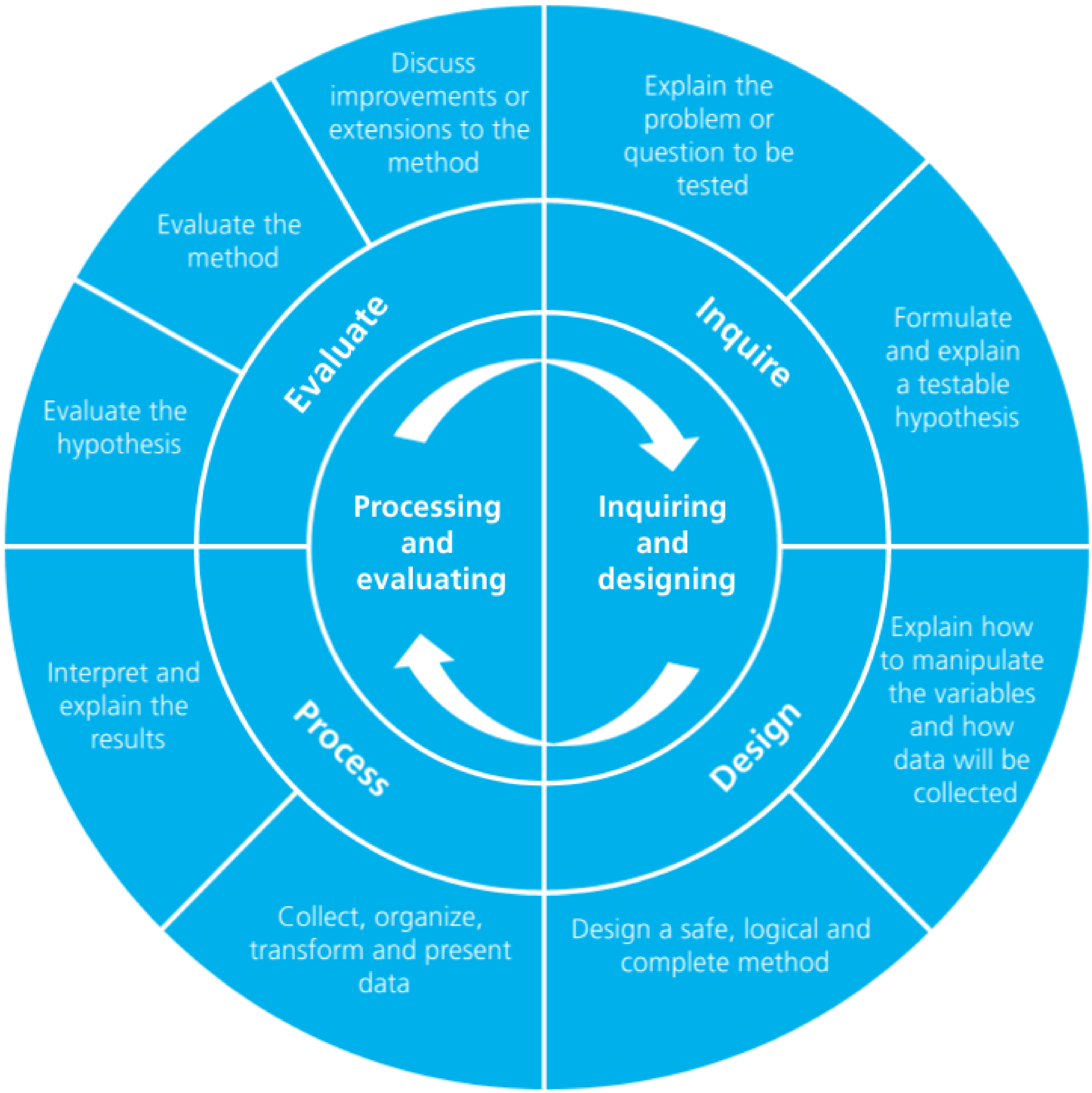


Figure 1.9 MYP Sciences Inquiry Cycle

Links to: Design

In the egg experiment we found results that would be useful to help engineers design the egg-carrier. Good design is always informed by data about the job that the product will have to do – its *function*.

Take action

ATL

- Media literacy skills: Demonstrate awareness of media interpretation of events and ideas

- We have seen in this chapter how science stories are very popular in the media. Sometimes though the media gets it wrong – and people can be misled, because not everybody thinks scientifically.
- Here are a few common misunderstandings:

It is perfectly safe to eat something that has fallen on the floor provided you pick it up within five seconds

The other side of the Moon is dark

Gravity stops outside the Earth's atmosphere

When it is summer, the Earth is closer to the Sun. When it is winter, the Earth is further away.

Lightning never strikes in the same place twice

- You can research some of these misunderstandings online by searching: popular scientific misconceptions. Make a poster, web presentation or a movie in which you 'de-bunk' these misconceptions by explaining the real science behind them.

EXTENSION

Further explore the MYP Sciences Inquiry Cycle by finding out the meaning of these in a scientific inquiry: **prediction**; **hypothesis**; **evaluation**.

Reflection

In this chapter we have **discussed** how to think and work scientifically and **formulated** inquiry questions that can lead to scientific investigation. Within the scientific investigation, we have **identified** variables and **classified** variables as independent or dependent for experimental investigations we have carried out. We have thought about and **listed** the main features of a scientific laboratory, **formulated** rules for safe laboratory practice, and **evaluated** the environmental impact of laboratory activities.

Fill in this table to evaluate and reflect on what you have learnt in this chapter. Perhaps there are new questions which have been brought to light by your learning.

Use this table to evaluate and reflect on your own learning in this chapter.		
Questions we asked	Answers we found	Any further questions now?
Factual: How do scientists behave? How is a laboratory different? What is an experiment?		
Conceptual: How are scientific theories made?		
Debatable: Can science tell us everything we need to know?		

Approaches to learning you used in this chapter	Description – what new skills did you learn?	How well did you master the skills?			
		Novice	Learner	Practitioner	Expert
Media literacy skills – we have analysed the way information about scientists is presented.					
Information literacy skills – we have researched information about scientists.					
Critical-thinking skills – we have learnt how to ask testable inquiry questions, to observe carefully and to evaluate what we observe.					
Creative-thinking skills – we have used brainstorming to generate and share ideas.					
Collaboration skills – we have taken responsibility for safe behaviour in the laboratory.					

Learner profile attribute	How did you demonstrate your skills as an inquirer in this chapter?
Inquirer	

Change | Form, Transformation | Fairness and development

2 What changes?

Science enables us to **change the form** of matter into useful **materials that can make the world a better place**.

CONSIDER THESE QUESTIONS:

Factual: What are things made from? How do we classify materials? What changes do we observe every day? How do physical changes happen? How do chemical changes happen?

Conceptual: How might physical and chemical changes help us to manipulate materials? What does purity mean in science?

Debatable: What prevents us from giving access to pure water to everyone?

Now **share and compare** your thoughts and ideas with your partner, or with the whole class.

■ **Figure 2.1** Materials make the world

IN THIS CHAPTER WE WILL ...

- **Find out** what kinds of materials there are, how they can be combined to make new materials, and how materials can be changed.
- **Explore** the ways in which we can manipulate materials to make new things, or purer materials.
- **Take action** to improve access to pure water for everybody in the world.

■ These Approaches to Learning (ATL) skills will be useful …

- Creative-thinking skills
- Critical-thinking skills
- Transfer skills
- Information literacy skills

● We will reflect on this learner profile attribute …

- Inquirers – we will use observations to make new questions to explore.

◆ Assessment opportunities in this chapter:

- **Criterion A:** Knowing and understanding
- **Criterion B:** Inquiring and designing
- **Criterion C:** Processing and evaluating
- **Criterion D:** Reflecting on the impacts of science

KEY WORDS

artificial	natural	stone
gas	plastic	wood
liquid	powder	
metal	solid	

ACTIVITY: Material words

■ ATL

- Critical-thinking skills: Practise observing carefully

Individually or in pairs, what materials can you see in Figure 2.1?

Look at the key words box and decide which words can be used for each of the materials. If you are unsure about the meaning of any of the words, search online or in a dictionary to find definitions.

Organize your ideas in a table like Table 2.1.

Material in picture	Words to describe it

■ **Table 2.1** Material words

Materials make our world. Since the earliest times, human beings have used the materials they found around them in nature to make new things. At first, humans fashioned **natural materials** into new forms to make useful things that made life easier. Later, humans discovered that materials could be changed in various ways, and they created new processes to transform natural materials into **artificial materials** that better suited their needs. In this chapter, we will **identify** and **classify** the materials we find in nature, and those that human beings have made for themselves. We will **demonstrate** ways to combine and to separate materials, and we will investigate one way in which purifying materials can save lives – to make pure, clean water for all.

What are things made from?

NATURAL AND ARTIFICIAL MATERIALS

Archaeologists have found plentiful evidence of the natural materials that early humans used to improve their lives and their chances of survival. Early humans fashioned natural materials to help them to cook, to clothe themselves, to hunt or to make shelter.
As civilization developed, we learnt more sophisticated ways to transform natural materials.

SEE–THINK–WONDER

Look at the pictures in Figure 2.2.

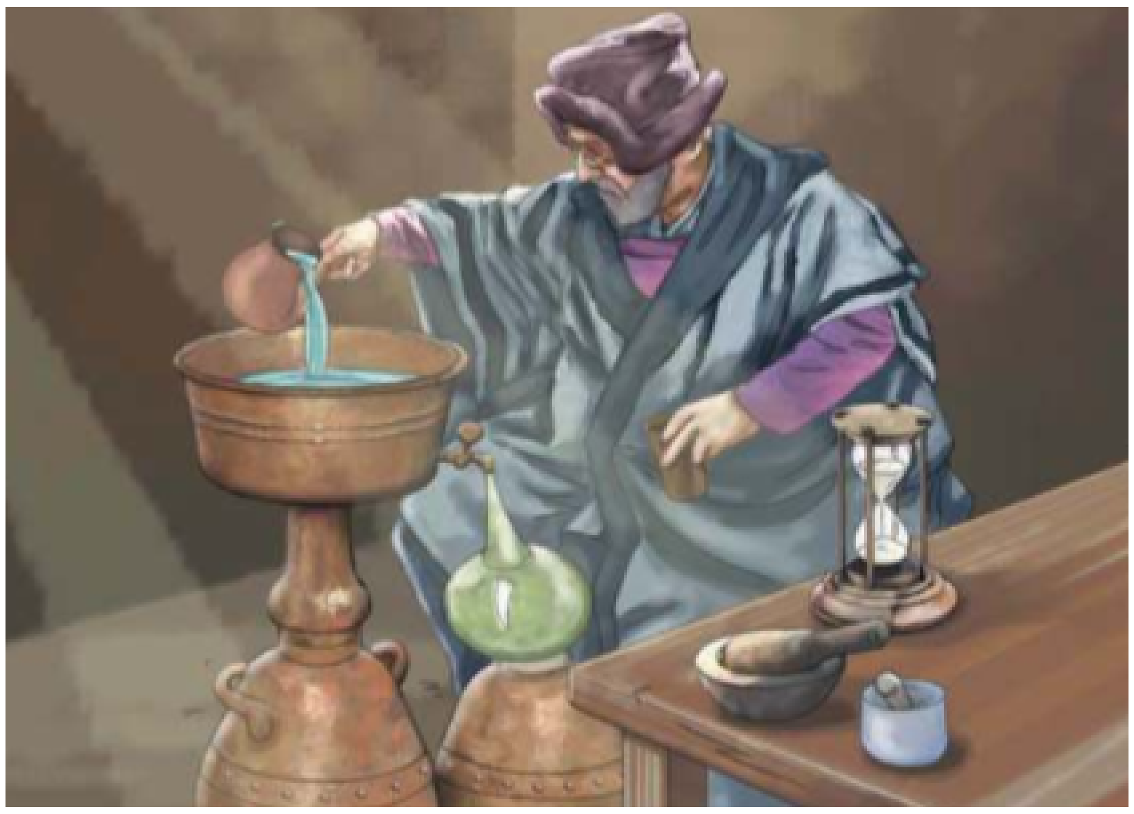
- **What do you see?**
- **What do they make you think?**
- **What do they make you wonder?**

Discuss your **interpretation** of the images with your partner.

What do the images tell us about the ways in which our use of materials has changed?

Of the materials you see in the pictures, which could be considered 'natural' and which 'artificial'?

Share your ideas with the class.



■ **Figure 2.2** Materials through human history

What does purity mean in science?

While it is interesting to consider whether materials are natural or artificial, this way of categorising materials doesn't tell us much about the kinds of substances they contain. Another way to think about materials is to consider whether they are pure, or a mixture. Sometimes it is not easy to decide just by looking at the materials.

Look at Figure 2.3. Both table salt and spice powder look like powders, but when we look at the ingredients on the side of their containers we find they are different types of material. Salt is just one substance: it is called sodium chloride and has a chemical formula: NaCl. However, table salt bought in a shop sometimes contains other substances, too. Similarly, spice powder looks like a simple powder – but look at the list of ingredients!

Other substances may even be a mixture of different **states of matter**.

Figure 2.3 (a) Pile of table salt, (b) label showing ingredients; (c) pile of spice powder (d) spice ingredients list

ACTIVITY: States of matter

■ ATL

- Critical-thinking skills: Gather and organize relevant information to formulate an argument

Individually or in pairs, we will carry out some tests in this activity to make observations about the **physical properties** of three states of matter.

Inquiry: What are the different properties of the states of matter?

Background: A physical property is any characteristic a material has due to the way the matter it contains is arranged.

The physical properties we will test here are given in Table 2.2. Read the table carefully.

Name of property	Description of property	Questions
Rigidity	How 'stiff' the material is	**1** Does it fall apart?
Fluidity	How 'runny' the material is	**2** Does it spread out?
Compressibility	How 'squashy' the material is	**3** Does its shape change when force is applied to it?

■ **Table 2.2** Physical properties

The third column in the table suggests questions we might ask about the property. Can you think of your own questions to add?

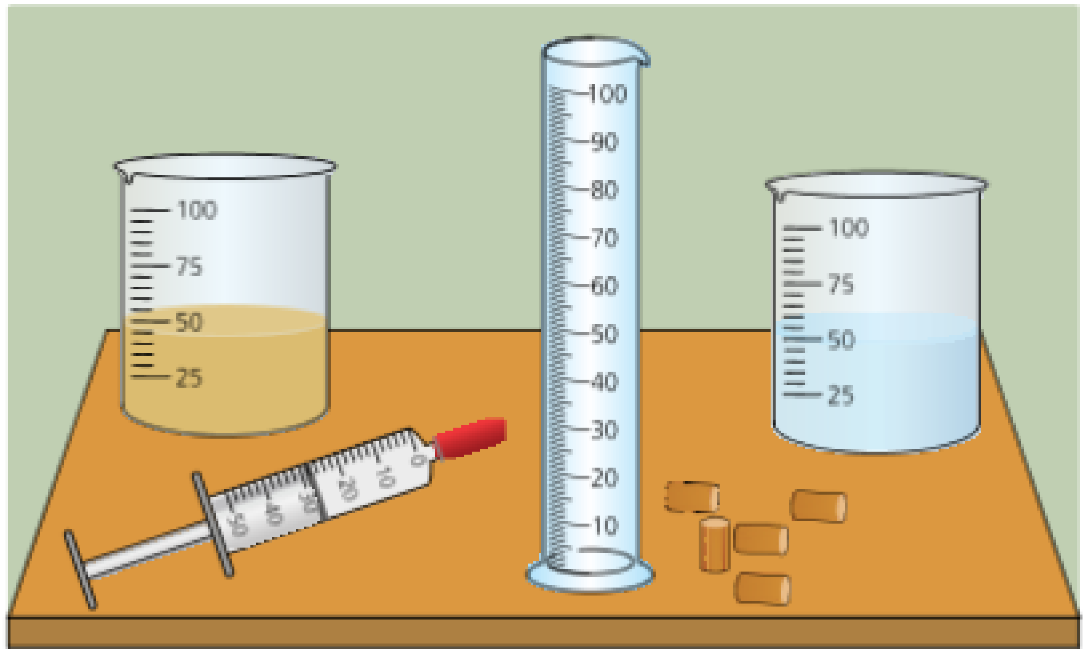
The materials to test are:

- **wood**
- **sand**
- **water**
- **air.**

You are going to change the material, and observe the physical properties of each.

You will need the equipment shown in Figure 2.4.

- **Plastic syringe, 50 ml volume, with the nozzle sealed up (you will need your teacher to help with this)**
- **Measuring cylinder, 100 ml volume minimum**
- **Beaker containing approximately 50 ml of sand**
- **Beaker containing approximately 50 ml of water**
- **Small blocks of wood that can fit inside the syringe**



■ **Figure 2.4** Equipment for the experiment

Method

1. **Take one of the small blocks of wood and place it inside the syringe. Do not put the syringe plunger inside yet.**
2. **Ask question 1 from Table 2.2, and make a note of your observation. Does the material fall apart?**
3. **Ask question 2 from Table 2.2, and make a note of your observation. Does the material spread out?**
4. **Now place the plunger inside the syringe (you may need to push it in). Press the plunger down until it touches the block.**
5. **Ask question 3 from Table 2.2, and make a note of your observation. Does the material change shape with force?**
6. **Now pull out the syringe plunger and remove the material.**
7. **Repeat steps 1–6 with the sand. Make sure that you fill the syringe to the top with the sand, so that there is little or no air inside.**
8. **Now measure out 50 ml of water using the measuring cylinder. Fill the syringe to the top with water. Repeat steps 1–6.**
9. **Finally, dry out the syringe using a paper towel. Put the plunger back into the empty syringe.**
10. **Repeat steps 1–6 with air trapped inside the syringe.**

Results

When you have finished making your observations, **organize** them in a table that clearly shows the material, the property and the observation.

Hint

You might use ticks or crosses to record your observations for each of the three property questions!

Conclusion

Two of the materials we tested were **solids**. One of these was in a rigid form, the other was in the form of a powder.

One material was a **liquid**. The third material was a **gas**.

Solid, liquid and gas are three of the states of matter.

Summarize your observations in a conclusion about the properties of the states of matter. You can use the following starter sentences to help **organize** your conclusion:

- **An example of a solid/liquid/gas was … It was rigid/fluid/compressible because …**
- **When the solid was in the form of a powder, it was rigid/fluid/compressible because …**

Evaluation

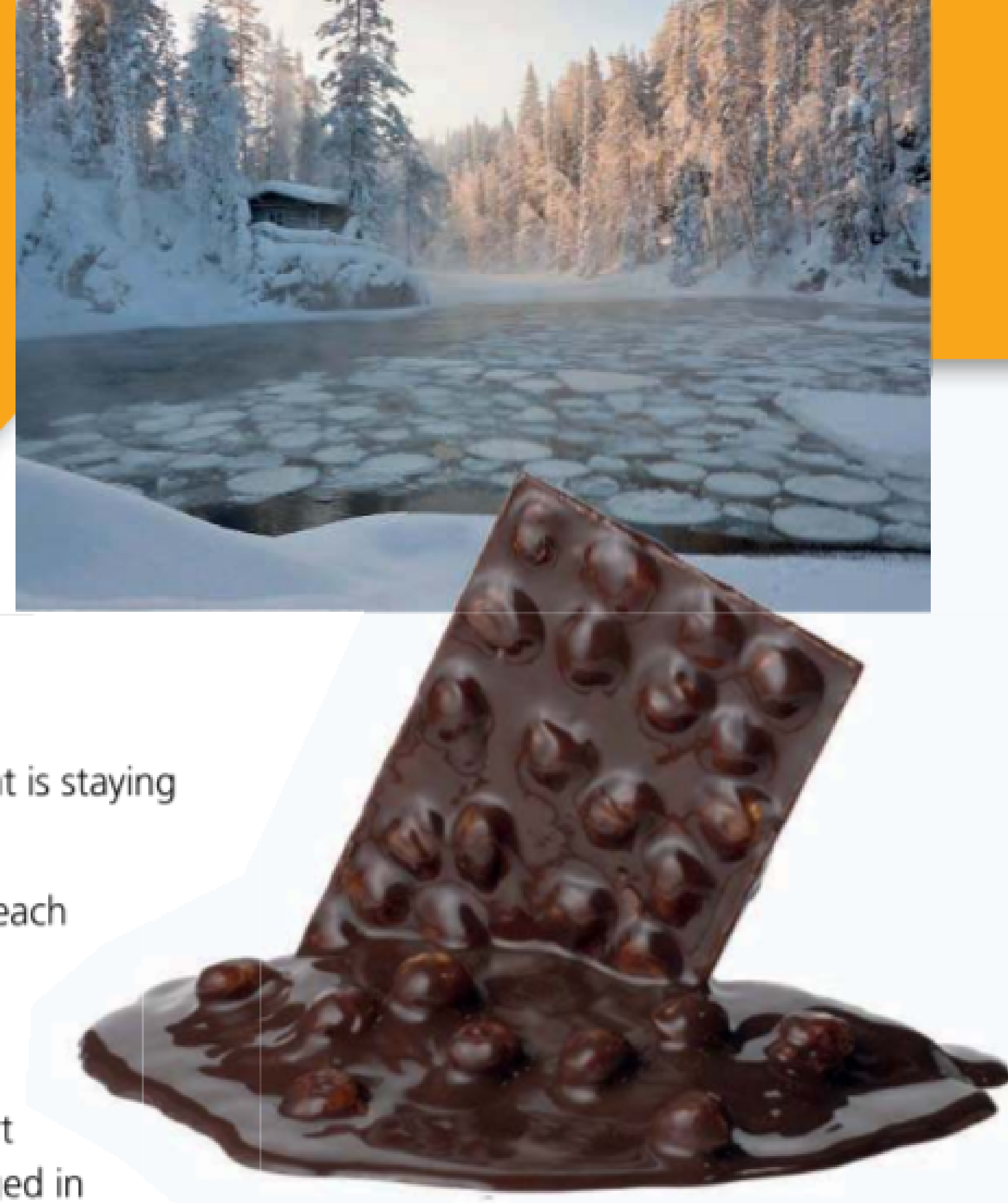
Was your experiment valid? Consider these questions:

- **When testing sand and water, why was it important to fill the syringe to the top?**
- **What did you find out from testing the two different forms of solid in the experiment?**
- **How could the experiment design be improved? Discuss and think of one improvement that could be made.**

◆ Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion C: Processing and evaluating.

What changes do we observe every day?



■ **Figure 2.5** Physical changes

PHYSICAL CHANGES

Look at the pictures in Figure 2.5. What is changing? What is staying the same?

In each case, the substance is changing somehow. Yet in each case, we still have the same material before and after the change – melted chocolate is still chocolate, and melted ice is still water. These are examples of **physical changes** because the change that occurs does not make a new sort of matter – rather, the same sort of matter is just rearranged in some way. A clue to the physical nature of these changes is to ask, can we get back to the material we started with?

Compare the changes happening in Figure 2.5 to the changes shown in Figure 2.6.

■ **Figure 2.6** Cooking changes involve both physical and chemical changes

When spaghetti is cooked, it changes its properties. Afterwards, the spaghetti has undergone both a physical change called hydration and **chemical changes** to the carbohydrate and protein molecules involving a **chemical reaction**. Similarly, when egg is cooked, the proteins in the egg are also chemically changed. You can't make a raw egg from an omelette!

In this section, we will first explore physical changes, and the techniques that scientists can use in the laboratory to manipulate and use those physical changes.

ACTIVITY: Making changes

ATL

- Critical-thinking skills: Practise observing carefully

In pairs, we are going to explore two substances that change state. Follow the instructions carefully.

SAFETY: We will be using hot liquids in the experiment. You will need to wear protective clothing and safety glasses. Carry out a safety assessment before you begin.

Melting and freezing candle wax

Candle wax is made from a substance called paraffin, which is in turn derived from crude oil. Paraffin wax changes state at a little above room temperature.

Follow these instructions to watch the change of state of paraffin wax:

1. Place some chippings of solid paraffin wax in the bottom of a boiling tube (a large test tube).
2. **Describe** the properties of the paraffin wax in the tube, using precise words – refer to the vocabulary you have learnt in this chapter.
3. Now fill a large beaker with around 200 ml of boiling water. (Care! Pour carefully and make sure not to spill any of the hot water on your skin.) Place a stirring rod in the water for a few moments, so that it becomes hot.
4. Place the boiling tube in the beaker of hot water. Place the stirring rod in the paraffin wax chippings.
5. Observe what happens to the paraffin wax as it heats up, and **describe** its properties as it changes. (Note: if the paraffin wax does not change state, you may need to heat the beaker of water using an electric heater or Bunsen burner – ask your teacher for help with this.)
6. Finally, coat the stirring rod with liquid paraffin wax. Remove the stirring rod from the wax and plunge it into another beaker of cold water.
7. Observe what happens to the paraffin wax on the stirring rod, and **describe** its properties.

Making oobleck

We watched a video about oobleck in Chapter 1. Oobleck is a suspension of corn starch in water. When these two substances are mixed, the suspension produced has a very unusual property – it changes state according to the amount of physical force that is placed on it.

1. To make oobleck, mix two volumes of corn starch to one volume of water in a beaker. For example, if you want to make 150 ml of oobleck, you will need 100 ml of corn starch and 50 ml of water.
2. To test your oobleck, pour some of the suspension into a beaker, or a tray around 10 mm deep. Push your finger slowly into the oobleck. How does it feel?
3. **Describe** the properties of oobleck when you do this.
4. Now try stabbing your finger rapidly into the oobleck. How does that feel?
5. **Describe** the properties of oobleck now!

Organize your observations for each change to make them clear and easy to **interpret**.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion C: Processing and evaluating.

Observing accurately

An experiment is only as effective as the person carrying it out and making the observations. In the activity above, you used scientific vocabulary to make precise descriptions of observations. In Science, we always try to use words that have a precise meaning.

Precise terms are words such as: mass, volume, transparent, opaque, solid, liquid, gaseous.

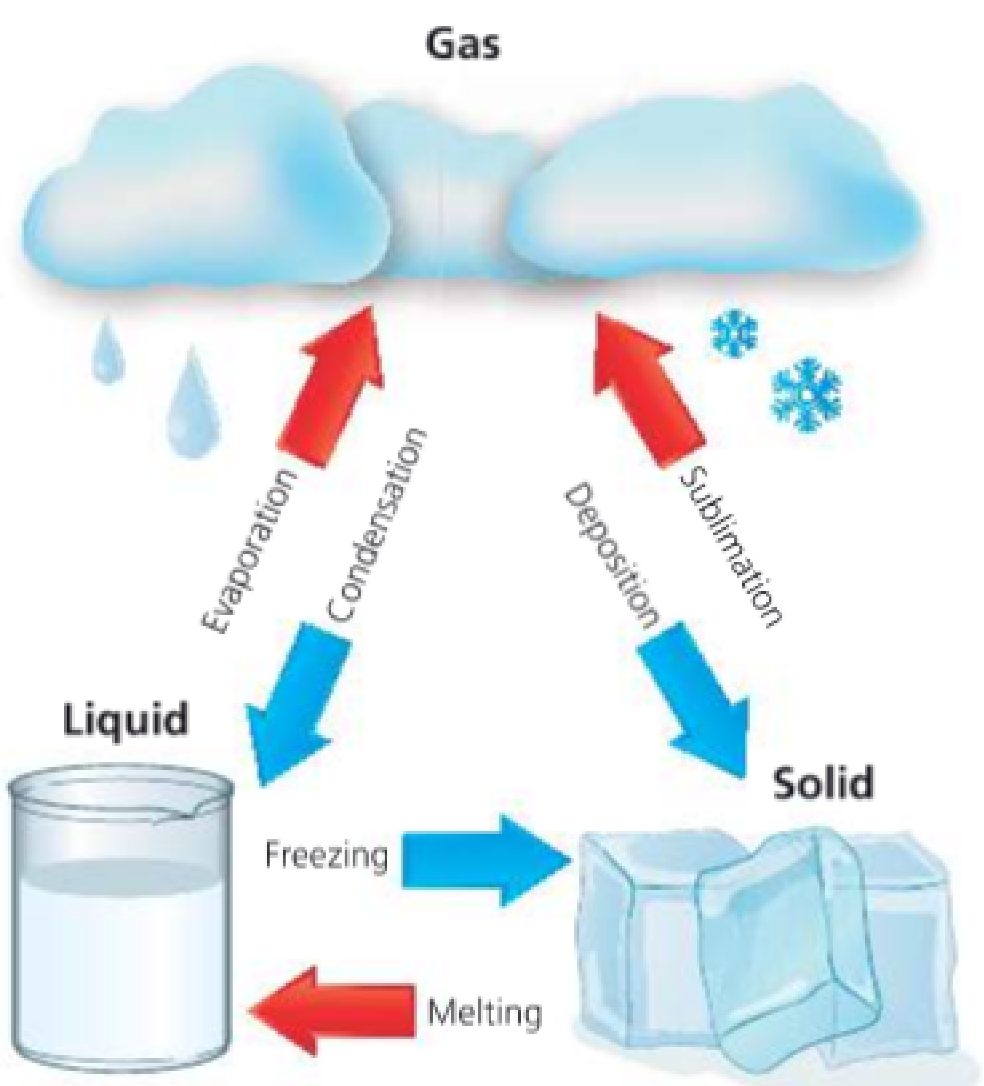
Terms that are less precise, and therefore not so effective if used in scientific observations, are words such as: how long, see-through, thick, strong, runny.

CHANGES OF STATE

Changes of state are physical changes. One material changes state all the time around us, and is vital for all life on Earth – water (chemical formula: H_2O).

The energy of the Sun causes water to change state in the atmosphere around us, causing all the weather we know: storms, fog, hurricanes, snow … . We will look in more detail at water in the Earth's environment in Chapter 6.

Figure 2.7 shows the ways that water changes state, and the names given to each of the changes of state. Notice that the changes of state have different names, depending on which direction they are going!



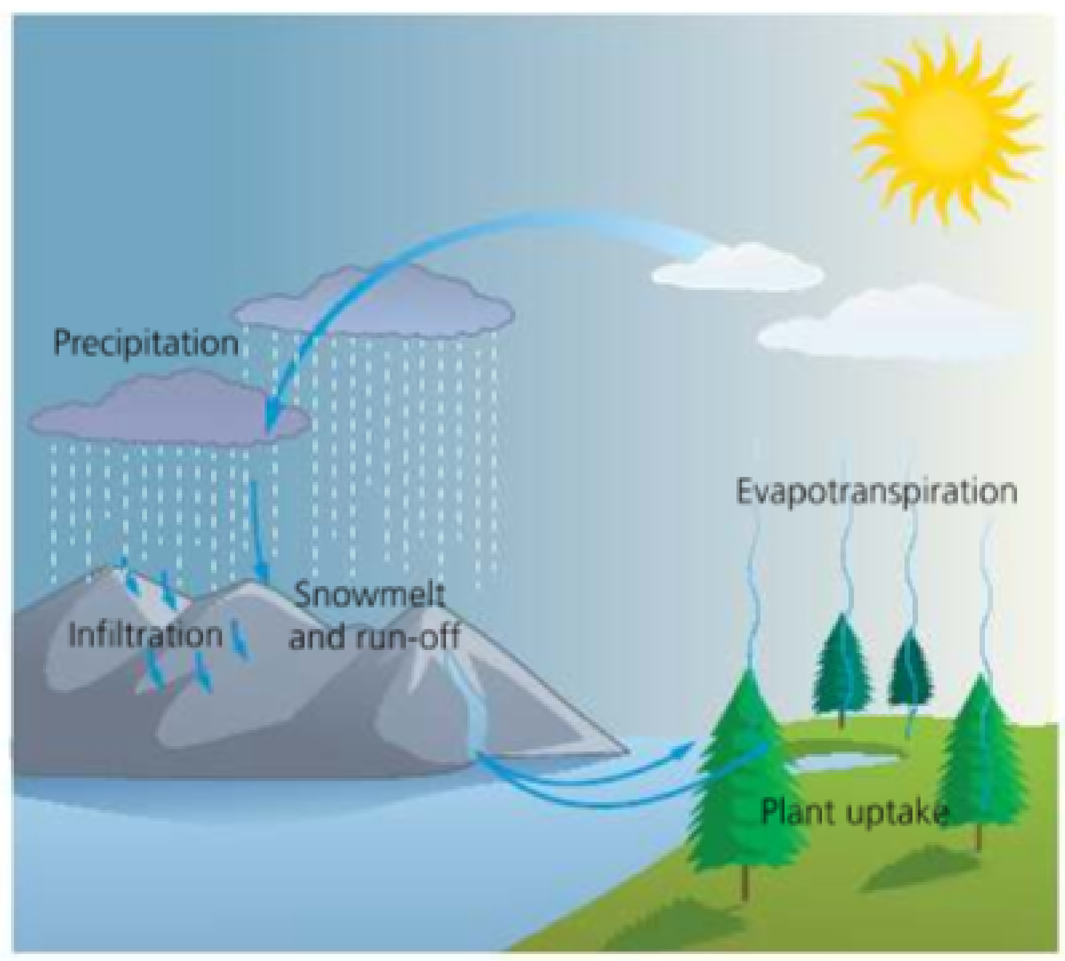
■ **Figure 2.7** Changes of state of water

ACTIVITY: Water for life

ATL

- Transfer skills: Apply skills and knowledge in unfamiliar situations

Figure 2.8 shows the natural processes by which water changes state in the Earth's environment.



■ **Figure 2.8** The water cycle

Interpret the diagram. For each part of the water cycle:

- **identify the change of state taking place and state its name**
- **outline the way the properties of the water change for this change of state.**

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Knowing and understanding.

We have seen that with some materials, appearances can be deceiving. A substance that seems pure can in fact be a mixture. Materials may also be mixtures of different states of matter. Figure 2.9 shows some different mixtures of liquids with other substances. Can you work out which states of matter are in these mixtures?

The mint tea is mostly hot water, but the tea has **dissolved** in it to make the brown colour. Also, some of the oils from the mint leaves dissolve to add the minty flavour. Most often mint tea will also be served with lots of sugar – and this is also dissolved in the hot water to make a refreshing, sweet drink for a hot day! Since all the substances stay together in the mixture, mint tea is a **solution**.

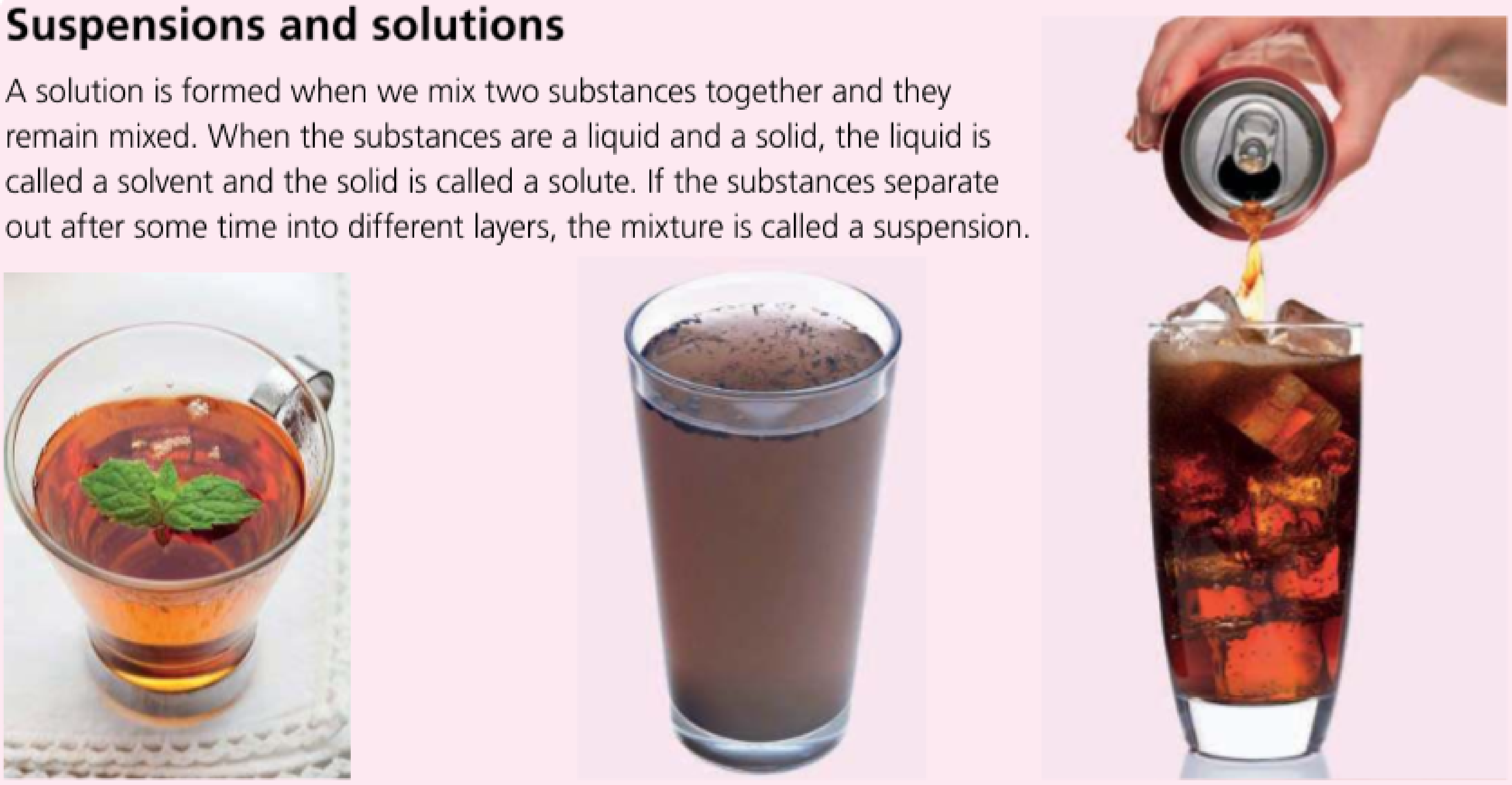
It looks like the dirty river water has substances dissolved in it also, as the colour of the water does not look very healthy. On the other hand, we can see that other material from the river is slowly sinking to the bottom of the water. The material is not dissolved in the water, since after some time it separates out again into different layers. When this happens, it is called a **suspension**.

Finally, the fizzy drink contains a lot of different substances. (If you want to know which, look at the ingredients label on any can of fizzy drink!) But what makes the drink fizzy is the gas that is dissolved in the drink. The gas is carbon dioxide (chemical formula: CO_2) and it is added to the drink in the factory. The drink is then sealed – either in a bottle or in a can – and the gas is 'trapped' inside the drink – until you open it! When you open the drink there is a drop in **pressure** which, with time, allows the gas bubbles to escape. It's the sensation of the bubbles escaping the solution on our tongue that gives the drink its fizz.

In the two activities that follow, you can choose to investigate different types of solutions or suspensions: those made from a solid **solute** in a liquid **solvent**, and those made from a gas solute in a liquid solvent.

Suspensions and solutions

A solution is formed when we mix two substances together and they remain mixed. When the substances are a liquid and a solid, the liquid is called a solvent and the solid is called a solute. If the substances separate out after some time into different layers, the mixture is called a suspension.



■ **Figure 2.9** Suspensions and solutions: (from left to right) mint tea, dirty river water, fizzy drink

ACTIVITY: Mixing it up – MY Chocodrinks

ATL

- Creative-thinking skills: Generate testable hypotheses

In pairs, you are food scientists working in the laboratory of the MY Chocodrinks company. The manager of the company wants to find out about the **solubility** of the different ingredients that can be used to make a mixer for chocolate drinks. Your task is to report on this information to the manager.

Your report must include a conclusion about the solubility of the different ingredients in different drinks, so that the company can decide how best to make the chocolate mixer.

SAFETY: In this experiment you will be using foodstuffs which you must not taste or eat. Be sure to carry out risk/safety and environmental impact assessments and make sure that your teacher checks your design before you begin.

Look at the ingredients in Figure 2.10. Choose **one** solvent and **two** solutes from the ingredients.

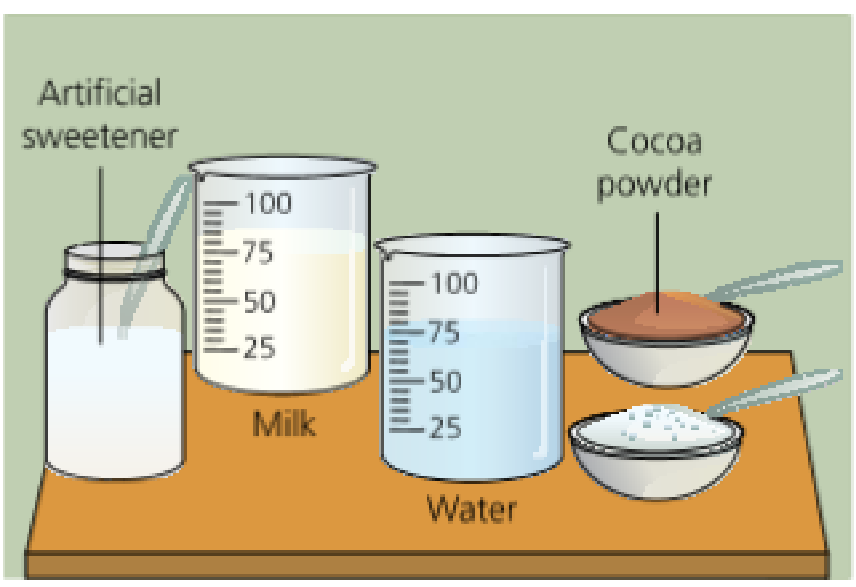


Figure 2.10 Solvents and solutes

1. **Outline the aim of your experiment in the form of an inquiry question.**
2. **Use the scientific investigation cycle in Figure 2.11 to help you to design a method to answer your inquiry question.**
3. **In your method, identify the independent variable and the dependent variable.**
4. **State what other variables could affect the results, but which you will control by keeping the same.**
5. **Predict what you think will happen in your experiment, and explain why you think this with scientific reasoning.**
6. **Now carry out your experiment.**
7. **Organize your results in a table. Make sure your table has headings that clearly show the variables you used, and any units of measurement.**

When you have gathered all your results, write a conclusion for the manager of the company. **Evaluate** your experiment for validity and **suggest** any improvements you could have made. Could you have carried out any further measurements? **State** any other measurements you could have made to improve your experiment.

Assessment opportunities

- This activity can be assessed using Criterion B: Inquiring and designing and Criterion C: Processing and evaluating.

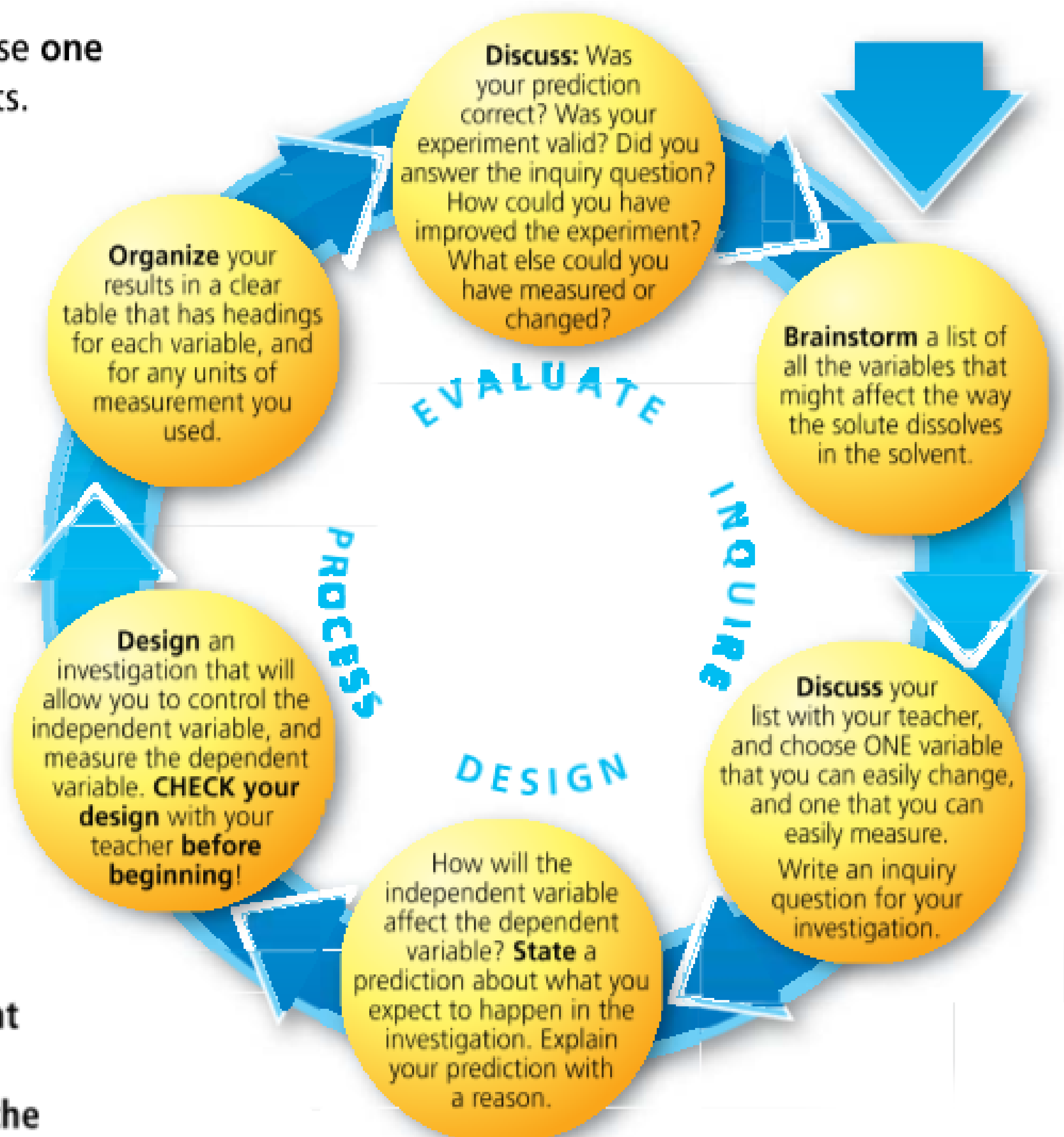


Figure 2.11 Scientific investigation cycle – MY Chocodrinks

Finding the best answer

In the experiment, the first thing we did was to select our variables and also figure out which variables we were going to change, and which we were going to measure.

At the end of the experiment, we go back to the beginning and ask 'did we really answer our question?' To do this, we need to consider the validity of the experiment – did we actually measure the right things in order to produce the results we wanted?

When we **evaluate** the validity of the experiment, we also have to consider whether we could have improved the experiment – either by doing things a little differently, or perhaps by making further measurements.

ACTIVITY: Fizzing it up – MY fizzy drinks

ATL

- Creative-thinking skills: Generate testable hypotheses

In this activity you will work in pairs as food scientists working for a government food testing laboratory.

The government wants to find out whether all fizzy drinks have the same fizz! Your task is to report to the government on one brand of fizzy drink.

Background

When a gas is added to liquids, the gas can be made to dissolve by adding the gas to the liquid under pressure. The drinks bottle or can is then sealed, and the gas remains dissolved in the liquid until the pressure is released by opening the container.

1 **Choose a particular kind of fizzy drink to test.**
2 **Outline the aim of your experiment as an inquiry question.**
3 **Design a method to find out how much gas is dissolved in the drink. You may wish to modify the scientific investigation cycle in Figure 2.11 to help you write your method.**
4 **In your method, identify the independent variable and the dependent variable you will use.**
5 **Predict what you think will happen in your experiment, and explain why you think this with scientific reasoning.**

Hint

How can you observe the gas leaving the liquid? How can you measure the amount of gas released for each container of drink?

6 **State what other variables could affect the results, but which you will control or keep the same.**
7 **Now carry out your experiment.**
8 **Organize your results in a table. Make sure your table has headings that clearly show the variables you used, and any units of measurement.**

When you have gathered all your results, write a conclusion for the government. **Evaluate** your experiment for validity and **suggest** any improvements you could have made. Could you have carried out any further measurements? **State** any other measurements you could have made to improve your experiment.

Assessment opportunities

- This activity can be assessed using Criterion B: Inquiring and designing and Criterion C: Processing and evaluating.

How do physical changes happen?

All the solutions we have looked at have been made using a liquid solvent, and the solution is then a liquid. But is it possible to make a solid solution? Look at the pictures in Figure 2.12.

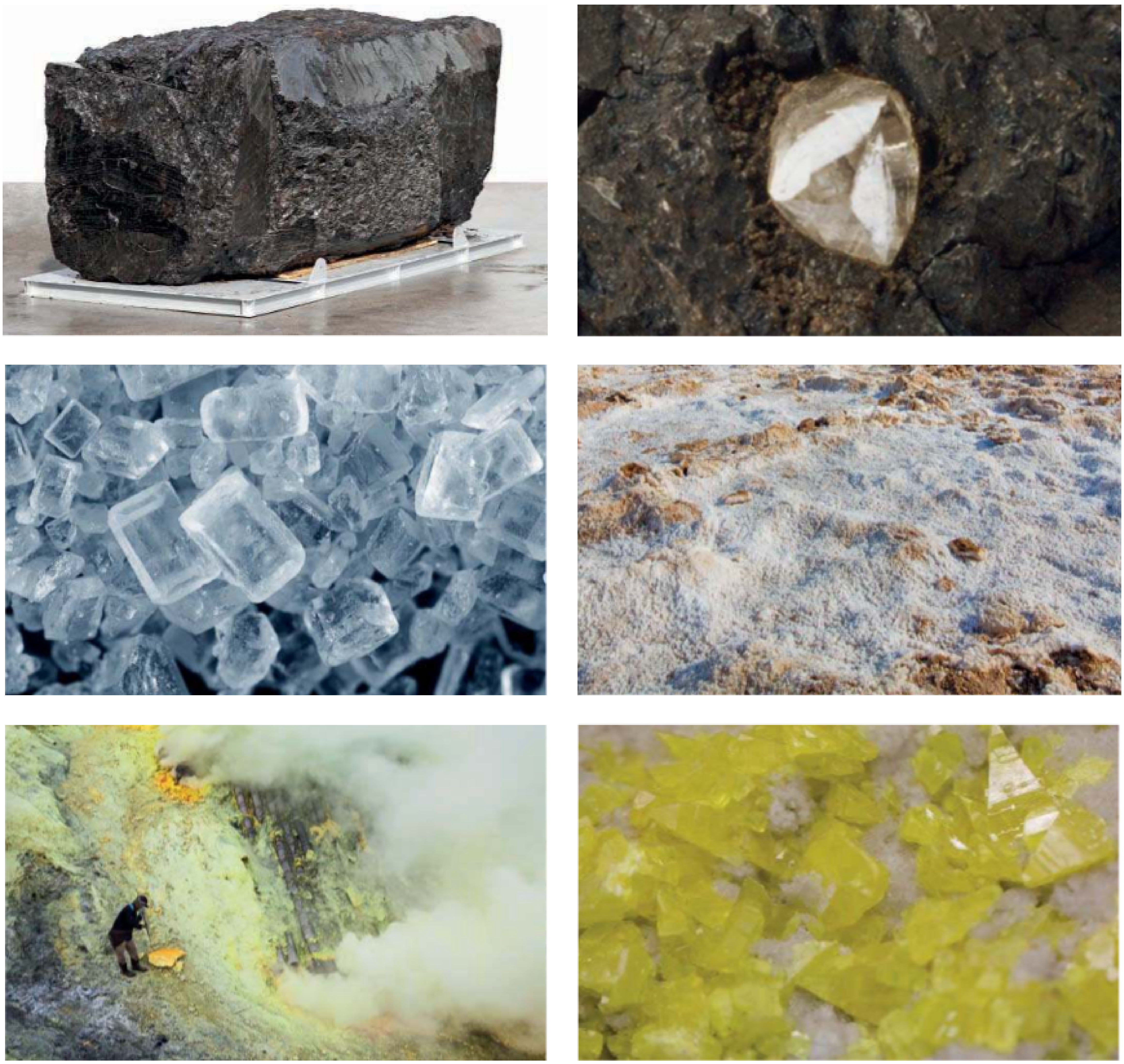
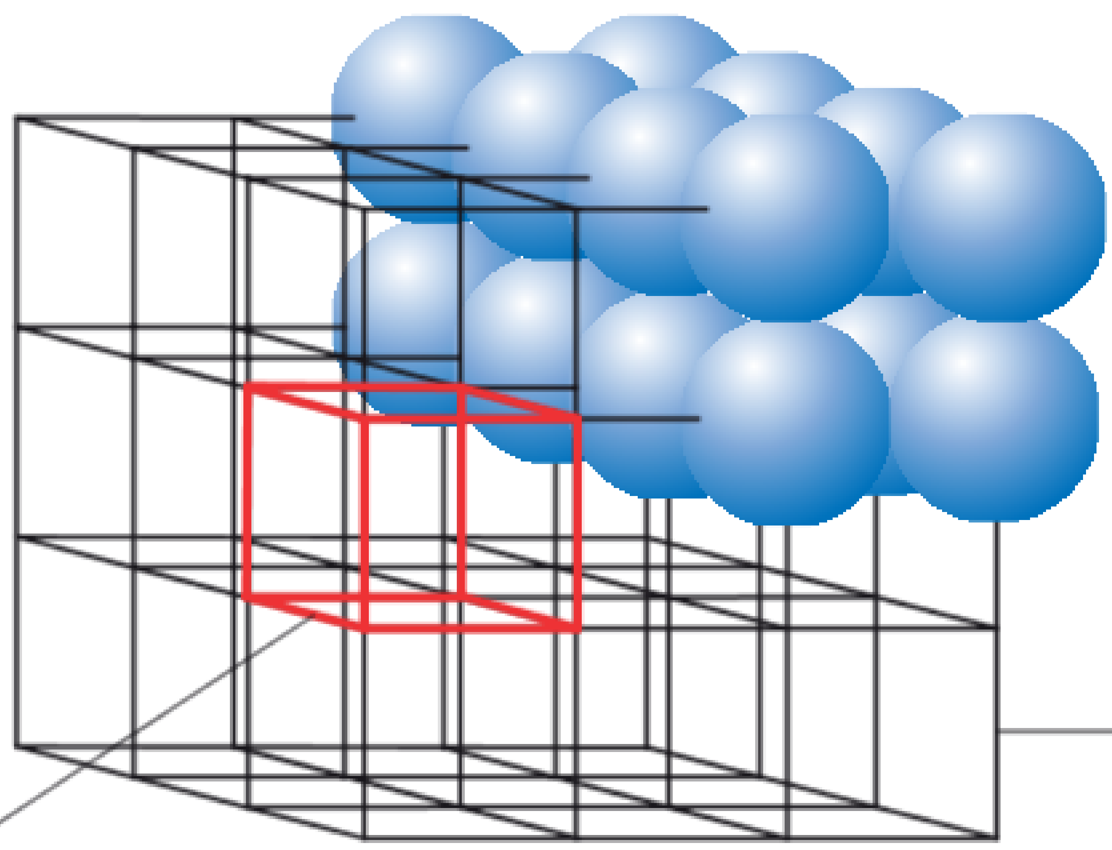


Figure 2.12 Raw materials and their crystals – carbon as graphite and diamond; salt and salt crystals; sulphur powder and sulphur crystals

All the images in Figure 2.12 show raw materials, and the **crystals** they can form. A crystal is a special form of solid, where the arrangement of the particles in the crystal is very regular, and this regular arrangement of particles becomes building blocks that fit together to form larger crystal shapes.



■ **Figure 2.13** Particles in crystalline substances arrange themselves to form building blocks called unit cells

Crystals

The shape of the crystals formed by a substance can change depending on the arrangement of the particles in the crystal. Both carbon and sulphur can form different crystals according to the physical arrangements of their atoms. In Figure 2.12, graphite is in fact another crystalline form of carbon – although carbon is most often found in this form naturally. Sulphur can also form long, needle-like crystals, known as monoclinic sulphur.

■ **Figure 2.14** A quartz geode. Geodes are found deep in the ground and are formed by geological processes. We can see why they might have been mistaken for dragons' eggs!

Links to: Individuals and societies

Crystals are often found in natural form in the ground. Some of them – like diamonds – are very rare, and because people found them beautiful they were thought precious – these are jewels and gemstones. Others are more common, but still beautiful – such as quartz (Figure 2.14). Perhaps because they are so unusual and strange, people thought crystals might be magical objects.

How have natural materials like these been valued in different cultures though the ages? How have they affected human societies?

ACTIVITY: Making crystals

ATL

- Critical-thinking skills: Practise observing carefully in order to recognize problems; Interpret data

Inquiry: How can we make crystals?

Background

One material that forms crystals is called copper sulphate (chemical formula: $CuSO_4$). In its usual form, copper sulphate is a pale blue powder. When it is dissolved in water, water molecules surround the particles from the copper sulphate. When the solution is evaporated, some of the water molecules remain in the crystals that form.

SAFETY: Copper sulphate is poisonous if we **ingest** it. Be very careful when using the chemical not to get any on your hands, or especially near your mouth. If you do get the chemical on your hands, wash them immediately.

In this experiment we will be heating a liquid. If you have never used a Bunsen burner or electric heater before, this experiment may be demonstrated by your teacher.

Equipment

- Safety glasses and protective clothing
- Bunsen burner, tripod, gauze or an electric heater
- Heatproof mat
- 250 ml beaker
- Stirring rod
- Spatula or measuring spoon
- Water
- Copper sulphate powder
- Evaporating basin
- Short piece of string

Procedure

1. First, prepare a solution of copper sulphate. To do this, take some warm water (use an electric kettle or similar to heat it). Pour around 50 ml of warm water into the beaker.
2. Slowly add copper sulphate using the spatula or spoon. Stir continuously until all the copper sulphate dissolves. The solution should turn blue.
3. Keep adding copper sulphate to the solution until the copper sulphate will not dissolve any more, but sinks to the bottom of the solution. When this happens you have dissolved as much copper sulphate as possible and the solution is said to be **saturated**.

4 **Now pour the solution into the evaporating basin.**
5 **Place the basin on the heater, or on the tripod and gauze. Heat gently. Take care – the solution may spit as it evaporates away.**
6 **Wait until most of the water has evaporated. Turn off the Bunsen burner or heater. Place the string inside the basin. Leave the last of the solution to cool and evaporate.**

Hint

If you want to make larger crystals, allow the solution to evaporate without heating it. This will take a longer time however.

Results

What has been formed in the basin? **Summarize** your observations carefully.

Conclusion

Explain what has happened to the copper sulphate solution.

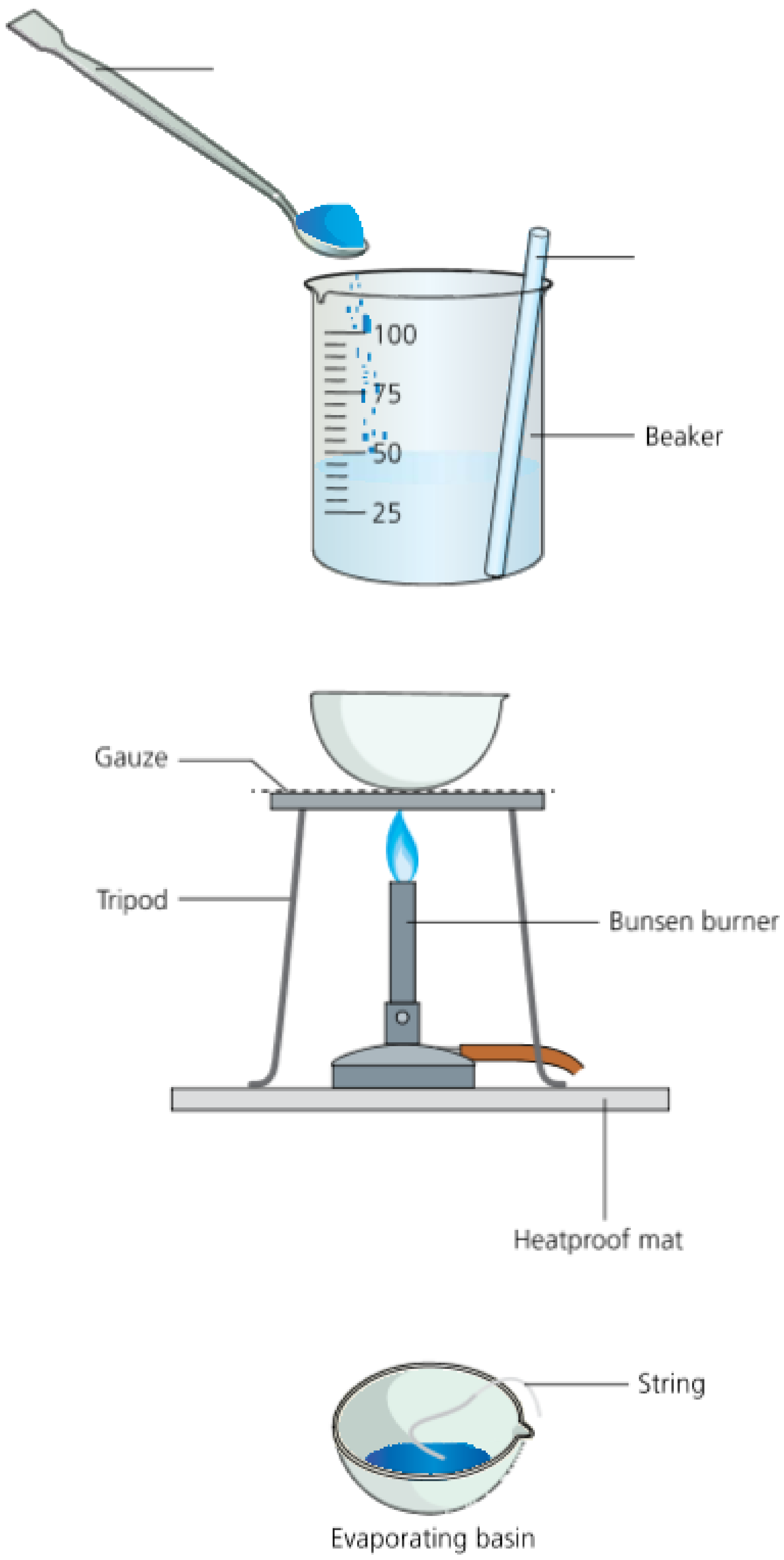
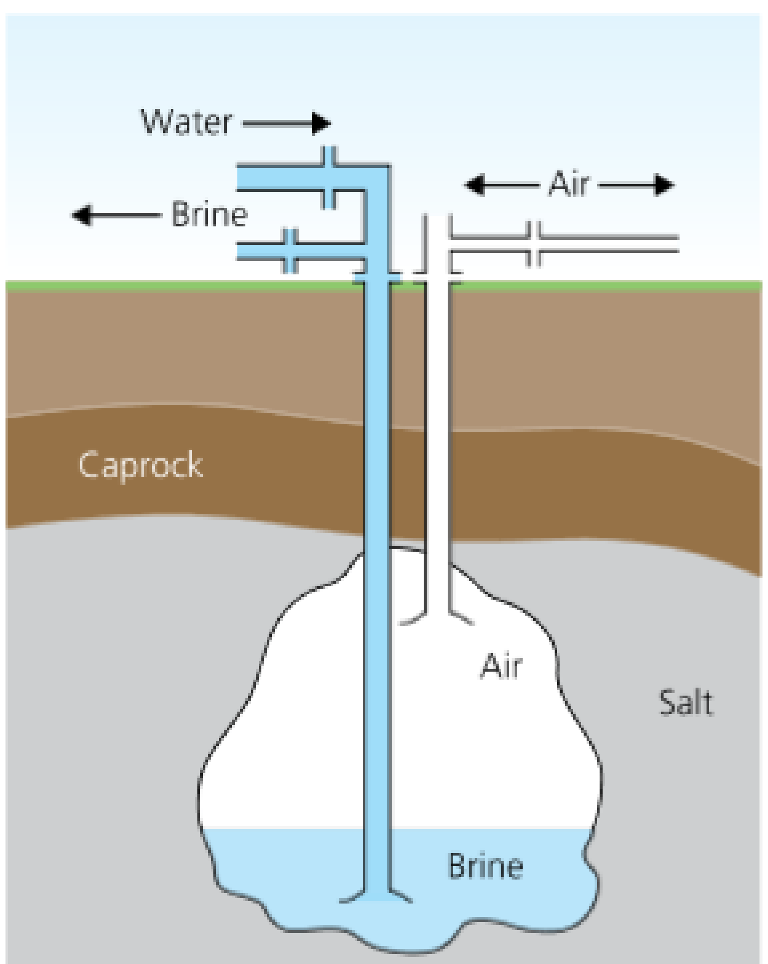


Figure 2.15 Crystallization experiment

How might physical and chemical changes help us to manipulate materials?

SEPARATING MATERIALS

Look at the diagram of a salt mine in Figure 2.16. Salt is found in the ground as a naturally occurring mineral called rock salt, but when it is found it is usually mixed up with other substances – rock, stones, and other minerals.



■ **Figure 2.16** Salt excavation with water in a salt mine

The salt in the mine is being extracted using water. Salt (chemical formula: NaCl) is soluble in water, while the other materials found with it are not. The water can be used to dissolve the rock salt away from the other materials. Afterwards, the salt solution can then be separated using another process (we will see how later in this chapter) to leave crystals of pure salt (as seen in Figure 2.12).

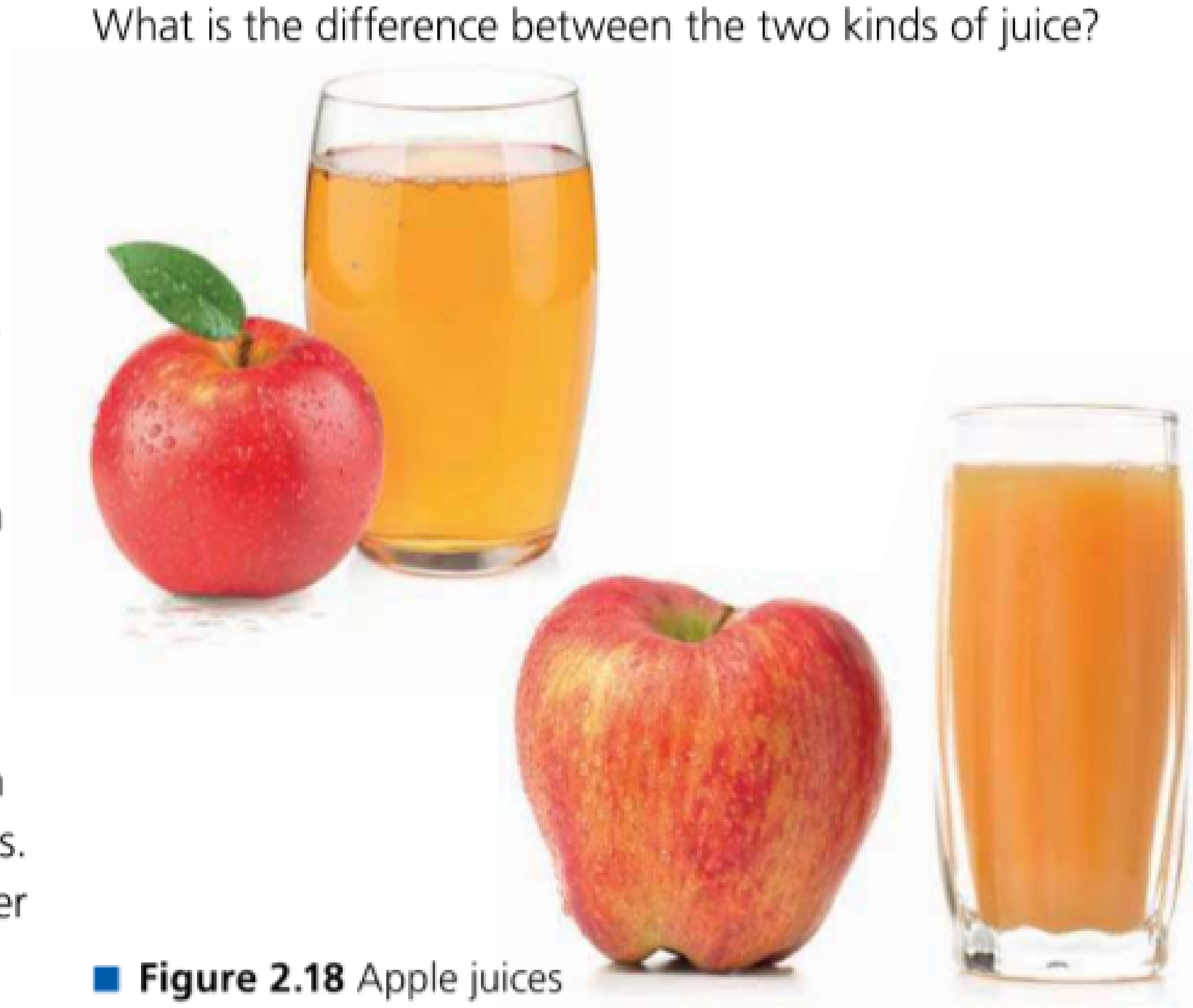
We can use the physical properties of each material in a mixture to separate the mixture into pure substances. A pure substance is any material that cannot be further split up by physical changes – although it may be

■ **Figure 2.17** Minerals in bottled water

possible to split up the pure substances using chemical changes, as we will also see later in this chapter.

It isn't always easy to tell whether we have a pure substance or not. Drinking water, for example, is rarely pure – a glance at the contents label of any bottled water will show that the water contains many dissolved minerals, which actually can be beneficial to our health in small quantities (Figure 2.17). Different dissolved minerals also give different bottled waters a slight 'taste', while really pure water (for example, the **distilled water** used in scientific laboratories) has no taste at all.

Look at the pictures of apple juice in Figure 2.18. What is the difference between the two kinds of juice?



■ **Figure 2.18** Apple juices

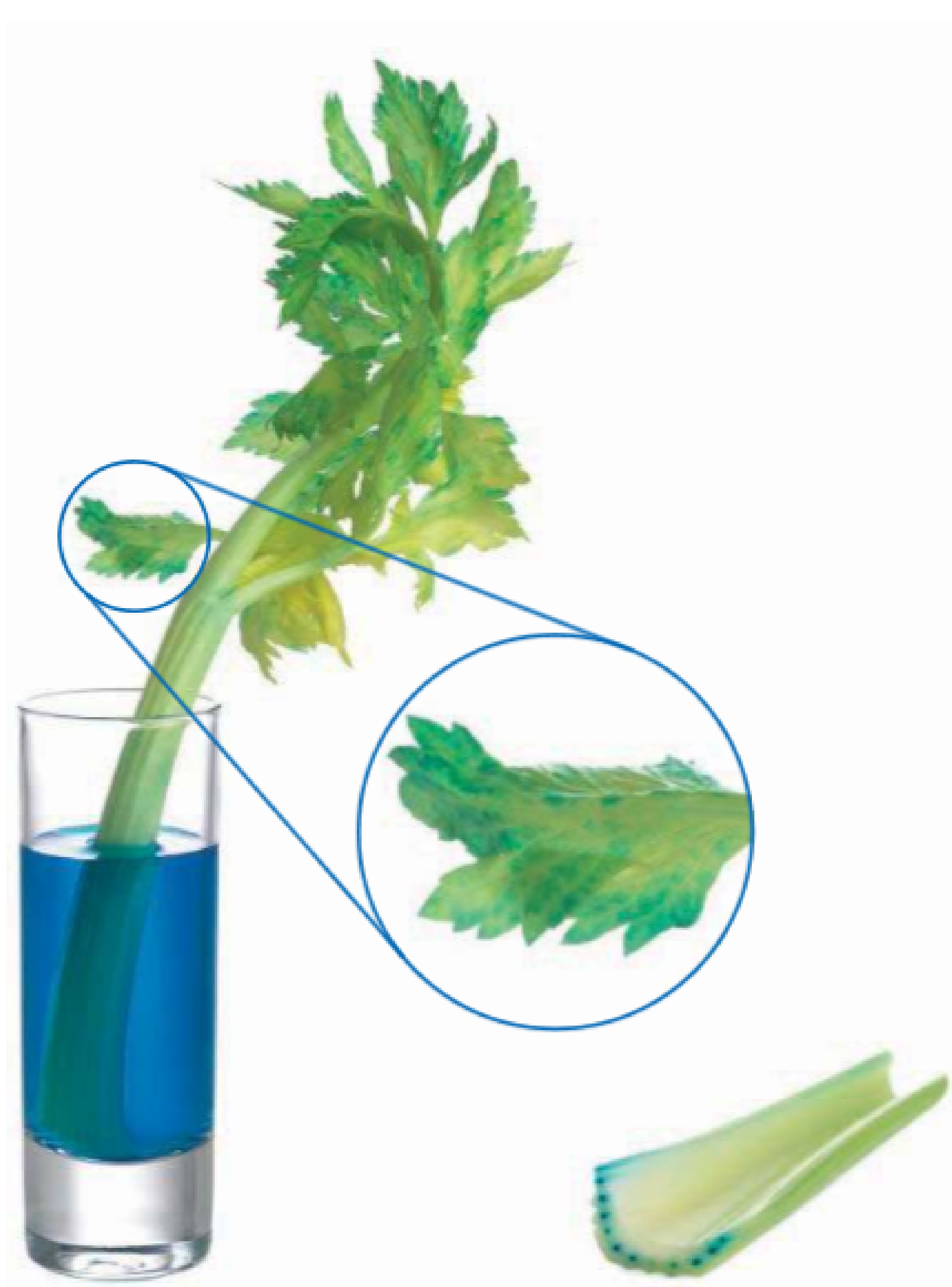
■ **Figure 2.19** Filter paper, magnified many times

■ **Figure 2.20** Coffee filter

■ **Figure 2.21** Dunking a biscuit

We can separate the materials in a suspension by using a method called **filtration**. The particles in a suspension are much, much larger than those in a solution, and we can use their different physical size to filter them out. A filter is a material that contains many **microscopic** holes or 'pores.' If we choose a filter whose pores are small enough to trap the suspended particles then the liquid part of the suspension will pass right through, leaving the suspended particles behind. Laboratory filter paper is made from tiny fibres that trap the larger suspended particles (Figure 2.19). Filters are also used in coffee makers, for example to remove the coffee 'grounds' from the coffee (Figure 2.20).

Another physical property used to separate mixtures of different liquids is to use their different solubilities. Have you ever dipped a biscuit in a drink? If so, you will have seen how the drink is **absorbed** by the dry biscuit and is drawn up into it (Figure 2.21). This is due to a process called **capillary action**, and it is also how plants draw water from the ground up into their stems (Figure 2.22). Different liquids are absorbed at different rates, so this can be used to separate them out in a process called **chromatography**.



■ **Figure 2.22** Capillary action in celery

ACTIVITY: Clear juice

ATL

- Critical-thinking skills: Practise observing carefully in order to recognize problems

In pairs, we will investigate filtration of suspensions.

SAFETY: Apple juice is tasty, but even if you are thirsty remember that in the experiment the juice is a chemical, and not to be drunk.

Inquiry: Which filter materials can be used to make clear apple juice from cloudy apple juice?

Background

When apples are crushed to make apple juice (sometimes called 'apple cider') a lot of small particles of the apple material remain suspended in the juice, making it cloudy.

Equipment

- **Different filters: coffee filter, laboratory filter paper, blotting paper, tissue paper, coarse-weave cloth**
- **Beakers**
- **Funnel**
- **Stirring rod**
- **Piece of white card with a cross drawn on it**
- **Cloudy apple juice**

Prediction

State which of the filters you have available will be effective in filtering the apple juice suspension, and which will not. **Explain** your reasoning using the science of filtering.

Outline how you will measure the effectiveness of the different filters.

Hint

What variable will you use to decide between the filtered juices? What is the card with the cross for?

Set up the apparatus as shown in the diagram (Figure 2.23).

Assessment opportunities

- This activity can be assessed using Criterion C: Processing and evaluating.

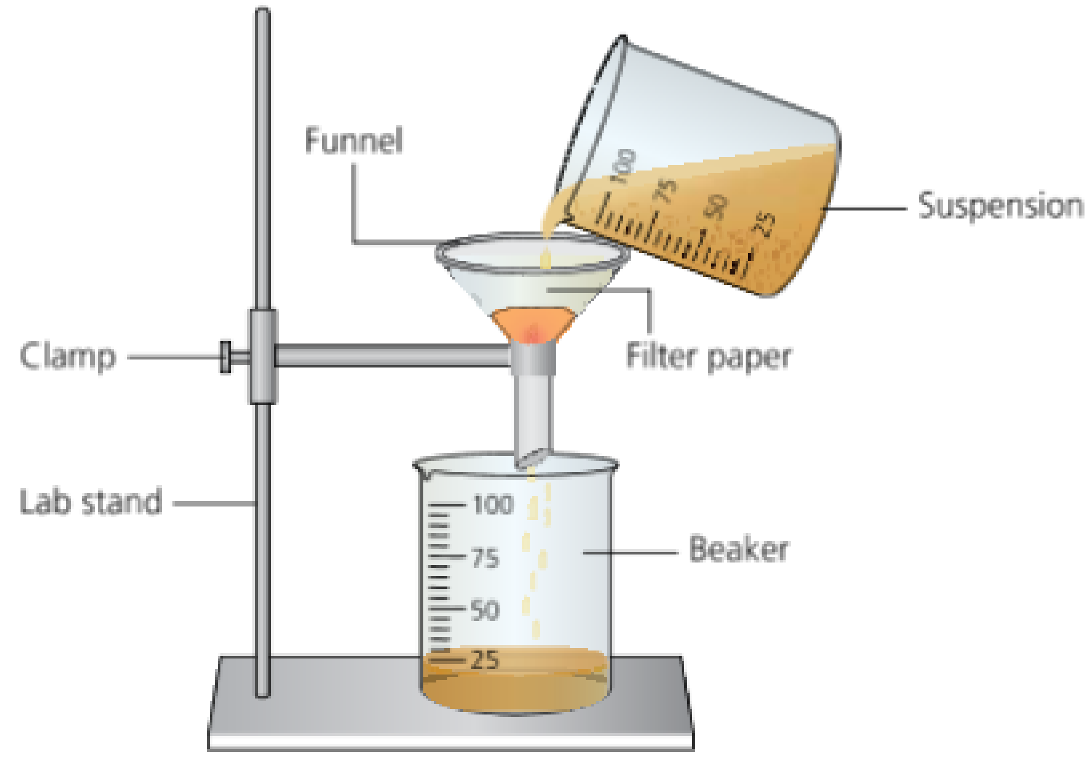


Figure 2.23 Filtration apparatus

Procedure

1. **Cut the filter into a circle whose diameter is 1–2 cm larger than the top of the funnel.**
2. **Fold the filter down the middle to make a semi-circle. Now fold it again to make a quarter-circle shape (see Figure 2.24).**

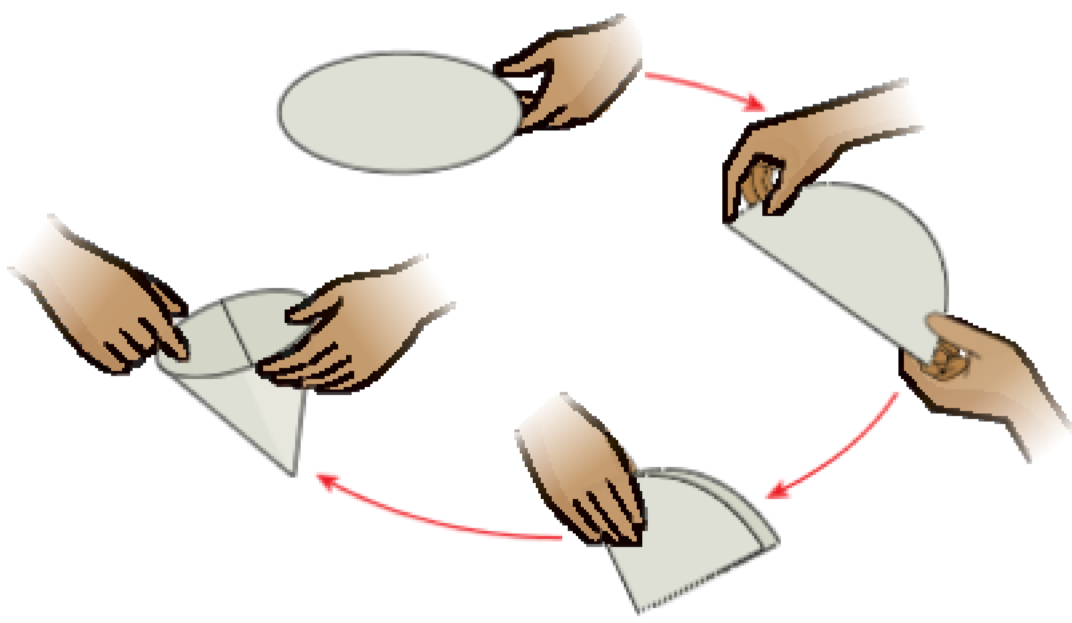


Figure 2.24 Folding a filter paper

3. **Open one fold so that you have a cone.**
4. **Place the cone in the funnel. If it doesn't stay open, dab a little water on the sides to stick it to the sides of the funnel.**
5. **Stir the cloudy juice thoroughly to make sure the suspended particles are not all at the bottom.**
6. **Pour the cloudy juice a little at a time to fill the filter cone half way.**
7. **Wait until all the juice has filtered through into the beaker.**
8. **Record your results clearly in a table, showing how you compared the different filtered juices.**

State which of the filters worked best. **Discuss** whether your prediction was correct. **Evaluate** your method, and **outline** how you could have improved it.

ACTIVITY: Colourful separation

ATL

- Critical-thinking skills: Draw reasonable conclusions and generalizations

In pairs, we will investigate how to use capillary action to separate mixtures of different liquids.

Inquiry: How many colours make black ink?

SAFETY: Do not ingest any of the fluids.

Background

Black marker pens use ink made from a mixture of other, differently coloured inks. The different coloured inks have different solubilities in different solvents. Most board-marker pens use water-based inks so water can be used as a solvent, but other solvents can also be used. Solvents to try are:

- A mixture of water and vinegar (10 volumes water to 1 volume vinegar)
- Window cleaning fluid
- Distilled water

Prediction

State your predictions for these questions, and then **explain** your views with scientific reasoning, or perhaps from your own experience!

- How many colours are required to make black ink?
- Which solvent will work best?

Equipment

- Strips of filter paper (coffee filter paper works well) approximately 2 cm × 20 cm
- 250 ml beaker
- Paper clip
- Ruler
- Black marker pen
- Solvents (as listed above)

Procedure

1. Draw a line with the marker pen across the bottom of the filter paper strip, about 1.5 cm from one thin edge.
2. Pour a solvent into the beaker, to a depth that is a little less than 1.5 cm.
3. Carefully lower the filter paper strip into the beaker so that the bottom just dips into the solvent. Attach the strip to the rim of the beaker using the paper clip.
4. Observe what happens as the solvent is absorbed into the filter strip!
5. Repeat the experiment for the different solvents.
6. Record your observations in a table that allows you to compare the different tests you have carried out.

Write a conclusion for your experiment and **evaluate** it. Was your prediction demonstrated? Was the experiment a valid way to answer the inquiry question? Could you have improved it? **Outline** your ideas and improvements.

Assessment opportunities

- This activity can be assessed using Criterion C: Processing and evaluating.

Links to: Art

Have you ever mixed paints in Art to make new colours? In the activity *Colourful separation*, we have seen how the dyes used to make a single colour can be separated – so you can see which colours have been used to make the ink!

WHAT MAKES YOU SAY THAT?

■ **Figure 2.25**

■ **Figure 2.26**

Look at Figures 2.25 and 2.26. **Discuss** in pairs:

- **What do you think is going on in the pictures?**
- **What makes you say that?**
- **What might connect the two pictures?**

We saw earlier in the chapter how temperature changes lead to changes of physical state, and how this happens all the time to water in the environment. We can use change of state to separate mixtures because materials have different melting and boiling points. This means that we can use temperature to separate solutions – because increasing the temperature of the solution will cause the different materials in the solution to boil and separate, leaving behind the material with the highest boiling point (as long as we don't raise the temperature *that* high). Of course, the situation becomes a little more complicated if the material we want to collect is the material that boils away first – as is the case if we wanted to collect the water evaporating from the salt pans in Figure 2.25. If we could collect the evaporated water, then we might be able to produce drinkable, pure water from undrinkable, salty sea water. Does Figure 2.25 give you a clue as to how we could do this?

DISTILLATION

The process of heating a solution or mixture to separate out its component materials is called **distillation**. Distillation (Figure 2.27) is used in all kinds of processes – for example in some countries it is used to separate out and purify the alcohol from solutions made through the process of **fermentation**, to produce strong alcoholic drinks. Fossil fuels such as gasoline, diesel or paraffin are separated out from crude oil using a similar process.

ACTIVITY: Laboratory disaster!

■ ATL

- Creative-thinking skills: Create novel solutions to authentic problems

Disaster! A bird flew into the laboratory store at your school and while flapping around it broke the containers for a number of materials.
All of the materials from the containers are now thoroughly mixed up.

Table 2.3 shows the different materials in the mess, and some of their properties.

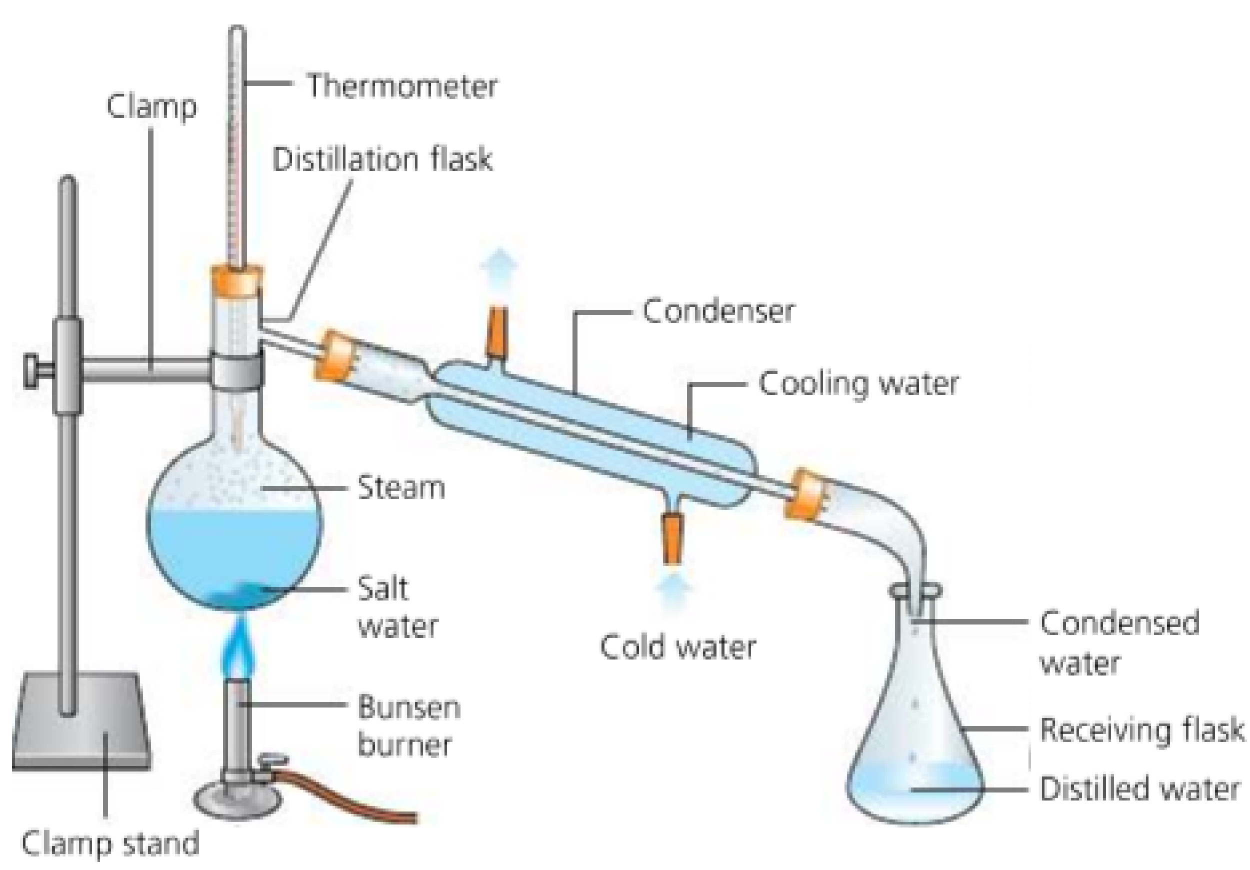
Material	Property
Sand	Insoluble
Salt	Soluble
Iron powder	Magnetic, insoluble

■ **Table 2.3**

Interpret the information in Table 2.3 and then **outline** a procedure for separating the mixture. In your procedure, **describe** each process carefully and **explain** how you made a scientific judgment so that each of the materials in the mixture will be obtained.

◆ Assessment opportunities

- In this activity you have practised skills that can be assessed using Criterion A: Knowing and understanding.



■ **Figure 2.27** Full distillation apparatus

ACTIVITY: Separation by distillation

ATL

- Critical-thinking skills: Analyse complex projects into their constituent parts and synthesize to create new understanding

In pairs or groups, we will use different boiling points to separate a solution.

Inquiry: How can we collect evaporated water?

Background

Sea water is not good to drink! It contains many dissolved minerals, in particular a relatively high quantity of dissolved salt. By using evaporation, we could separate the solution of salt and water.

In this experiment, we will use some simple apparatus to separate a solution of salt and water.

SAFETY: If you have never used a Bunsen burner or electric heater before, you will need to practise doing so safely. Alternatively, this experiment may be demonstrated by your teacher. If you are allowed to carry out the experiment yourselves, complete a safety assessment for the experiment. Refer to the safety rules you agreed in the Chapter 1 activity *Making up the rules*.

Use these guiding questions to consider the important safety points for your safety assessment: What could happen if you touch the apparatus after it has been heated? What could happen if you continue heating the beaker when all the water has been evaporated away?

Equipment

- **Salty water**
- **Glass funnel**
- **100 ml beaker**
- **Tripod, gauze and heatproof mat**
- **Bunsen burner or electric heater**
- **Safety glasses**
- **Ice cubes**
- **Test tube**

Set up the apparatus as shown in the diagram (Figure 2.28). Note that the stopper is placed inside the funnel so that meltwater from the ice cannot escape.

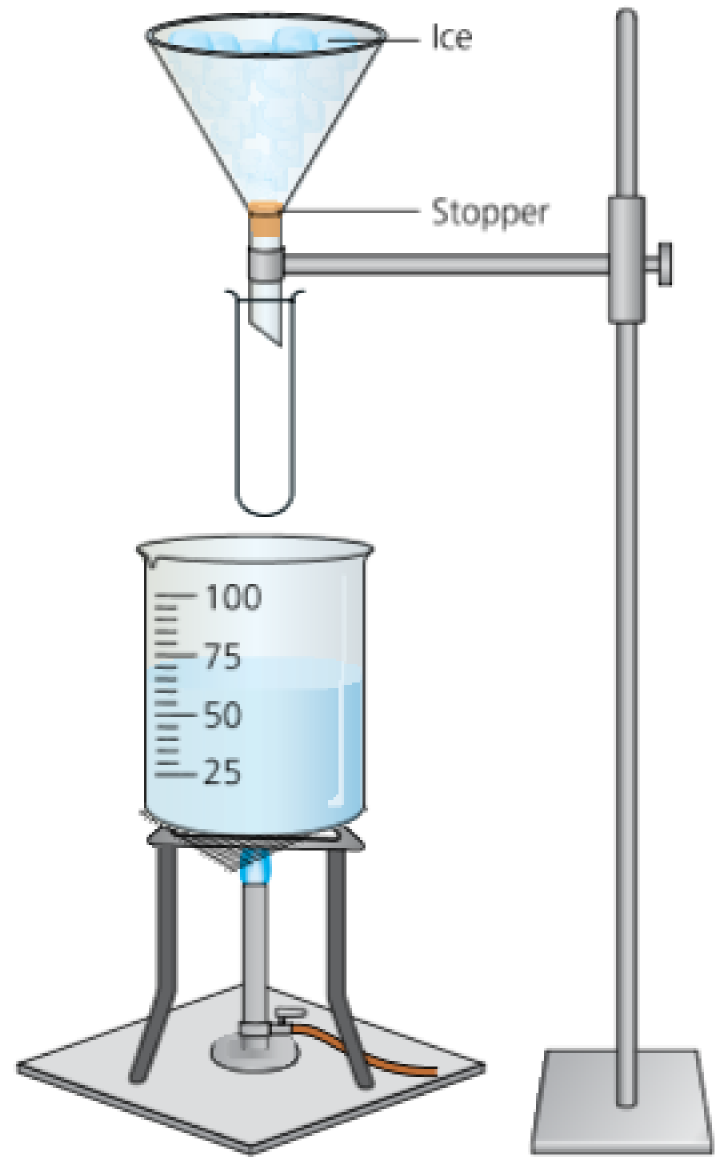


Figure 2.28 Simple distillation experiment

Prediction

State your answers to the following questions and **explain** using scientific reasoning.

- **What will happen to the water when it reaches boiling point, 100°C?**
- **What will happen to the salt in the solution when the water boils?**
- **What will happen to the steam from the boiling water when it touches the funnel containing the ice cubes?**
- **What will be collected in the test tube?**

Procedure

1. **Pour 50–100 ml of salt solution into the beaker.**
2. **Place the beaker on top of the tripod and gauze.**
3. **Make sure the funnel is positioned over the top of the beaker.**
4. **Light the Bunsen burner. Set to a blue flame. If you are using an electric heater, turn it on.**
5. **Continue heating the beaker until all the water has evaporated from the beaker.**

Record your observations. What is left in the beaker at the end? What is in the test tube?

Write a conclusion to **explain** what happened in the experiment. Refer to the questions you answered for the prediction at the beginning. How might the products of this process be used?

How do chemical changes happen?

THINK–PAIR–SHARE

Look at the images in Figure 2.29.

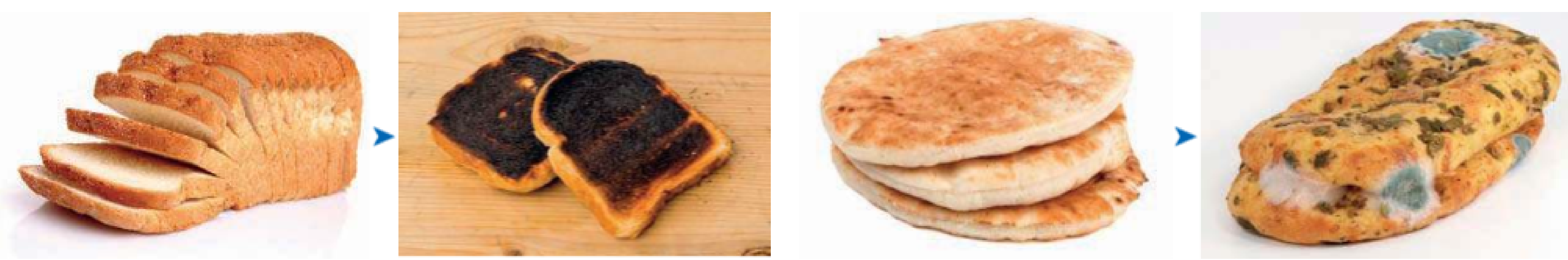
- **Think: What connects the images? What is different between the images?**
- **Pair: What has caused the changes you see?**
- **Share your ideas with the class. What kinds of changes are these?**

As we already discussed, all of the changes we have looked at so far are physical changes because we are not changing the materials themselves, only re-arranging them in some way. Ice is made from water molecules (H_2O) that are strongly joined together, while in liquid water the water molecules are less strongly joined and so they can move about in a container. Finally, in steam, the water molecules are not joined at all and can whizz around and fill a container with gas. All the same, in every case we still have water: H_2O.

This is not the only kind of change we can see going on around us, even when humans are not involved!

In the examples in Figure 2.29, the bread has changed in a new way. The material we have after the change occurs has quite different properties. Both of these are examples of chemical changes. Burning toast is an example of a process called **oxidation**, while the process of bread being changed by the growth of mould on its surface is an example of **decomposition**. Decomposition is a biological or **biotic change** also, because the chemical changes that are happening in the bread are caused by living things – in this case, bacteria and fungi.

Table 2.4 summarizes some common kinds of chemical and biological change, and the observable changes.



■ **Figure 2.29** Two kinds of chemical changes that can happen to bread

Name of change	Chemical/biological	Description of change	Observations
Oxidation	Chemical	Oxygen joins chemically to a material	Change of colour; change of physical structure; heat is released
Displacement	Chemical	One atom or molecule chemically joined to another atom or molecule is replaced by a different atom or molecule	Change of colour; sometimes change of physical state
Neutralization	Chemical	An acid and a base react to form new chemicals	Change of pH value; gas sometimes released
Decomposition	Biological	Bacteria digest organic material, breaking down large molecules into smaller ones	Gas released; odour; colour change; change of physical structure (often to liquid)
Fermentation	Biological	Bacteria or fungi cause a reaction that produces alcohol	Alcoholic liquid with odour is produced; gas (carbon dioxide, CO_2) released

■ **Table 2.4** Some chemical changes and their characteristics

ACTIVITY: Making a chemical change happen

ATL

- Critical-thinking skills: Draw reasonable conclusions and generalizations

In pairs, we will investigate an example of a chemical reaction.

Inquiry: What happens when something rusts?

Background

When objects that contain iron (Fe) – such as steel nails – are left in the open air, they slowly change. The process is commonly called rusting.

Discuss: Why might rusting be a problem? In what situations, and to what kinds of things, does it occur?

In this experiment, we will **investigate** what causes rusting. Our independent variable to change will be the conditions in which the nail is kept.

Prediction

Which of the following situations will cause the most rusting?

- **Dry air**
- **Water**
- **Vegetable oil**
- **Copper sulphate solution**

State your answer and **explain** using scientific reasoning, with reference to what we have learnt about chemical changes.

Equipment

- **4 iron or steel nails**
- **4 test tubes, with bungs (stoppers)**
- **Cotton wool**
- **Distilled water**
- **Vegetable oil**
- **Copper sulphate solution**

SAFETY: Copper sulphate is poisonous if we ingest it – which means we must not swallow copper sulphate. Be very careful when using the chemical not to get any on your hands, or especially near your mouth. If you do get the chemical on your hands, wash them immediately.

Procedure

1. **Place a nail in each of the test tubes.**
2. **In the first tube, push cotton wool into the top of the test tube and then seal with the stopper.**
3. **In the second tube, pour distilled water over the nail until it is completely covered. Seal with the stopper.**
4. **In the third tube, pour vegetable oil over the nail until it is completely covered. Seal the tube.**
5. **In the fourth tube, pour copper sulphate solution over the nail. Seal the tube.**
6. **Leave the test tubes in a place they will not be disturbed for at least one week.**

Results

After one week, look at the nails in the tubes. **Record** your observations in a way that makes it possible to compare. Consider how to **compare** the amount of change you observe in each test tube.

If possible, repeat for up to three weeks.

Conclusion

Describe what is happening to the nails in the tubes. **Outline** any chemical changes that may have occurred. Using Table 2.4, **identify** the kind of chemical change that is occurring. **Explain** your reasoning.

Evaluation

Has your experiment enabled you to **identify** the conditions that cause rusting? Has anything else happened? What improvements could you make? What further investigations do your results suggest?

Assessment opportunities

- This activity can be assessed using Criterion C: Processing and evaluating.

What prevents us from giving access to pure water to everyone?

SEE–THINK–WONDER

Look at Figure 2.30.

- **What do you see?**
- **What does the image make you think?**
- **What does the image make you wonder?**

Figure 2.30 Collecting water for life

EXTENSION

Find out about the difficulties caused by having to collect water this way every day. What are the health problems associated with drinking water from natural sources?

The most effective way to provide clean water for all is to provide pumps that can draw water from deep underground, where it is often cleaner. Use the search term Water Aid to find out about projects to help bring fresh water to all.

Take action: Clean water for all?

ATL

- Information literacy skills: Access information to be informed and inform others
- Creative-thinking skills: Create novel solutions to authentic problems

! In many parts of the world, clean, pure water is hard to find. People who live in areas without fresh water supplies have to obtain their water from natural sources such as rainfall – but if they also live in a place with little rainfall, they must collect their water from ponds, lakes or rivers.

- **Your goal:** You are the chief scientist for a charity that is concerned with bringing clean water to the less economically developed world. Your clients are health agencies in another country that wants to extend clean water to everyone. You must **design**, **test**, and market a water purifier that will turn dirty water into pure, clean drinking water. You need to design and test a clean-water maker that will be easy to assemble and cheap to make. The clean-water maker must work without access to electricity or gas!
- **Your product:** You will produce a working laboratory 'model' of your clean-water maker. It doesn't have to be exactly as it will be made in real life, but it must **demonstrate** the science behind the purification of water. Your clean-water maker will be tested for the purity of the water it produces.

! When you have **designed**, built and tested your water purifier, prepare a presentation of your design and present it to your class! In your presentation, **explain** how you have used the science of separation and purification to solve the problem of providing clean water for all. Be sure to research the problems faced by people who do not have easy access to clean water, and **document** your sources. Use everybody's ideas to produce the best water purifier you can as a group.

Assessment opportunities

This activity can be assessed using Criterion D: Reflecting on the impacts of science.

Reflection

In this chapter, we have **classified** materials as natural or artificial and **suggested** uses for them. We have **outlined** three states of matter using their physical properties and **identified** what happens when they change. We have **classified** mixtures, suspensions, solutions and pure substances, and **defined** solutions, solutes and solvents. We have then **explained** how dissolving occurs, and **described** some special forms of solutions such as some crystals. We carried out experiments that **demonstrated** ways to separate mixtures, suspensions and solutions using their physical properties, and finally we **identified** some chemical and biological changes.

<table>
<tr><th colspan="6">Use this table to evaluate and reflect on your own learning in this chapter.</th></tr>
<tr><td>Questions we asked</td><td>Answers we found</td><td colspan="4">Any further questions now?</td></tr>
<tr><td>Factual: What are things made from? How do we classify materials? What changes do we observe every day? How do physical changes happen? How do chemical changes happen?</td><td></td><td colspan="4"></td></tr>
<tr><td>Conceptual: How might physical and chemical changes help us to manipulate materials? What does purity mean in science?</td><td></td><td colspan="4"></td></tr>
<tr><td>Debatable: What prevents us from giving access to pure water to everyone?</td><td></td><td colspan="4"></td></tr>
<tr><td rowspan="2">Approaches to learning you used in this chapter</td><td rowspan="2">Description – what new skills did you learn?</td><td colspan="4">How well did you master the skills?</td></tr>
<tr><td>Novice</td><td>Learner</td><td>Practitioner</td><td>Expert</td></tr>
<tr><td>Critical-thinking skills – we have practised observing carefully, generated testable predictions, and generalized to make conclusions.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Creative-thinking skills – we have found ways to separate and purify materials.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Transfer skills – we have applied skills and knowledge in unfamiliar situations.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Information literacy skills – we have accessed information about the problems associated with lack of access to clean water.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Learner profile attribute</td><td colspan="5">How did you demonstrate your skills as an inquirer in this chapter?</td></tr>
<tr><td>Inquirer</td><td colspan="5"></td></tr>
</table>

3 How do living things work?

By understanding the **relationship** between the necessities of life and the specialized **forms** and **functions** of living things, we can make decisions and take actions for healthier and more **sustainable** lifestyles.

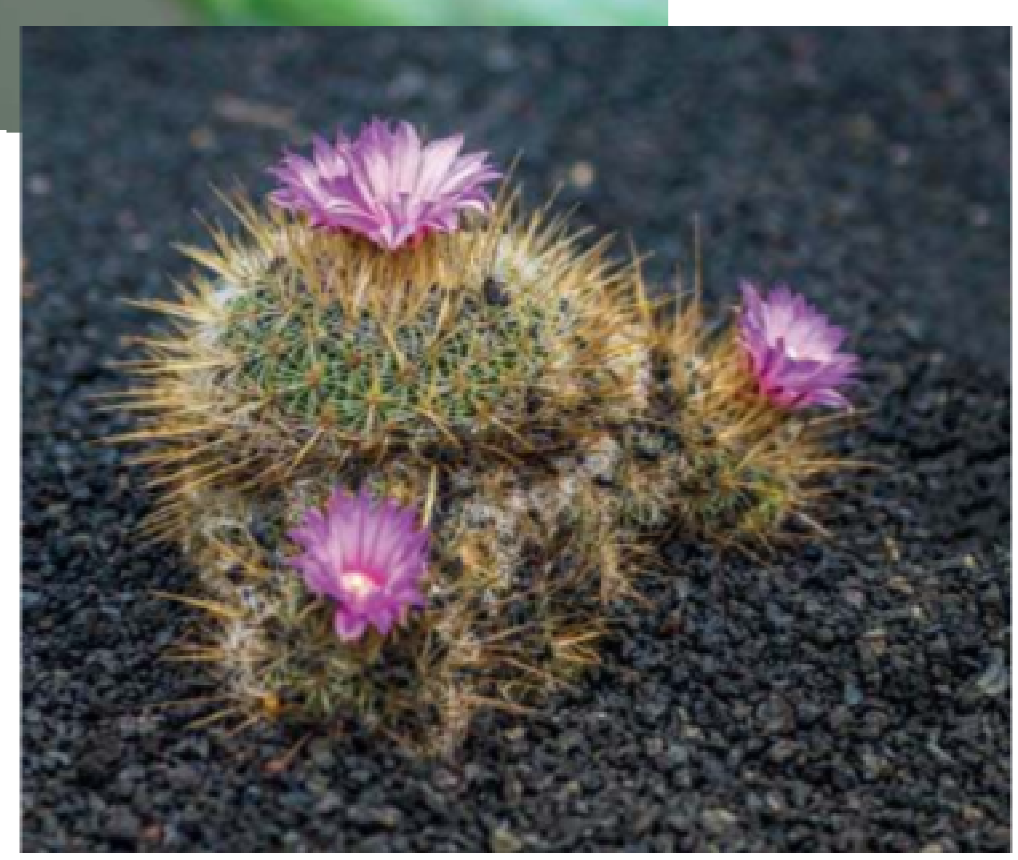


Figure 3.1 Living things look so different, and yet in fact are so similar

CONSIDER THESE QUESTIONS:

Factual: Are all living things different? What are the characteristics of living things? What are the necessities of life? What are specialized forms and functions of living things?

Conceptual: How can we use our understanding of the characteristics, needs, forms, and functions of living things to make healthier and more sustainable decisions and actions? How are our decisions and actions limited by the needs, forms and functions of living things?

Debatable: To what extent should we take decisions and actions that benefit some human lives but have a negative effect on other living things?

Now **share and compare** your thoughts and ideas with your partner, or with the whole class.

IN THIS CHAPTER WE WILL ...

- **Find out** what characteristics and needs all living things share, and which are specialized for different types of organisms.
- **Explore** the relationship between the specialized forms and functions of living things and where and how they live.
- **Take action** by advising people how to save money and eat more healthily by producing and growing some of their own food.

● We will reflect on this learner profile attribute …

- Communicators – we will collaborate effectively and express ourselves confidently.

◆ Assessment opportunities in this chapter:

- **Criterion A:** Knowing and understanding
- **Criterion B:** Inquiring and designing
- **Criterion C:** Processing and evaluating

■ These Approaches to Learning (ATL) skills will be useful …

- Communication skills
- Media and information literacy skills
- Critical-thinking skills

KEY WORDS

characteristics	reproduce
complex	specialized
DNA	stimuli
genes/genetic material	structure
modified	

For this chapter, you will take the role of a professional blogger for a blog that focuses on healthy living and life choices. Professional bloggers research and write articles for online audiences. You have been assigned to create a blog post about strategies for growing and making some foods, such as sprouts, yogurt, or bread dough, from home in a natural, inexpensive, and **sustainable** way. In order to create the post, you must first investigate and identify a strategy for growing or preparing the food in a systematic and reliable way that anyone could do from their own home.

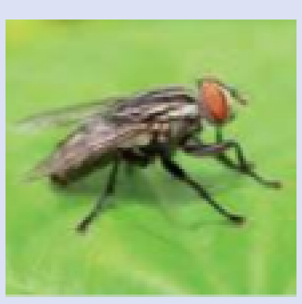
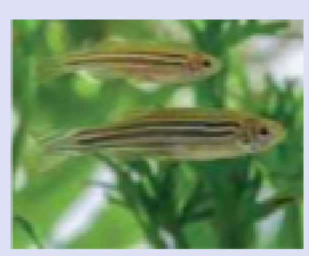
Are all living things different?

■ **Figure 3.2** Examples of different living things

ACTIVITY: Sharing DNA

How much do we have in common with the other living things that surround us? If we think about our **DNA** (the chemical 'alphabet' inside the cells of all living things that provides the instructions for how we function and look), how much of the DNA 'alphabet' forms the same 'words' between different organisms? For example, what percentage of our DNA 'instruction manual' is the same as in the banana you eat with breakfast, the fruit flies in your kitchen, the chimpanzee in the wild, a pet dog or zebrafish, or the bacteria that surround us? Pause now and **write down** your **predictions**.

■ **Table 3.1** Predictions of shared DNA

I think we have ...	______%	______%	______%	______%	______%	______%
of our DNA in common with ...	bananas 	fruit flies 	chimpanzees 	dogs 	zebrafish 	bacteria 

ACTIVITY: Similarities and differences

Observe the pictures of the living things in Figure 3.2. In a copy of Table 3.2 **list** what you notice is similar or shared between all of the organisms, and what you notice is different or dissimilar. Then complete a copy of Table 3.3 with your ideas on why living things are all similar, yet different.

Some similarities I notice between all the living things are ...	Some differences I notice between all the living things are ...

■ **Table 3.2** Some similarities and differences between living things

I think living things are similar in these ways because ...	I think living things have these differences because ...

■ **Table 3.3** Thoughts about similarities and differences

Now that you have finished making your predictions, look at Table 3.4 for the correct percentages.

Does the information in the activity *Sharing DNA* surprise you? Does it seem strange to you that 85% of our DNA is the same as a fish? Or that we have 7% of our DNA in common with the microscopic, single-celled bacteria that can make us ill? Or that half of our DNA is the same as a banana?

Percentage of DNA shared	Living thing
50%	bananas
36%	fruit flies
98%	chimpanzees
84%	dogs
85%	zebrafish
7%	bacteria

■ **Table 3.4** Percentage of DNA shared with various living things

It may seem strange or unexpected at first, but, actually, when we think about the fact that we are all living things, that we all have the same basic needs for survival and the same basic characteristics that make us 'living', it can make a bit more sense that we have so many similarities in our DNA 'instruction manuals'.

In this chapter, we will learn more about those shared characteristics and needs. We will explore how we can use our understanding of our commonalities in order to live healthy, more sustainable lives. And then, we will put our knowledge and understanding into action by investigating, developing, and blogging about strategies to help us grow or produce some foods in natural, healthy, and inexpensive ways.

What are the characteristics of living things?

What does it mean to 'be alive'? As we have already started to think about, all living things share certain characteristics and have some of the same needs. Table 3.5 explains some of the characteristics of all living things, with an example of each of them.

DISCUSS

With your partner or as a class, create two lists. One list should be headed 'Characteristics of all living things', and the other list should be 'Needs of all living things'. Be sure that you keep your list in a safe place – you will need it for an upcoming activity.

When you have finished your list, look at Table 3.5. What can you add or take away from your list? What other examples can you add for each characteristic?

I USED TO THINK … BUT NOW I THINK …

ATL

- Critical-thinking skills: Revise understanding based on new information and evidence

As you read the information from Table 3.5 and learn more about living things, change or add to the list you made of 'Characteristics of living things'. Share your new list with your class.

Characteristic *All living things ...*	Explanation	Example
Are made of one or more cells	Cells are the smallest units of life. Cells have specialized smaller structures inside them, which perform chemical reactions (**metabolism**) that keep the **organism** alive. Some living things are single-celled and others are multi-celled.	Bacteria are single-celled organisms.
Use energy for life functions	Living things take in substances that they can use in chemical reactions (metabolism) that produce energy. These chemical reactions are part of the process of **cellular respiration**, which occurs in every cell of every living thing. Living things use this energy to perform all life functions.	Plants use water and carbon dioxide to produce a sugar that their cells use to make energy by cellular respiration.
Respond to stimuli	A **stimulus** (plural: stimuli) is something that causes a reaction. For living things, a stimulus can come from their surroundings or from inside their cells. Stimuli can be physical – like feeling the wind or a sharp surface; chemical – like the presence of water or a gas; or energetic – such as sunlight or electricity. All living things can detect different kinds of stimuli and then react or respond to the stimuli in ways that help their survival.	A dog smells food and begins to produce extra saliva that will help it digest the food.
Maintain homeostasis	The root 'homeo' means *similar* or *the same kind*, while 'stasis' refers to *stability*. Therefore maintaining **homeostasis** means that an organism is able to make physical or chemical adjustments so that conditions within the organism stay in the same stable state.	You sweat when it is hot so that you can maintain a safe body temperature.
Grow and develop	All living things grow and develop over time by reproducing new cells to add to existing cells, or to replace dead or damaged cells. Even organisms that are made of only one cell grow during their life cycle!	A plant begins as a seed and adds new cells so it grows over its whole life.
Reproduce	Some living things (mostly single-celled organisms) reproduce by **asexual reproduction**, which means the organism **clones**, or makes a copy of, itself. Other living things reproduce by **sexual reproduction**, which requires a male and a female to combine **genetic information** in order to produce a new, unique individual, or **offspring**.	A single bacterium clones itself by doubling all of the contents of its cell and then dividing, so that there are two identical cells instead of one.
Contain genetic material	Inside each cell is genetic information, usually in the form of DNA. DNA gives an organism its characteristics. DNA acts as an 'instructional manual' of sorts, so that each cell can perform the functions necessary to sustain life. DNA is **inheritable** – this means that during the process of reproduction the DNA is passed to the new cells, so that each offspring has the 'instructional manual' from its parent or parents.	The genetic information of male and female dogs combines during the process of sexual reproduction, so that the puppies have characteristics of the mother and the father.
Adapt to their environment and evolve over time	Sometimes, by chance, the genetic information of an individual results in characteristics that are different from most of the other individuals in the species. If those differences make it easier for that individual to survive, it is more likely that it will reproduce and pass on these characteristics in its DNA to its offspring. This will make the offspring more likely to survive and reproduce ... and so on. After some time, these changes, or **adaptations**, can result in a new species. This means that **evolution** has occurred.	Some bacteria have genetic information that make the cells resistant to antibiotics (a type of medicine people take when they have some kinds of infections). This means those bacteria will not be damaged by the antibiotic medicine, and they will keep reproducing. After some time, a new species of bacteria can evolve.

■ **Table 3.5** Characteristics of living things

ACTIVITY: How to survive

ATL

- Media literacy skills: Locate, organize, analyse, evaluate, synthesize and ethically use information from a variety of sources and media

For each of the groups, or **kingdoms**, of organisms, write an example of each characteristic of living things in a copy of Table 3.6.

To find out more, use the search term: characteristics of life. If you are not sure of what the specific characteristics of life are for the different kingdoms of organisms, you could search, for example: how fungi reproduce and use the responses to inform your answer.

Be careful, though! You should be able to **explain** in your own words everything that you write in your copy of Table 3.6. So, if your Internet search provides you with words that you are unfamiliar with, you will have to look up *those* words (either in a web or image search) so that you understand what you are writing about. Also, be sure to credit the sources of information by writing the websites in your table. The first one has been done for you as an example.

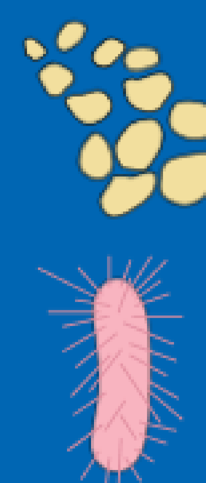
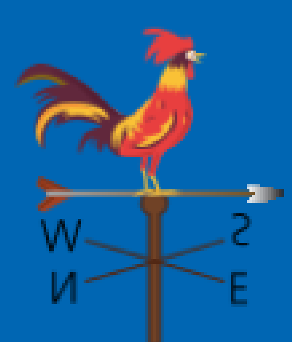
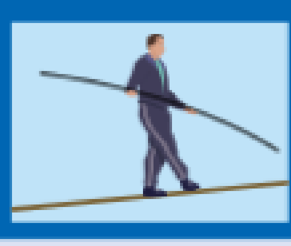
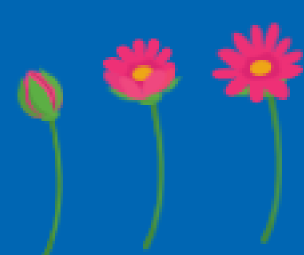
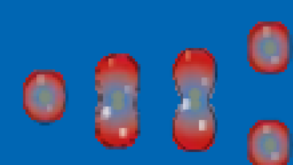
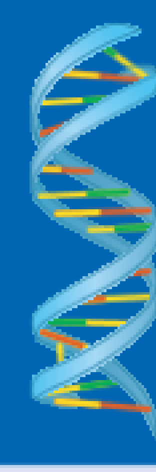
All living things ...		
Kingdom of organisms	Are made up of cells 	Use energy for life functions 
	Animals are multi-cellular and contain many different types of cells	Use food as 'fuel' to make energy by cell respiration for all life processes
Plants		
Algae		
Fungi		
Bacteria		

Table 3.6 Examples of the characteristics of living thing

		Maintain homeostasis by ... 	Grow and develop by ... 	Reproduce 	Contain genetic information 	Adapt to their environment and evolve over time 	Sources
	Using their five senses and different parts of their body (eyes, nose, mouth, skin and ears)	Sweating or shivering or moving to hotter or cooler places if they get too hot or cold	Adding new cells so they get taller or bigger	Sexual reproduction	Animal cells have DNA that they pass on during reproduction	New species of animals have evolved over time, for example different types of finches on the Galápagos islands	Discovery news website

WHAT ARE THE NECESSITIES OF LIFE?

At the start of this section, you made a list of all the things you think are necessary in order for living things to survive. Figure 3.3 shows what two types of living things need to survive. Let us use what we learnt about the characteristics of living things as well as the information from the images in Figure 3.3 to identify or confirm the necessities of life. Make a list based on what you see in each picture. Then share your ideas with your partners and the class.

ACTIVITY: Survival

ATL

- Critical-thinking skills: Draw reasonable conclusions and generalizations

Look at Figure 3.3, copy the following sentence starters and then complete three lists:

1. **Figure 3.3 shows us that plants need …**
2. **Figure 3.3 shows us that animals need …**
3. **Because plants and animals are living things, we can combine their specialized needs to identify some *general* needs of all living things …**

We will come back to these needs in a later activity, when you will have to think of and research specific examples of these necessities for different types of living things.

Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding.

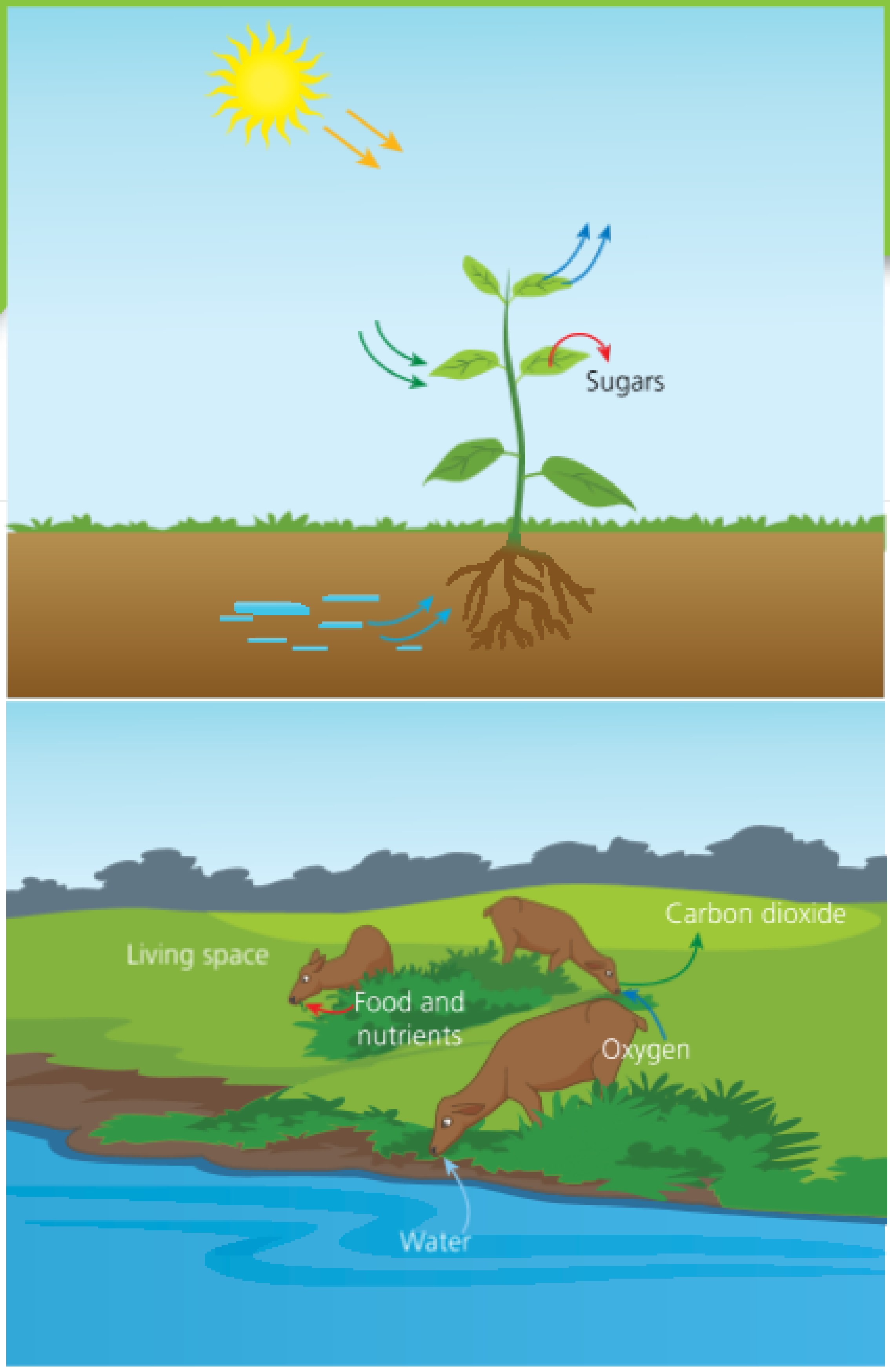


Figure 3.3 All living things require certain necessities to stay alive

From the pictures in Figure 3.3, we can see that in order to survive, all living things need:

- water
- air/gases
- a source of energy
- living space.

I USED TO THINK … BUT NOW I THINK …

ATL

- Critical-thinking skills: Revise understanding based on new information and evidence

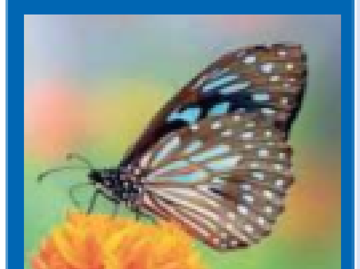
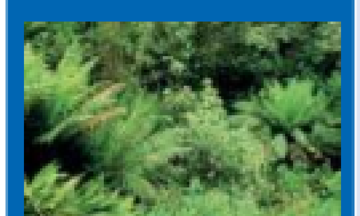
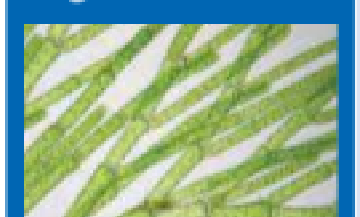
As you look at the information in Figure 3.3 and learn more about living things, change or add to the list you made of 'Needs of living things'. Share your new list with the class.

ACTIVITY: What do living things need?

For each of the kingdoms of organisms, write a specific example of what they need to survive, how they get access to their needs, or how they use them in a copy of Table 3.7.

If you are not sure of the specific needs of the organisms, you could search, for example: **source of energy for bacteria** and use the responses to inform your answer.

Be careful, though! You should be able to **explain** in your own words everything that you write in Table 3.7, as you did for Table 3.6. The row for animals has been completed for you as an example.

Kingdoms of living things	All living things need ...				
	Water	Air/gases	Source of energy	Living space	Sources
Animals 	Animals drink water to perform cell functions. Different animals need different amounts of water to survive. For example, lizards do not need much water while frogs need a lot.	Animals need the oxygen they breathe from the air, or take from the water in the case of fish, so that their cells can make energy in cell respiration.	The nutrients found in the food animals eat provide them with the raw materials necessary for cells to make energy in cell respiration.	Animals need enough living space with the right conditions according to the particular species. For example, species need different temperatures or different amounts of space to move around and find food.	
Plants 					
Algae 					
Fungi 					
Bacteria 					

■ **Table 3.7** Examples of the needs of living things

◆ Assessment opportunities

- In the activities *How to survive* and *What do living things need?* you have practised skills that are assessed using Criterion A: Knowing and understanding.

What are the specialized forms and functions of living things?

One of the most important underlying principles of biology, which is the study of living things, is that the different forms (or structures) of living things are closely related to their functions for survival. Scientists have spent a lot of time analysing these relationships between form and function. This is why, as we can see in the statement of inquiry, by understanding the relationship between the necessities of life and the specialized forms and functions of living things, we can make decisions and take actions for healthier and more sustainable lifestyles.

In this section, we will learn about some of those specialized forms and functions so that in the next section we can explore how we can use our understanding of those relationships to inform our decision-making.

First, we will look at the specialized structures that make up individual cells, and infer how those structures contribute to the function of the cells. Then, we will make connections between the forms and functions within cells to the forms and functions of larger organisms.

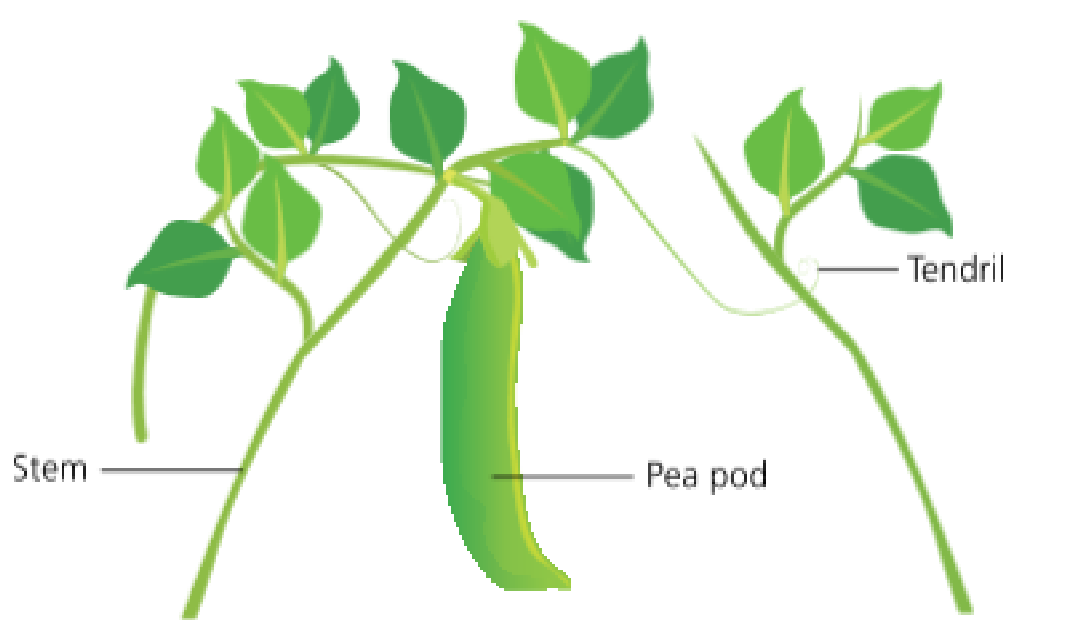
How do we infer information? In order to understand what you will have to do to infer the relationship between cell structures and functions, try an image search for the word **inferences**. What do you understand it means to 'infer' as a result of the images you see? What are some strategies you can use while reading to help you infer more effectively?

■ **Figure 3.4** The different forms of the pieces in a table setting match their functions for eating and drinking. How does this relate to the different forms and functions of living things?

CELL STRUCTURES

The different structures that make up a cell have specialized characteristics or forms that allow the cell to perform the actions necessary to support life. For example, through the activity *Cell structures and functions*, you will discover that ribosomes are small, round structures located throughout the cell so that the proteins they produce are available everywhere in the cell that the proteins are used.

This same principle can be applied to the form of different structures on larger, multi-celled organisms. For example, all plants have stems, but some plants, like the pea plant in Figure 3.5, have modified stems, known as tendrils, that allow them to grow around and up other objects. Also, all mammals have hair or fur, but only some, such as arctic foxes, have thick, fluffy fur. Others, such as giraffes, have short, thin fur.

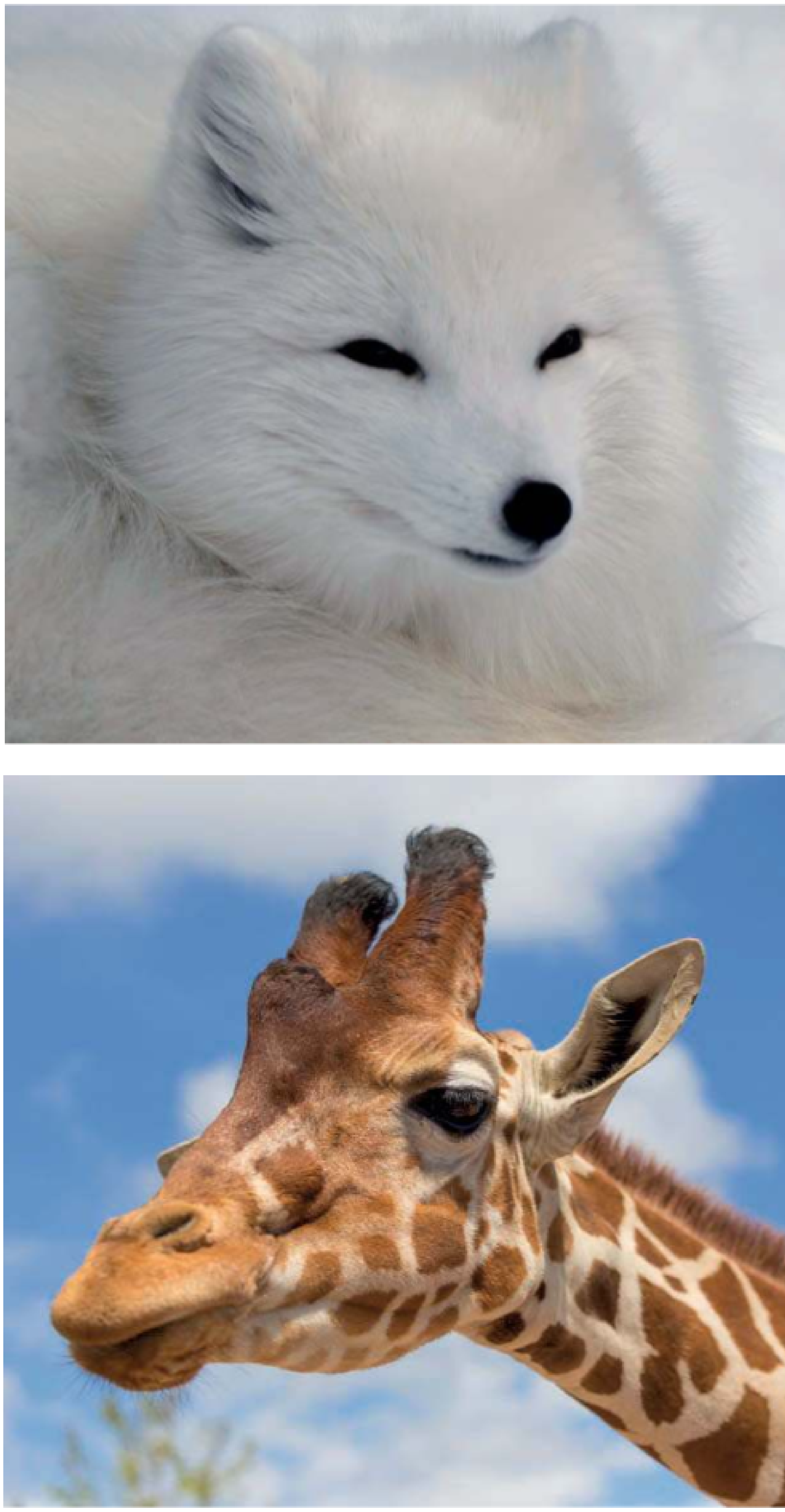


■ **Figure 3.5** Pea and bean plants have modified stems called tendrils

DISCUSS

Why do you think peas and beans have tendrils? Why would tendrils help the peas and beans survive?

How about artic foxes and giraffes – how does the type of fur that each species has help improve its chances of survival?



■ **Figure 3.6** Arctic foxes and giraffes have different types of fur: what differences do you notice?

ACTIVITY: Cell structures and functions

ATL

- Communication skills: Make inferences and draw conclusions; Paraphrase accurately and concisely; Organize and depict information logically
- Information literacy skills: Create references and citations

Open a new document in your Science folder, and title it 'Cell structures and functions'. Create a table so that you have a column for each of the following headings:

- **Cell structure**
- **Form: what it looks like (illustration or image)**
- **Form: what it looks like (written description)**
- **Function: what it does**
- **Sources**
- **How the form of the structure allows it to complete its function**

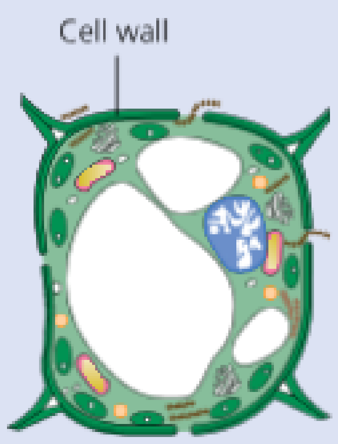
Then, add a row for each of the following cell structures:

- **Cell wall**
- **Cell membrane**
- **Nucleus**
- **Mitochondria**
- **Chloroplast**
- **Ribosome**

Conduct a web and image search to help you complete the Form and Function columns, and **document** the websites in the Sources column. Remember, you should not simply copy and paste the information you read about the form and function of the different cell structures; instead, you should read this information, **identify** the most important ideas, and write those ideas in your own words in the table.

Then fill in the last column, How the form of the structure allows it to complete its function, by making inferences and conclusions based on your research and prior knowledge.

An example is shown in Table 3.8.

Cell structure	Form: what it looks like (illustration or image)	Form: what it looks like (written description)	Function: what it does	Sources	How the form allows it to complete its function
Cell wall		The cell wall goes around the cell membrane in plants and some other cells such as bacteria and fungi. The cell wall looks rigid and tough and almost forms a 'box' around the cell. We can see some small holes in the cell wall.	The cell wall gives structure to the cell it surrounds. Nutrients and other important chemicals can pass into and out of the cell.		Because the cell wall is rigid and goes around the cell, it is able to support and give structure to the cell. This makes sense because plants do not have backbones or muscles to hold them up straight as they are growing. Also, because there are holes in the cell wall, nutrients and other things the plant needs can get through the wall and into the cell.

■ **Table 3.8** Example of how to organize information to infer the relationship between form and function

Complete the activity with a partner so you can come to an agreement about the most important information to include in the Function column, and how you can best express those important ideas in your own words. You can help each other **infer** and express the relationship between the form and the function when you complete the column, 'How the form allows it to complete its function'.

Then share your table with the class and come to a final understanding for each cell structure. Make sure you highlight or underline the information that you and your class **infer** as the most complete description of the function, and the relationship between form and function.

◆ Assessment opportunities

- In this activity, you have practised skills that are assessed using Criterion A: Knowing and understanding.

ACTIVITY: Where form matches function

ATL

- Critical-thinking skills: Draw reasonable conclusions and generalizations

Use the information listed below to complete Table 3.9 with forms, functions and the relationship between the form and functions of the specialized structures in plants and animals. An example has been highlighted for you.

These are the forms, functions and 'form matches function' explanations you can choose from.

Forms

- **Tightly closed structures that are covered by a meltable plastic-like substance called resin.**
- **Balloon-like structures that grow off the cells.**

Functions

- **They function as an expandable storage space while the cell makes copies of its genetic information and other cell contents. Each one will eventually break off as a new cell.**
- **Store water**
- **Whips back and forth or spins around like a propeller to move the cell.**

Form matches function

- **Young plants need to get access to plenty of sunlight to grow. After a fire, the forest floor is likely to be open to the sky, which will give the sprouts a chance to get the sunlight they need to grow.**

Kingdom	Structure	Form
Plant	Stem 	Thick, spongy stems
Plant	Cone 	
Bacteria	Flagella 	Long, thin, tail-like structure that comes off the end of the cell
Bacteria	Nucleoid region 	The chromosomal DNA is one small, circular strand that coils up around itself in a region of the cell known as the 'nucleoid' region (instead of in a nucleus). The plasmid is a separate, smaller ring-like structure of DNA.
Fungi	Budding vesicles 	

Table 3.9

- **Some cell types need to move towards nutrients and other chemicals that the cell needs to survive. The movement of long, thin shapes allows the cell to move in the direction it needs to go.**
- **The stems are like sponges, so they can store water whenever it is available, for use during drier times.**
- **The cells reproduce quickly, so it is important they have genetic information that can be quickly copied. Since there is no nucleus and the chromosomal DNA is small, it can be copied more quickly. Also, a plasmid DNA gives the advantage that the cells can survive in challenging environments.**

◆ Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding.

Discussion

What are some other specialized structures and forms that living things have? In pairs or as a class, **discuss** what purpose those structures serve in order to help in the organism's survival. You might also want to do a search on the Internet and have a contest to see who can find and explain the **benefits of the most bizarre or unique forms and functions**.

Inferences and forming conclusions

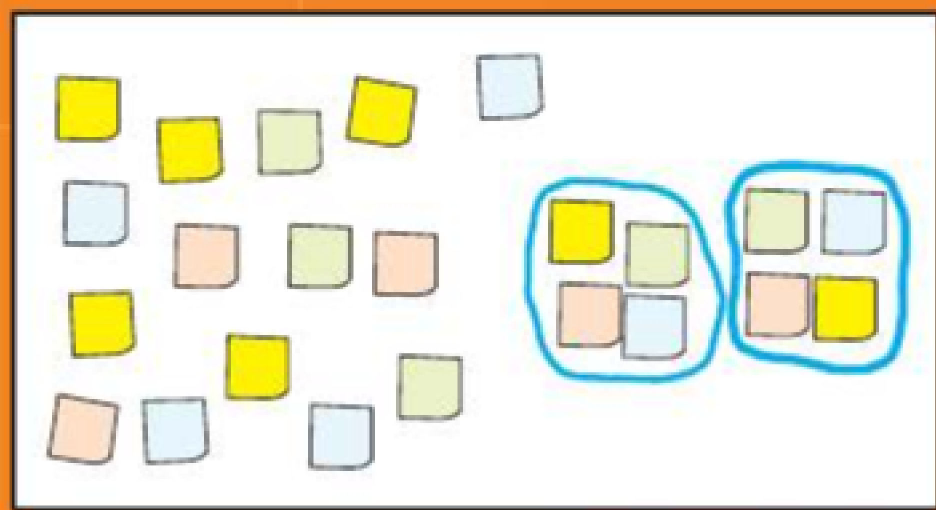
In this activity we have practised using our knowledge and understanding to make inferences and form conclusions, just as scientists do when they research and learn more about a new topic.

	Function	Form matches function because …	Example
	Store water	The stems are like sponges, so they can store water whenever it is available, for use during drier times.	Cactus
	To prevent sprouting until after a fire		Sequoia tree
			Helicobacter pylori
	The chromosomal DNA contains all the basic 'instructions' for the survival of the bacterial cell. The plasmid often contains 'instructions' for functions that benefit the bacteria, such as antibiotic resistance. The chromosomal and plasmid DNA are quickly duplicated during asexual cell reproduction, and can even be passed between separate bacterial cells.		*Escherichia coli*
		The budding vesicles provide space for all of the cellular contents that are shared during asexual reproduction. They allow the offspring to have the same genetic information and other cellular characteristics as the 'parent' cell.	Yeast cell

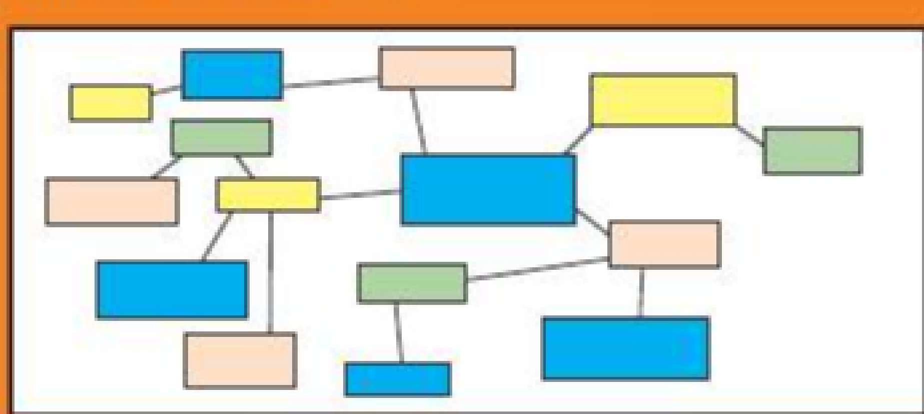
ACTIVITY: Generate, sort, connect, elaborate

Step 1: Generate (think about and write down) a list of the characteristics and necessities of living things and the specialized forms that different living things have to help them survive in their surroundings. You should also list any examples and important scientific words related to the characteristics, needs, and specialized forms and functions of living things. You can think of this as making a 'vocabulary list' of all the important words for this section. It is helpful to brainstorm this list with a partner or as a whole class. You can generate your list on a piece of paper, on your electronic device, or on sticky notes.

Step 2: Sort or **separate** the words into different categories or groups. Each category or group should have words that represent some sort of relationship or connection to characteristics, needs, and specialized forms and functions of living things. You may want to sort the words by colour-coding or making lists. Please note there is not one 'right' way to sort the words, and you may find that some words can easily go in more than one category. Again, talking with your classmates can help to identify different categories of information.



Step 3: Connect the words within and between categories by drawing lines or arrows. You could use a piece of blank paper to draw a 'mind map' or 'concept map' so that it is easier to show the connections between the ideas. If you used sticky notes, you can stick them on a large piece of paper or on a whiteboard to draw lines between the ideas. You could also make a table if you prefer. Try explaining the connections out loud to your partner in order to clarify your thinking for yourself.



Step 4: Elaborate or **explain** the connections between the words. For example, write a sentence or phrase on the connecting lines in order to say in what way(s) the ideas are connected. You may also want to write a paragraph or make a voice recording to summarize the connections between all of the words.

■ **Figure 3.7**

How can we use our understanding of living things to make decisions and take actions?

Now that we have learnt about the characteristics and needs of living things and how different structures in cells and organisms have specific and specialized forms that relate to their function, we can apply what we know and understand in order to take decisions and actions for healthier and more sustainable lifestyles. In particular, we will take the role of a blogger who has been assigned a project to investigate, develop, and blog about strategies to grow or produce some foods in natural, healthy, and inexpensive ways.

One of the ways that blogs make money is according to the number of readers that click on and read the blog. Therefore, it is important that the bloggers communicate in a way that makes the followers return to the blog for more.

DISCUSS

If you were a blogger, what would you to do in order to **create** a blog post with recommendations that people would understand, trust, and try? To answer this question, you can make a comparison between professional bloggers and scientists – they actually share many of the same characteristics.**Discuss** with your partner the process that scientists go through in order to come up with reliable scientific information, and then **compare** that to how professional bloggers create 'reliable' articles. What approaches do professional bloggers take that are similar to those that scientists take?

If you had to create a blog with suggestions for how to save money and eat more natural, healthy foods by growing and making some products yourself, how would you ensure that your posts were well-informed and trustworthy?

Milk

Uncooked beans

Yoghurt

Bread

Cooked beans

Yeast

■ **Figure 3.8** Are these common foods alive? We will conduct an investigation to find out

ACTIVITY: Is that alive?

ATL

- Communication skills: Exchanging thoughts, messages and information effectively through interaction

In this activity, you will inquire into the foods shown in Figure 3.8 – uncooked and cooked beans, yoghurt, milk, yeast and bread – to see if the food contains living cells. Before you begin the experiment, you must first decide how to determine whether or not the foods contain living cells. Work with your partner or the class in order to answer the following questions:

- **What are some things we could look for in order to decide if these foods contain living cells?**
- **What would we have to 'give' the foods if we want to see if they contain living cells?**
- **How might we set up an investigation in order to see if the foods contain living cells?**

Hint

Look back at your notes and work for the section about the characteristics and needs of living things.

Now that you and your classmates have thought of some possible ways to determine if the food items contain living cells, you are ready to start with this investigation. Perhaps the method in this investigation is similar to what you and your classmates have discussed, or perhaps it is different. In either case, be sure to take careful notes about what you learn from this investigation, because you can use this learning experience as the basis for the experiment you will plan and do on your own to create your blog.

Background

To determine if uncooked beans, cooked beans, yoghurt, milk, yeast, and bread contain living cells, you will conduct three 'mini' investigations, outlined in the tables on the following pages. Each mini investigation is designed so that it takes into consideration the specific needs of the cells present in the food.

The mini investigations are:

- **Uncooked beans and cooked beans – place some cooked beans and some uncooked beans in Petri dishes containing damp paper towels for a couple of days.**
- **Yeast and bread – put small amounts of yeast or bread, sugar, and warm water in plastic bottles with a balloon over the top of the bottle.**
- **Yoghurt and milk – put a few drops of diluted plain yoghurt (preferably organic or 'bio') and milk on microscope slides and look at them under the microscope.**

Question: Do uncooked beans, cooked beans, yoghurt, milk, yeast, and bread contain living cells?

Hypothesis: If we put uncooked beans, cooked beans, yoghurt, milk, yeast, and bread into different conditions that are appropriate for cells to live, then we will find that ....

Before you start, write down your predictions in a copy of Table 3.10. You can **identify** the variables in Table 3.11 as you read the materials, equipment, and methods.

Food test group	Prediction (circle your prediction)	Scientific reasoning to support prediction (write a reason based on background knowledge or prior learning)
Uncooked beans	contain / don't contain living cells	because …
Cooked beans	contain / don't contain living cells	because …
Yeast	contains / doesn't contain living cells	because …
Bread	contains / doesn't contain living cells	because …
Yoghurt	contains / doesn't contain living cells	because …
Milk	contains / doesn't contain living cells	because …

Table 3.10 Predictions

Mini investigation	Independent variable	Dependent variable	Controlled variable
	What is the factor that is different between the two foods you are comparing in the mini investigation?	What will you count, measure, or observe to know if each food contains living cells? (Note: you might have to fill this in after the investigation, but normally you **identify** the dependent variable before you begin)	What will you do exactly the same for both foods you are comparing in the mini investigation?
1 Beans, cooked and uncooked			
2 Yeast and bread			
3 Yoghurt and milk			

■ **Table 3.11** Variables

Quantity	Materials	Notes
10	Uncooked dry beans	Some good beans to try are mung beans or lentils.
10	Cooked beans	Use the same kind as the uncooked beans; you can either cook the beans in boiling water for 45 minutes before the investigation or use canned beans.
7–10 g	Dry, active baker's yeast	Make sure that you use yeast that says 'active' on the package.
7–10 g	Dry bread	Make sure that the kind of bread you use contains yeast – look at the ingredients label to check. Use the same amount of dry bread as yeast.
60 g	Sugar	You will divide the sugar into two 30 g portions.
500 ml	Warm water	The water should be between 40 and 45°C.
1 pot	Plain yoghurt	Preferably, use organic or 'bio' low fat or whole milk yoghurt; check the label and use the freshest yoghurt you can get.
10 ml	Whole (full fat) milk	Preferably, use organic or 'bio' milk; check the label and use the freshest milk you can get.

■ **Table 3.12** Materials to use

Quantity	Equipment	Notes
1	Electronic balance	
2	Petri dishes	If you don't have Petri dishes, you can also use small sized plastic bags, like the ones you might use to bring a sandwich or snack to school.
4	Paper towels	You might also need some paper towels to clean up spills or messes, so be sure you have four pieces for the investigation.
2	Droppers or plastic pipettes	
1	Microscope	
2	Microscope slides and covers	
2	Plastic water bottles	
2	Balloons	
1	Mortar and pestle	
1	50 ml beaker	
1	250–300 ml beaker	
	Distilled water	You will need a small amount.

■ **Table 3.13** Equipment

Method

Note: This investigation takes 4 days before you will have the final results. Try to start the investigation at the beginning of the week, so you can monitor the changes, make any necessary adjustments, and write your observations. It is possible to leave the investigation over a weekend, but you will miss the opportunity to make important observations.

Step	Description	Rationale: Why is this step necessary? (Fill in this row as you do the experiment. Thinking about why you are doing each step will help you when you plan your own experiment.)
1	Fold the four paper towels individually so that they will fit in the Petri dishes. It is okay if they come over the edge of the dish.	
2	Soak each folded piece of paper towel in water. The paper towels should be completely wet, but not dripping. Try to make sure that each paper towel is equally wet – in other words, don't have some towels that are very wet, and some that are only damp.	
3	Place one of the wet paper towels in the bottom half of each Petri dish.	
4	Place the 10 uncooked beans on top of the wet paper towel in one of the petri dishes. Spread out the beans so that they are not touching each other or the side of the Petri dish. If you are using bigger beans, and you can't spread them out in the Petri dish, you can use fewer than 10 beans.	
5	Put another wet paper towel on top of the beans.	
6	Repeat steps 4 and 5 for the cooked beans. Label one of the Petri dish covers as 'uncooked' and the other as 'cooked'.	
7	Close the Petri dishes with the appropriately labelled covers.	
8	Put the Petri dishes in a cabinet or closet where they will not be disturbed for a few days.	
9	Every day for 4 days, check your Petri dishes. If the paper towel seems dry, open the cover and use a dropper to carefully add enough water to make the towels wet again. Write and photograph or sketch your observations.	
10	On the 4th day, take the Petri dishes out of the closet or cabinet. Write and photograph or sketch your observations.	

■ **Table 3.14** Method for mini investigation 1 – uncooked and cooked beans

Step	Description	Rationale: Why is this step necessary? (Fill in this row as you do the experiment. Thinking about why you are doing each step will help you when you plan your own experiment.)
1	Stretch out the balloons by blowing them up a few times. Then set them aside.	
2	Use the balance to measure out 30 g sugar and 7–10 g yeast.	
3	Add the sugar and yeast to one of the empty water bottles.	
4	Use the balance to measure out 30 g sugar and 7–10 g dry bread (the same amount as you used of yeast).	
5	Use the mortar and pestle to break up the dry bread. Try to make the crumbs the same consistency as the yeast.	
6	Add the sugar and dry bread crumbs to the other empty water bottle.	
7	Measure out 250 ml of warm water and add it to the bottle containing the sugar and yeast; swirl it around to dissolve the sugar and yeast.	
8	Immediately cover the bottle with one of the balloons.	
9	Repeat steps 7 and 8 for the bottle containing the sugar and bread crumbs.	
10	Put the bottles aside for at least 5 minutes. If nothing happens during that time, leave for a few more minutes.	
11	Write and take photographs of or sketch your observations.	

■ **Table 3.15** Method for mini investigation 2 – yeast and bread

Step	Description	Rationale: Why is this step necessary? (Fill in this row as you do the experiment. Thinking about why you are doing each step will help you when you plan your own experiment.)
1	Take a spoonful of yoghurt and put it in the 50 ml beaker.	
2	Add a few drops of distilled water to thin the yoghurt enough so that you can pick it up with the dropper or pipette.	
3	Use the dropper or pipette to put one drop of the thin yoghurt on a microscope slide and cover it with a slide cover.*	
4	Look at the slide under the microscope.	
5	Sketch what you see and write about your observations.**	
6	Put a drop of milk on a clean microscope slide; you may have to add a drop of distilled water if the milk is too thick. Cover the milk with a slide cover.	
7	Repeat steps 4 and 5.	

■ **Table 3.16** Method for mini investigation 3 – yoghurt and milk

* and ** – see overleaf

*Note: You may want to search on youtube.com: how to prepare a wet-mount slide for suggestions for how to prepare your slides.

**Note: Using a microscope is definitely a skill that develops over time. If you have difficulty seeing anything, you may want to search: yoghurt under microscope to see what some others have seen. You can make your sketch and write your observations from the video shown.

Qualitative data

Collate (gather together) the qualitative data from your investigations in copies of Tables 3.17 to 3.19.

Day	Observations	
	Uncooked beans	Cooked beans
0 (start of investigation)		
1		
2		
3		
4		

■ **Table 3.17** Observations for mini investigation 1 – uncooked and cooked beans

	Sketch or photo	Observations
Yeast		
Bread		

■ **Table 3.18** Observations for mini investigation 2 – yeast and bread

	Sketch	Observations
Yoghurt		
Milk		

■ **Table 3.19** Observations for mini investigation 3 – yoghurt and milk

Conclusions

Record your conclusions, based on your results and observations, in a copy of Table 3.20.

Food test group	Conclusion (circle your conclusion)	Evidence from the investigation to support conclusion
Uncooked beans	contain / don't contain living cells	because …
Cooked beans	contain / don't contain living cells	because …
Yeast	contains / doesn't contain living cells	because …
Bread	contains / doesn't contain living cells	because …
Yoghurt	contains / doesn't contain living cells	because …
Milk	contains / doesn't contain living cells	because …

■ **Table 3.20**

Evaluation and improvements

Evaluation	Reasoning
The results of the investigation supported my hypothesis:	because …
The results of the investigation did not support my hypothesis:	because …

■ **Table 3.21**

Limitation of the method	Explanation of limitation	Suggestion for improvement
One of the steps of the method that was a possible source of error was ...	This step was a possible source of error because ...	To avoid this source of error, I could ...
Another step of the method that was a possible source of error was ...	This step was a possible source of error because ...	To avoid this source of error, I could ...

■ **Table 3.22**

◆ Assessment opportunities

- In this activity you have practiced skills that are assessed using Criterion B: Inquiring and designing and Criterion C: Analysing and evaluating.

Science skills

In this activity we have practised the many skills that scientists use, including making a hypothesis, following an experimental method, using a microscope, recording observations, and forming a conclusion based on experimental results.

Understanding the conditions under which the living cells in these foods grow best allows not only scientists, but also other people, to be able to produce food in a healthier, fresher, and less expensive way, compared with buying the same foods in the store.

Links to: Language and literature

In this chapter, you have practised different ways to communicate. Communication is also important in language and literature courses. Choosing appropriate ways to share ideas, and expressing yourself clearly and directly, are skills that you often practise in language courses – and now you are practising them in science.

Take action: Opportunity to apply learning through action ...

ATL

- Communication skills: Exchanging thoughts, messages and information effectively through interaction
- Media literacy skills: Interacting with media to use and create ideas and information

! You are a professional blogger for a blog that focuses on healthy living and life choices. You are creating a blog post about strategies for growing and making some foods, such as sprouts, yoghurt, or bread dough, from home in a natural, inexpensive, and sustainable way. You must first investigate and identify a strategy for growing or preparing the food in a systematic and reliable way that anyone could do from their own home.

! To do this, you must:

- **Design** an investigation to **identify** the best conditions to produce either bean sprouts, yoghurt, or bread dough.
- Carry out the investigation.
- Collect and process data from your investigation, make your conclusion about the strategy for growing or producing the food, and **evaluate** your investigation.
- Decide on an effective format to communicate your findings and recommendations in your blog post, including information on the background of the investigation, such as how you knew that the food contains living cells and how you used your understanding of the characteristics and needs of living things to design your investigation.
- **Summarize** your results, conclusions, and evaluation of your investigation.
- **Suggest** how the readers could produce the food in their own homes, based on the results of the investigation.

! There are different approaches that you can discuss with your classmates and teachers, but you might want to try these suggestions:

- Make a sketch or short summary of your general ideas for your investigation. Discuss your ideas with your teacher and get their approval before you continue to plan your investigation.
- Use the headings and guidelines from the activity *Is that alive?* to help you design and carry out your own investigation.

! Once you have your results and have completed the investigation, including the evaluation and suggestions for improvements, decide on the best way to communicate the findings in your blog post – should each student use his or her own blog? Or should the class create a new blog where everyone can add a post? Will you write about your results and recommendations, or will you use other forms of media to share information with your blog followers?

! Communicate in your blog the background information; your experimental findings, conclusion, and evaluation; and your decision about how to produce that food at home.

Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding, Criterion B: Inquiring and designing, and Criterion C: Processing and evaluating.

Reflection

In this chapter we have **outlined** scientific knowledge about the characteristics and needs of living things and we have **applied** our knowledge and understanding of the characteristics and needs of living things in order to **identify** how to produce food in a healthy, inexpensive, and natural way. We have **interpreted** data and other sources of information to make scientifically supported judgments about the most effective way for cells to live and grow. We have **outlined** an experimental question, testable hypothesis, and strategy for collecting data and **designed** a scientific investigation. We have **presented**, **collected**, and **transformed** data using scientific reasoning and **discussed** the validity of our hypotheses and methods as well as **describing** ways to improve the strategies we developed in our investigation.

Use this table to evaluate and reflect on your own learning in this chapter.					
Questions we asked	Answers we found	Any further questions now?			
Factual: Are all living things different? What are the characteristics of living things? What are the necessities of life? What are specialized forms and functions of living things?					
Conceptual: How can we use our understanding of the characteristics, needs, forms, and functions of living things to make healthier and more sustainable decisions and actions? How are our decisions and actions limited by the needs, forms and functions of living things?					
Debatable: To what extent should we take decisions and actions that benefit some human lives but have a negative effect on other living things?					
Approaches to learning you used in this chapter:	Description – what new skills did you learn?	How well did you master the skills?			
		Novice	Learner	Practitioner	Expert
Communication skills – we have exchanged thoughts, messages and information effectively through interaction.					
Media literacy skills – we have interacted with media to use and create ideas and information.					
Information literacy skills – we have accessed data, and created references and citations.					
Critical-thinking skills – we have revised our understanding based on new information and evidence, and we have drawn reasonable conclusions and generalizations.					
Learner profile attribute	How did you demonstrate your skills as a communicator in this chapter?				
Communicator					

4 What makes change happen?

Through controlling **energy** we can make **changes** happen that have an **impact on the way people live now and in the future**.

Figure 4.1 What is changing?

CONSIDER THESE QUESTIONS:

Factual: What types of energy are there? How can we classify energy? How can we measure energy? How can we control energy? How can we use energy efficiently?

Conceptual: How might our use of energy affect people's lives now, and in the future?

Debatable: Can individuals act to reduce energy consumption? Is there enough energy to go around?

Now **share and compare** your thoughts and ideas with your partner, or with the whole class.

IN THIS CHAPTER WE WILL …

- **Find out** how energy is changed, how it is measured, and how it can be controlled.
- **Explore** different ways to change energy, temperature scales, and ways to reduce energy loss.
- **Take action** to find ways to use energy sustainably, with the minimum impact on global climate.

These Approaches to Learning (ATL) skills will be useful …

- Communication skills
- Collaboration skills
- Critical-thinking skills
- Information literacy skills
- Transfer skills
- Creative-thinking skills

We will reflect on this learner profile attribute …

- Principled – what can individuals do about big problems such as climate change? What can we do to help those who do not have easy access to plentiful energy?

Assessment opportunities in this chapter:

- **Criterion A:** Knowing and understanding
- **Criterion B:** Inquiring and designing
- **Criterion C:** Processing and evaluating
- **Criterion D:** Reflecting on the impacts of science

KEY WORDS

conserve	potential	transfer
heat	solar	wasted
kinetic	stored	

THINK–PAIR–SHARE

Look at the images in Figure 4.1 on your own. In each case, what is changing? What is it changing from? What is it changing into?

Hint

You may find it useful to look at some of the words in the key words box.

Compare your ideas with your partner. Did you come to the same conclusions?

Share your ideas with the class. What ideas did people share? Which ideas were new and surprising to you?

ENERGY EVERYWHERE

'There is nothing so constant as change' – or so the saying goes. You will have experienced change in your life – changes in yourself, changes in the world around you and in your understanding of the world around you as you learn. It should be no surprise, then, that change is at the heart of science. Many of the questions that scientists ask are all about *how* change happens and *what* causes it to happen.

Energy is an important scientific concept that helps us answer these questions about change in nature. In this chapter you will explore what the concept of energy means, and build your own understanding of it.

Nature has many different systems, built from changes that are in relationship with each other, and so the concept of energy appears in many different forms. In order to use the concept of energy to effectively understand how things work, we need to recognize its different forms when they appear. If we can understand energy changes well, then perhaps we can design our own systems to use them and make life better for everyone.

What types of energy are there?

ACTIVITY: Energy 'learn and tell'

ATL

- Communication skills: Negotiate ideas and knowledge with peers
- Collaboration skills: Listen actively to other perspectives and ideas
- Critical-thinking skills: Practice observing carefully

The next pages give five different activities to help you explore different kinds of energy change. The activities then require you to **discuss, summarize** and then **explain** your discoveries to others. For each activity, **discuss** these guiding questions in pairs or in groups:

- **What do you observe happening?**
- **What do you think is making this happen?**
- **What does this tell you about energy changes?**
- **What does it make you wonder about energy?**

Summarize your answers in a few sentences.

Prepare to **explain** the activity to someone new.

Here are some different ways you can do this. Decide with your teacher which pathway your class will follow.

Pathway 1

Divide your class into two halves – 'learners' and 'instructors'. In the first part of the activity, a learner and an instructor sit together to do the activity (or two learners and two instructors, or whatever number works for your class!)

Now all learners move to the next activity, while all instructors stay in place. Instructors must now explain the activity to the new learners.

Continue until all the learners have been to every activity and returned to where they began.

Now *swap* roles – so learners become instructors and instructors become learners. Repeat the cycle.

Pathway 2

Split into groups for each activity. Learn about the activity, and prepare your explanation as above.

Each group now presents their activity to the whole class. Be ready to ask, and to answer, questions!

Activity 1: Physical energy

Equipment

- **Selection of similarly sized balls, for example 1 golf ball, 1 ping-pong ball, 1 squash ball, 1 bouncy elastic ball**
- **Graduated mat or sheet of squared paper**
- **Some sticky tape**
- **Balloon**
- **Small dynamics trolley or toy car**
- **Clockwork toy**

Bouncing balls: Tape the mat or squared paper to a wall. Draw a line across the top edge. Drop the balls vertically, and count how many bounces they make before they stop.

If you have a mobile phone or other video recording device try to record the balls bouncing. Replay the images and **interpret** what you see happening.

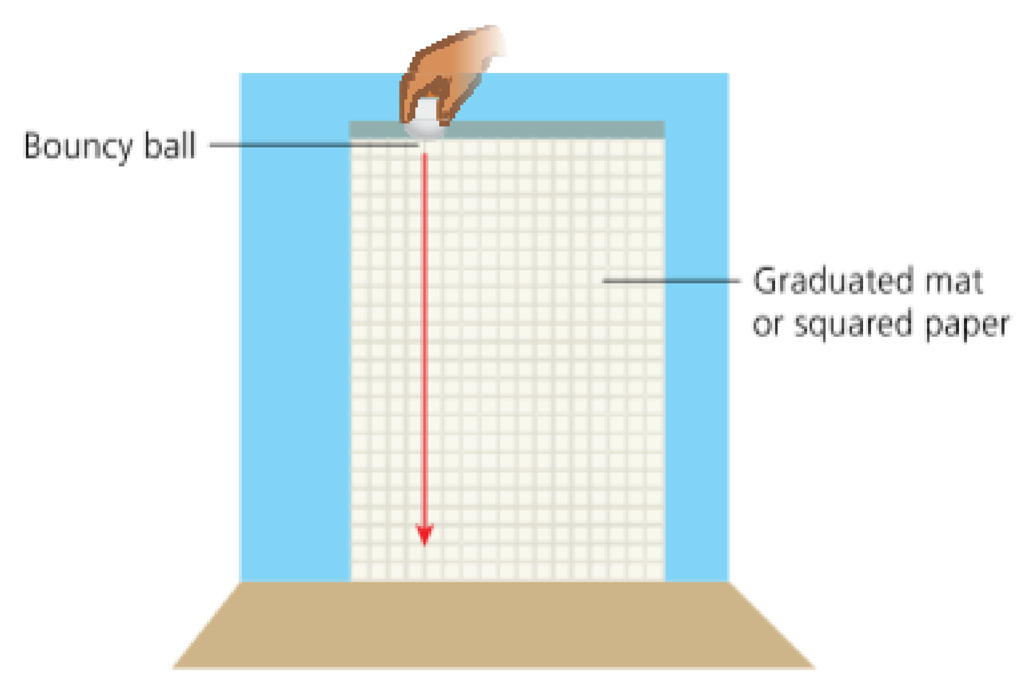


Figure 4.2 Bouncing balls experiment

Balloon jet: Tape the balloon to the trolley or toy car by doubling a piece of sticky tape over (better still, use double-sided sticky tape if available). Blow up the balloon, and pinch the nozzle closed with your fingers. Place the balloon on the table top and release.

Clockwork toy: Wind it up and watch it go! How long does it run for?

Now **discuss**, **summarize** and **explain** using the guiding questions above.

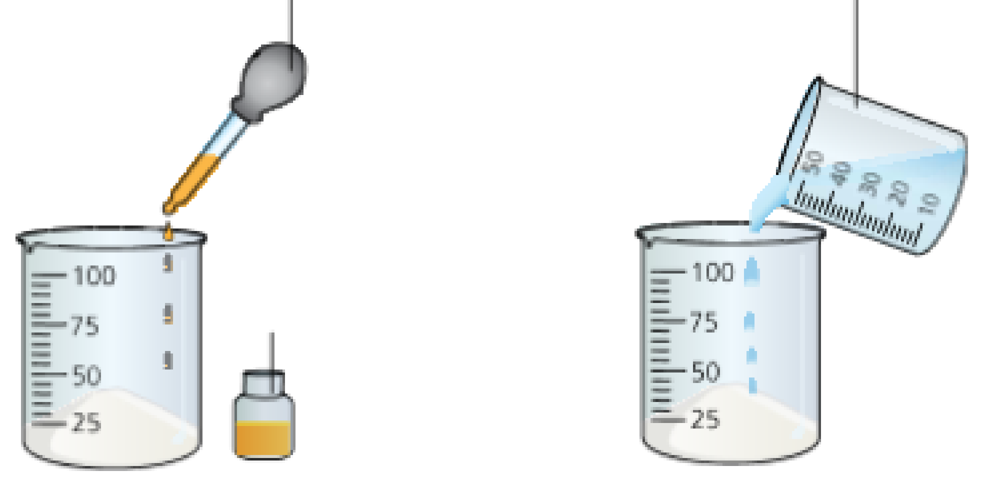
Activity 2: Energy from chemical and physical change

Equipment

- **50 g baking soda (chemical name: sodium hydrogen carbonate $NaHCO_3$)**
- **100 ml vinegar (chemical name: acetic acid CH_3COOH)**
- **50 g calcium chloride (chemical formula: $CaCl_2$)**
- **100 ml beaker containing 50 ml water**
- **2 100 ml beakers**
- **2 stirring rods**
- **2 spatulas**
- **Dropper pipette**

SAFETY: These experiments use chemicals that, while relatively harmless, should still be treated with care. Do not squirt vinegar from the pipettes. Wear safety glasses to avoid contact of any chemicals with your eyes. If you get chemicals on your hands, wash under a tap immediately.

Experiment 1: Take a 100 ml beaker. Use a spatula to put the baking soda inside. Now use a dropper pipette to take vinegar from the bottle and add to the baking soda (take care!). As one person stirs the mixture, the other should place their hands around the container.



■ **Figure 4.3** Chemical energy experiments

Experiment 2: Take a 100 ml beaker. Use a spatula to put the calcium chloride inside. Pour all the water into the calcium chloride and stir with a stirring rod. As one person stirs the mixture, the other should place their hands around the container.

Note: one of these experiments involves a **chemical neutralization**. The other involves dissolving. Can you work out which is which?

Activity 3: Energy rays

Equipment

- **Adjustable desktop lamp**
- **2 small squares of paper or card, one black and one white, 10 cm × 10 cm approximately**
- **Radiometer (bulb containing rotating vanes painted black one side, white on the other)**
- **Photovoltaic or 'solar' cells connected to a voltmeter. (If you do not have photovoltaic cells available in this form, use a solar powered calculator or something similar.)**

SAFETY: The light bulbs in lamps can become quite hot. Take care not to touch the light bulb, even after it has been switched off.

Experiment 1: Position the lamp so that the light bulb is closely above one of the paper squares. Turn on and leave for around 2 minutes. Turn off, then touch the surface of the paper. Repeat for the other square of paper.

Experiment 2: Place the lamp next to the radiometer and position it so that the light bulb is pointing at the little black and white vanes inside the radiometer. Turn on the lamp.

Experiment 3: Place the lamp over the photovoltaic cells so that the light bulb is pointing down at them. Turn on the lamp. Move the lamp nearer to and further away from the cells and observe the effect on the meter needle.

Activity 4: Hot matter

Equipment

- **Thick rubber band**
- **Bimetallic strip with insulating handle**
- **Heatproof mat**
- **Candle, oil burner or Bunsen burner**

SAFETY: This experiment involves using a flame to heat a metallic object. At all times observe laboratory safety rules when using the flames. Wear safety glasses. Do not put any part of your body close to the flame. Do not touch the heated metal strip after heating.

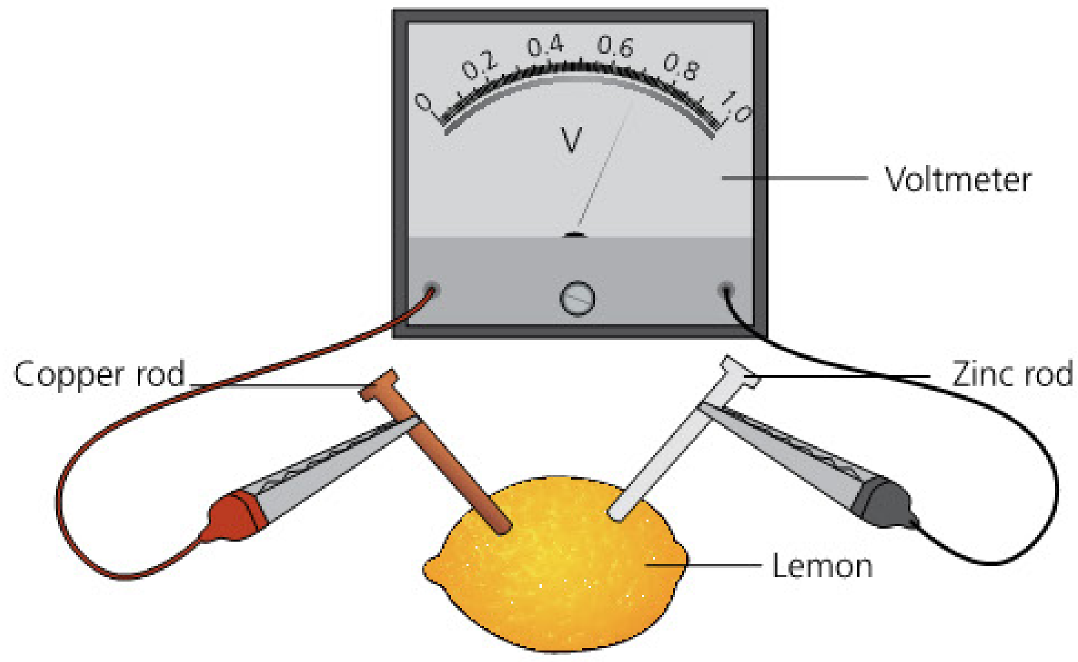
Experiment 1: Loop the rubber band around your thumbs. Stretch the band slightly and place against your forehead. Now stretch the band quite slowly to nearly breaking point. After a few moments, move your thumbs together to relax the elastic band, all the time keeping it in contact with your forehead.

Experiment 2: Light the candle or burner. Pick up the bimetallic strip by the handle and hold the metal part in the flame. When you have observed what happens after heating the strip, place it safely on the heatproof mat. Observe what happens as it cools down.

Activity 5: Electric results

Equipment

- **Lemon, lime, or apple**
- **Zinc rod (chemical symbol: Zn)**
- **Thick copper wire (chemical symbol: Cu)**
- **Voltmeter**
- **2 wire connectors with crocodile / alligator clips**
- **Hand-cranked torch with rechargeable battery inside**
- **Solenoid, 100 turns minimum**
- **6 V battery pack**
- **Plotting compass**



■ **Figure 4.4** Fruit battery circuit

Experiment 1: Take the fruit and push the zinc and copper rods through the skin at least half way, and a few centimetres apart. Attach the voltmeter connectors, one to each rod. Observe the needle on the meter.

Experiment 2: Crank the torch! Leave it on after you finish cranking, and observe the light produced.

Experiment 3: Place the plotting compass near to one end (or 'pole') of the solenoid. Connect the solenoid wires to each of the contacts (red and black) on the 6 V battery pack with the clips. Observe what happens to the compass. Now disconnect the battery pack from the solenoid. Observe what happens to the compass. Repeat the experiment, moving the compass around the solenoid.

In this activity we have used observations to try to understand what a concept means. Sometimes this leads to new questions, which might then lead to new experiments to improve our understanding even further. This is the way science makes knowledge!

EXTENSION

Some special wires 'remember' their shape even after they have been cooled and heated again. Use the search term: Nitinol wire demonstration to find a video of this demonstration. What are these wires useful for?

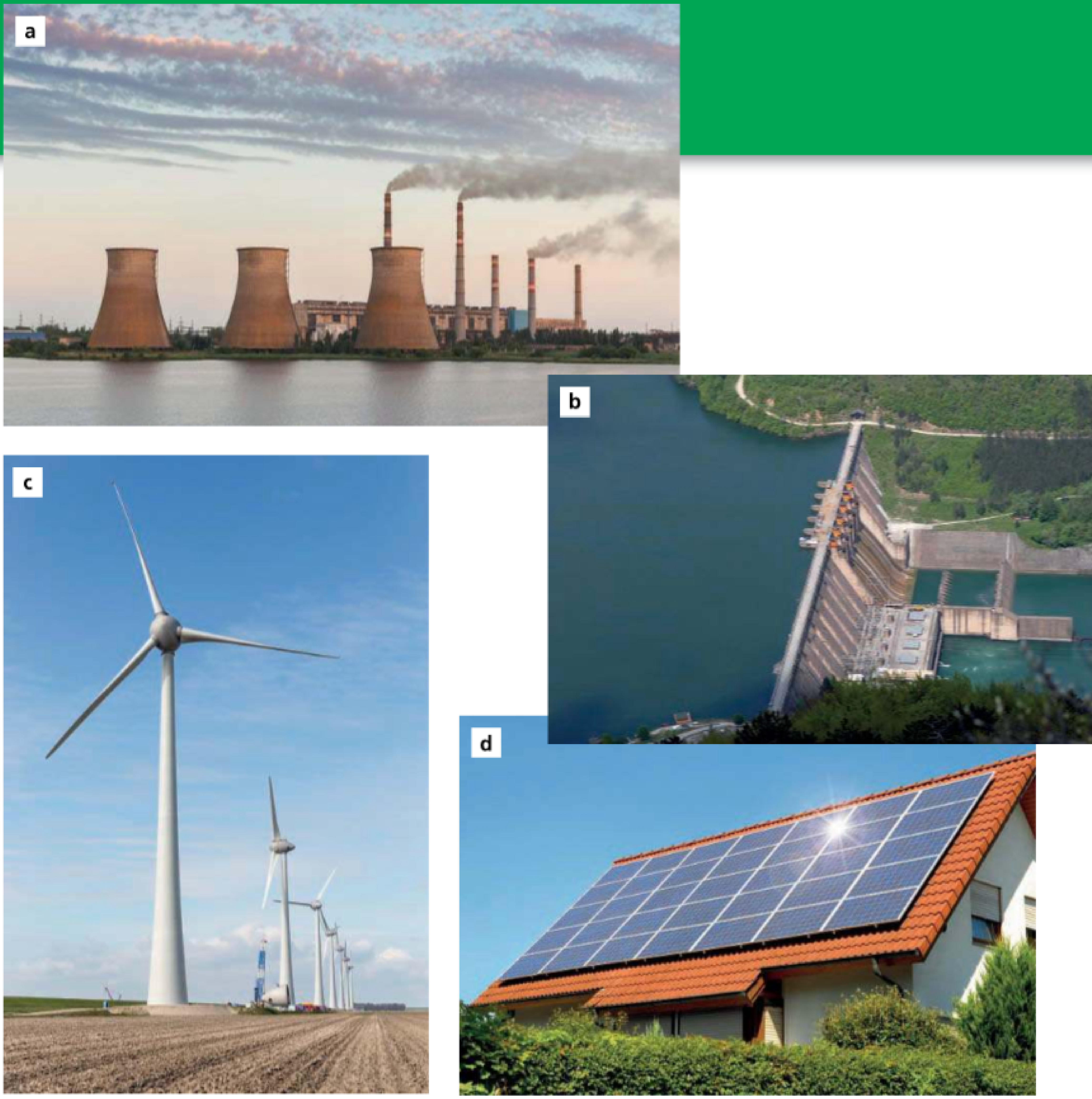


Figure 4.5 Some energy producers: (a) thermal power station, (b) hydroelectric dam, (c) wind turbines, (d) photovoltaic solar panels

In each of the activities on the previous pages, you experienced changes caused by different forms of energy. We can understand energy as the ability of something to cause change. We can then **classify** energy changes according to the forms the energy takes, and then show the energy changes in the form of an energy change chain. There are two categories of energy, however, that are particularly useful, because all the others fall into them in one way or another.

Potential energy is energy that is stored, so that through some process it can be used to make a change happen. **Kinetic energy** is the energy that things have through movement. Figure 4.5 shows some different ways in which energy from nature is **harnessed** to make electricity (we will look at these in more detail in *Sciences for the IB MYP 2: by Concept*).

We can show how each of them transforms energy to make it work. For example, in a thermal power station the energy is obtained from a fuel – usually a **fossil fuel** such as coal, oil or gas. The energy stored in the fuel is released through **combustion** or burning, which turns it into heat. This heat is then used to boil water and make steam, which is produced under high pressure. The molecules of water in the steam then have large kinetic energies, which mean they move very rapidly and can be used to drive a large turbine, so *transferring* the kinetic energy of the water molecules into kinetic energy in the machinery. The machinery is then used to drive electrical generators which use magnetic fields to make electrons in conductor wires move – which is electricity.

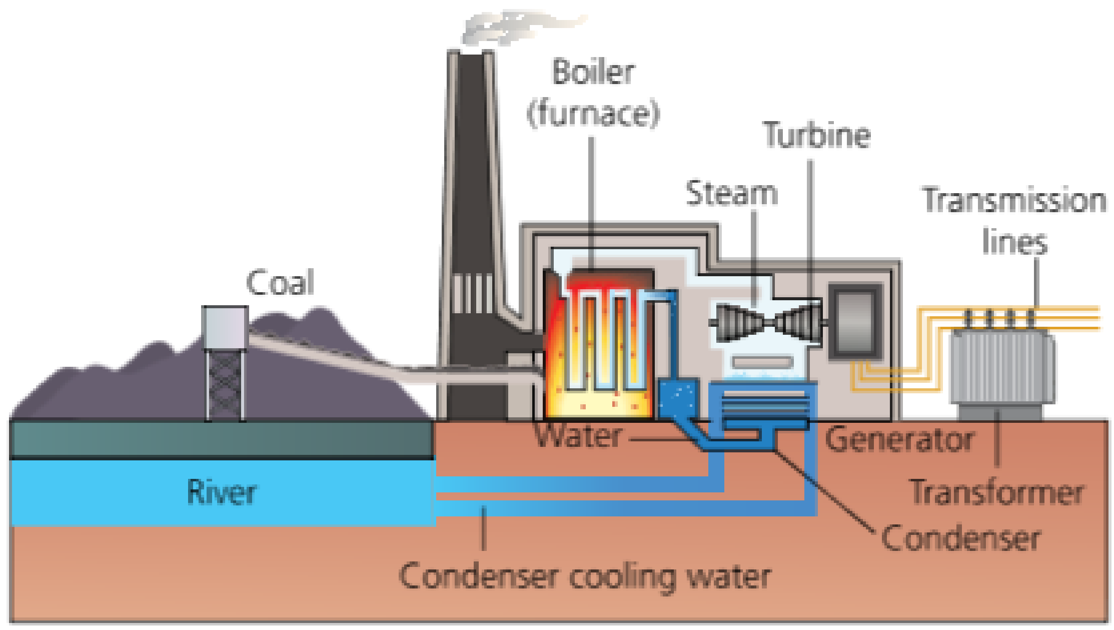


Figure 4.6 Diagram of a thermal power station

Thermal power station:

Chemical energy (fuel) → heat energy (combustion) → mechanical energy (turbines) → electrical energy

In a hydroelectric power station, energy is stored in water that is held high in a reservoir, such as in a mountainous area. The potential energy stored in the water is then changed into kinetic energy when the water is released to fall through turbines.

Hydroelectric power:

Potential energy (gravitational) → kinetic energy (water) → mechanical energy (turbine) → electrical energy

EXTENSION

Find out how different energy producers harness energy from nature to make electricity using these search terms: **wind power**; **tidal power**; **nuclear power**; **solar power**; **geothermal power**.

Identify the parts of the energy producer that are used for each energy change, and **outline** the energy chain in words and as a diagram.

ACTIVITY: Reflecting on energy impacts

ATL

- Critical-thinking skills: Gather and organize relevant information to formulate an argument
- Information literacy skills: Use critical-literacy skills to analyse and interpret media communications

Individually, reflect on the impacts of harnessing natural energy resources. You will make a magazine article for young scientists that summarizes the arguments for and against the use of a particular energy resource.

Choose ONE of the energy resources you have researched.

Summarize how that energy resource has been harnessed, using an energy chain in words and as a diagram.

Describe the benefits of this kind of energy resource. What positive impacts does it have on people's lives? What positive impacts might it have in the future? Then **describe** the negative impacts of the energy resource. What problems might it cause, now and in the future? Consider effects on the environment, and on people's lifestyles or wealth.

Hint

For this section, you may wish to research newspaper articles, magazine articles, or other media sources. Look carefully at the sources you are using. Who are they written by? Do you think they have a particular opinion (point of view) on this subject? Does that affect the information the source provides?

Summarize your views on the energy resource: should we develop this energy resource further?

In your article, use language that a young scientist like yourself can understand, but also make sure to use any scientific vocabulary you find in your sources with understanding. Make sure that you research to find out what words mean and then **apply** the scientific vocabulary in your own explanations.

At the end of the article, be sure to **document** any sources you used to inform your description.

Assessment opportunities

- This activity can be assessed using Criterion D: Reflecting on the impacts of science.

ACTIVITY: Energy match

ATL

- Critical-thinking skills: Gather and organize relevant information to formulate an argument

Look at the kinds of energy in Table 4.1.

	Electrical energy
Thermal energy	Radiated energy
Kinetic energy	Magnetic energy
Nuclear energy	Chemical energy

Table 4.1 Different forms of energy

Now read the descriptions below. **Identify** the kind of energy being described in each description.

- **Energy carried or stored by electrons inside conductors**
- **Energy carried by moving objects**
- **Energy stored in a magnetic field between two magnetized objects**
- **Energy stored in the movement of the particles in a material, which when it moves is called heat**
- **Energy which can travel through space in the form of waves**
- **Energy held inside the nucleus of an atom**
- **Energy held in the bonds that join atoms and molecules together.**

For each of the activities in *Energy 'learn and tell'*, **summarize** the energy changes in the form of an energy chain to show how the energy changed during the activity. (Don't worry if you don't use all the energy forms given here.)

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Knowing and understanding.

ACTIVITY: Energy rollercoaster

■ **ATL**

- Critical-thinking skills: Interpret data; Test generalizations

In pairs or in groups, investigate the way energy changes in a rollercoaster.

Inquiry: How long can a rollercoaster roll on?

Background

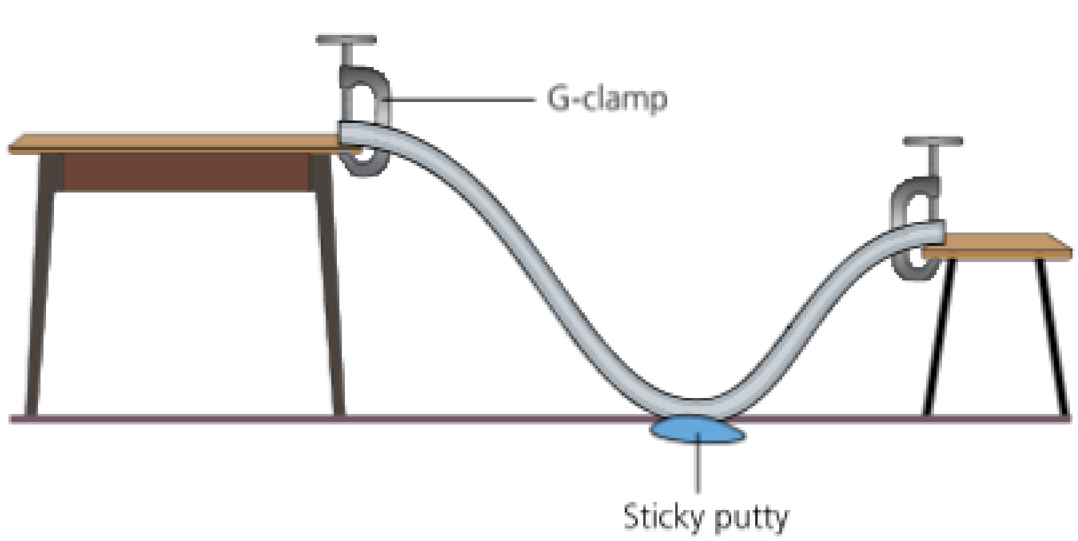
A rollercoaster uses gravitational potential energy to make the train move. The energy is first stored as the train is pulled very high to the top of the first 'bump'. Then the train is released and the potential energy is converted into kinetic energy. In this experiment we will find out how energy changes from potential energy to kinetic energy and back again.

Prediction

Summarize the energy changes in a roller coaster in the form of an energy chain. Can a rollercoaster go on forever? **Explain** your answer using scientific reasoning about energy changes.

Equipment

- **'Track', 2 m long approximately, such as curtain railing or similar**
- **Some marbles or other small balls**
- **Felt-tip pen**
- **Optional: Video recording device**
- **Optional: G-clamps, sticky tape, sticky putty**



■ **Figure 4.7** Rollercoaster experiment set-up

Procedure

1. **Set up the track as shown in Figure 4.7 – use lab stands or even stools as supports for your 'rollercoaster'.**
2. **Decide which end of the track will be your starting point. Release a ball from the starting point.**
3. **Observe the motion of the ball back and forth. If possible, record on video.**

Discuss the motion of the ball, using these guiding questions to help you:

- **What happened as the ball moved back and forth on the track?**
- **Where does the ball have most potential energy? Where does the ball have most kinetic energy?**
- **What is happening to the energy as the ball continues to roll?**
- **Decide what dependent variable you can measure in order to test your prediction.**

Results

Organize your data for your chosen dependent variable in a table, showing the units of measurement. How can you **present** this data in a visual form?

Conclusion

State whether your prediction was correct. **Discuss** how your results showed whether it was correct, or not, using the terms *potential energy* and *kinetic energy*.

Evaluation

Discuss whether the method you chose to measure the energy changes worked well. How could you have improved your method? **Describe** any changes you could have made to the experiment design, or to the measurements you chose to take.

◆ **Assessment opportunities**

- This activity can be assessed using Criterion C: Processing and evaluating.

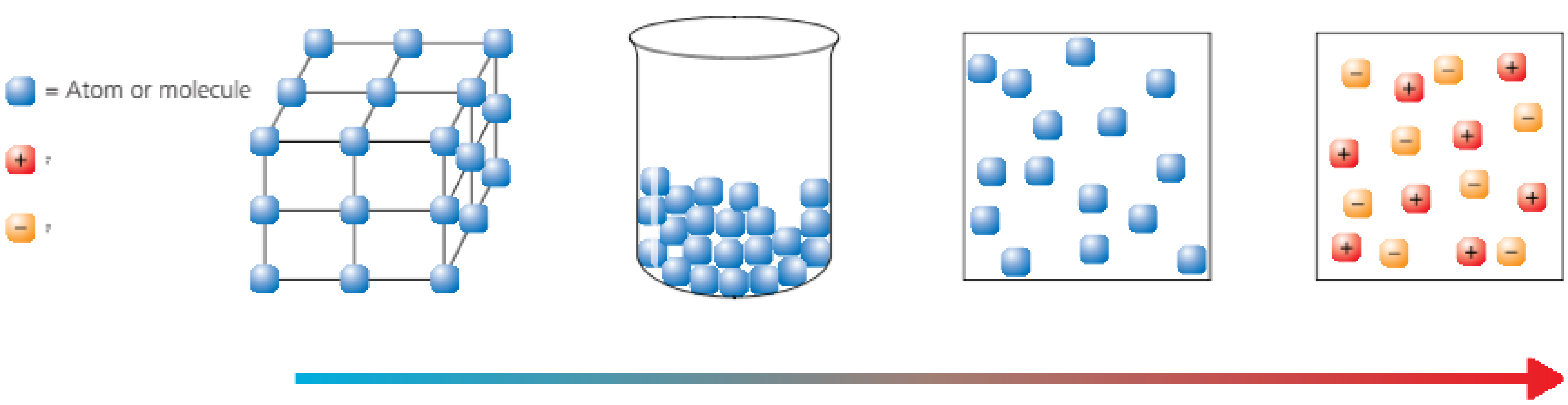
How can we measure energy?

Have you ever plunged your hand into ice water? The strange thing is, if you do this without *knowing* what your hand is plunging into, it is in fact very difficult to tell whether the water is very hot or very cold. This is because the nerves in our body that detect temperature are sensitive to difference in temperature. Our experience of temperature change is always relative to our own body temperature, which is around 37°C. In this section we will be exploring the science that allows us to measure and control thermal energy and heat. In *Sciences for the IB MYP 3: by Concept* we will explore further how other kinds of energy change can be measured and controlled.

You will know that temperature is a measure of how hot or cold an object is. Once, it was thought that heat was a sort of 'liquid' (called *caloric*) which 'flowed' from hot objects to cold ones. Now we know that thermal energy is really a form of kinetic energy – it is the energy of movement of the particles that make up all objects. Even in solid materials, the particles can wobble or 'vibrate' back and forth in their positions. Since we cannot observe thermal energy directly, we must measure it indirectly using temperature. To be exact, temperature is a measure of the *average* thermal energy of the particles in a material, since the particles in a material have a variety of different kinetic energies.

■ **Figure 4.8** Doing the ice-bucket challenge for charity

As we saw earlier, in Chapter 2, the physical state of a material depends on its temperature. In fact, the physical state is a consequence of the amount of kinetic energy the particles in a material have.



■ **Figure 4.9** Thermal energy in solids, liquids, gases and plasma

ACTIVITY: What's hot and what's not?

ATL

- Critical-thinking skills: Gather and organize relevant information to formulate an argument

Individually, look at the images in Figure 4.10.

- **Organize the objects in order of their temperatures. (If you are unsure of any, research their temperatures online.)**
- **State the state of matter for each.**
- **Outline the properties of each, in terms of the motion of the particles within them.**

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Knowing and understanding.

Figure 4.10 (a) Glacier, (b) espresso coffee, (c) molten lava, (d) a meal, (e) a metal spark, (f) liquid nitrogen

To measure the temperature of something, we have to compare it to the temperature of something else. Temperature scales do this by identifying two fixed temperatures, giving those a number, then dividing up the difference in between by degrees. The fixed temperatures are then called the **fixed points** for the temperature scale. One temperature scale was invented by Daniel Gabriel Fahrenheit (1686–1736) in Germany. For his scale, Fahrenheit chose the temperature of a cool bath of salty water as 'zero degrees Fahrenheit' or 0°F. He chose the temperature of boiling water as his upper fixed point, but gave it the temperature of 212°F and divided the temperatures in between. This seems an odd way to define a temperature scale and one story is that Fahrenheit wanted to fix the temperature of a human body as 100°F. In fact, the temperature of the human body is usually 98.6°F and not 100°F, but when Fahrenheit measured his wife's temperature that day it just so happened that she had a fever!

Although it is sometimes used for weather reporting in some countries, for example the United States, scientists rarely use the Fahrenheit temperature scale. They prefer instead the Celsius or centigrade (°C) or absolute (K) temperature scales.

ACTIVITY: High and low temperatures

ATL

- Information literacy skills: Access information to be informed

Individually, use the search term: **temperature scale fixed points** to complete a copy of Table 4.2.

	Fahrenheit (°F)	Celsius (°C)	Absolute (K)
Lower fixed point	Temperature of a cooling bath of salt water		Theoretical point at which materials contain zero thermal energy
Upper fixed point		Temperature of boiling water at standard atmospheric pressure	

Table 4.2

ACTIVITY: Extreme temperatures

ATL

- Information literacy skills: Collect and analyse data to identify solutions and make informed decisions

In pairs, refer again to the temperatures from the activity *What's hot and what's not?*

Using a piece of squared paper, **draw** a thermometer scale. At the top of the scale, mark the highest of the temperatures you found in the activity. At the bottom of the scale, mark the lowest of the temperatures.

Now divide the space between them in equal divisions of numbers of squares.

Plot the other temperatures on the scale.

Discuss and then **summarize** your answers to these guiding questions:

- **What do you notice about the temperatures you plot?**
- **Is this a useful 'thermometer'?**
- **What problems might there be with this scale?**

Hint

What if you wanted to check whether your meal was too hot to eat or just warm enough?

- **When might it be important to have an accurate measurement of temperature?**

Hint

How is the right temperature important to life?

In this activity we had to choose a scale that could show all the data we had to present. It is important to do this, since we do not want to leave data out – it could be important to our conclusion. The scale we used increased by the same temperature difference for each square we used. This is called a **linear scale**. Linear means 'straight line'. Sometimes scientists have to use more complicated scales if the data they want to present has a very wide range of values. These scales are **non-linear** – one example is the **decibel scale** (search for more information) for measuring sound or wave intensity – see *Sciences for the IB MYP 3: by Concept* for more information!

ACTIVITY: Warming up

ATL

- Critical-thinking skills: Interpret data

In pairs, you will **measure** external temperature variation over the human body.

Inquiry: What is the variation in temperature of the human body?

Background

Figure 4.11 shows a thermograph, an image of the thermal energy being radiated.

You can measure the temperature variation of different parts of the body using a hand-held digital thermometer, or a temperature strip.

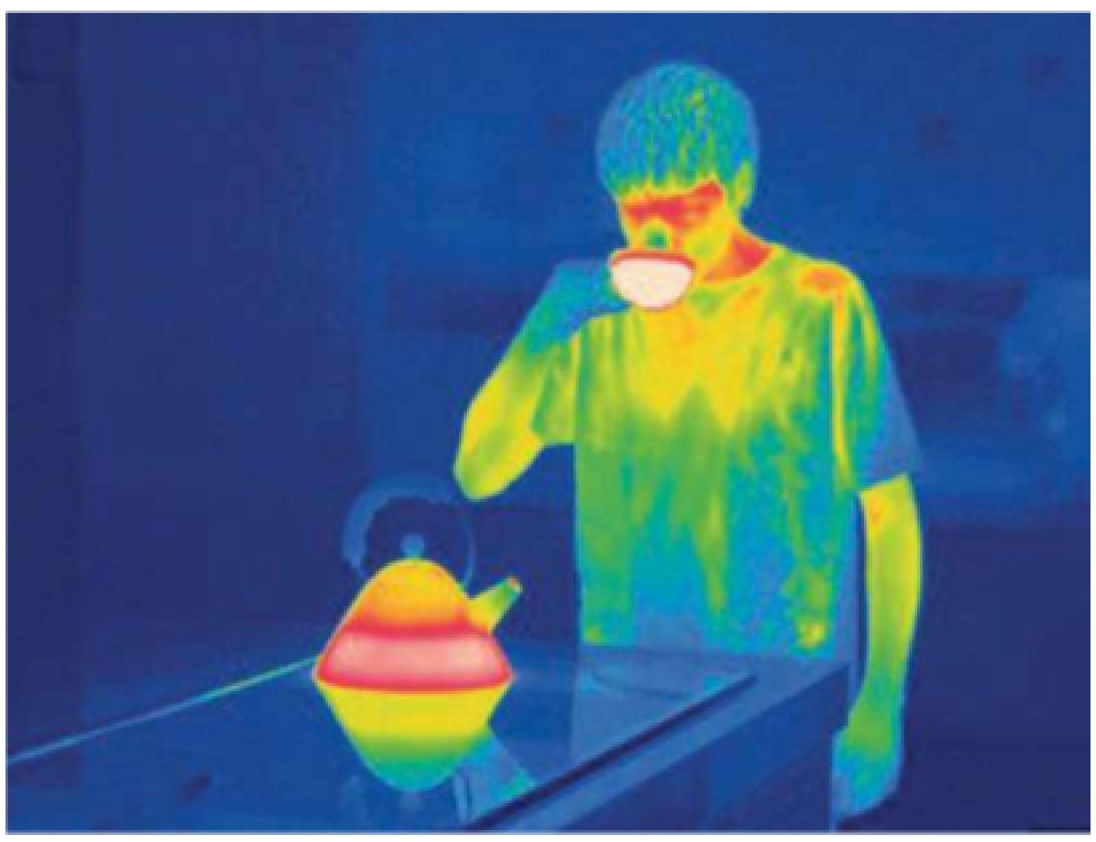


Figure 4.11 Thermograph of someone drinking a hot drink

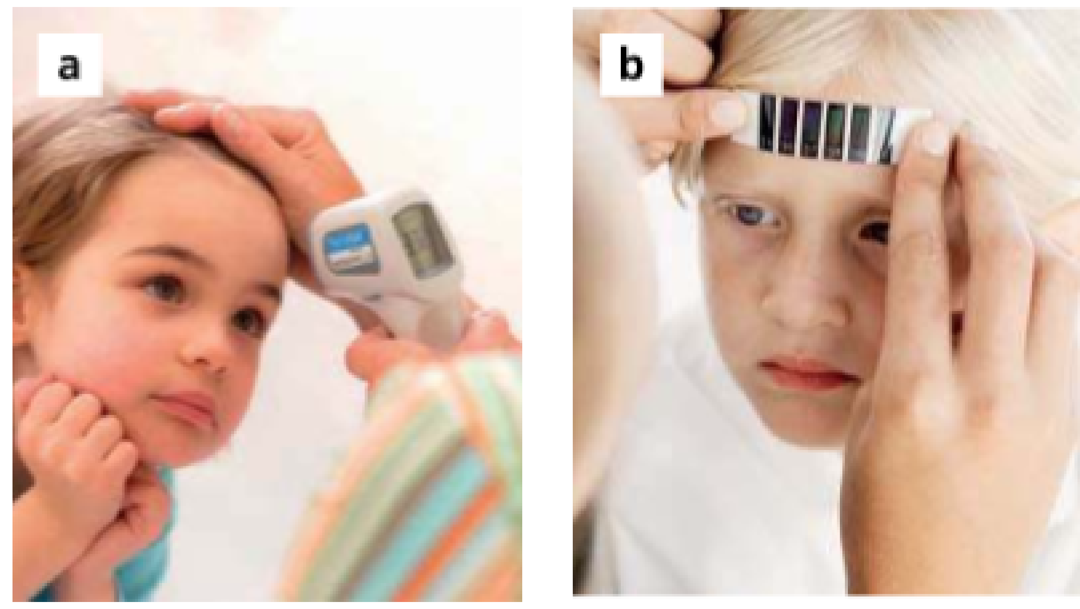


Figure 4.12 (a) Digital thermometer, (b) temperature strip

If you have either of these available, use it to compare the temperature in different parts of the body. Use the thermograph image to decide where to take your temperature readings.

Results

Record your results, **organize** them and **present** them in a suitable form.

Conclusion

Interpret your results. Where was the hottest part of the body? Where was the coolest part of the body? **Explain** the variation in temperature using scientific reasoning.

Assessment opportunities

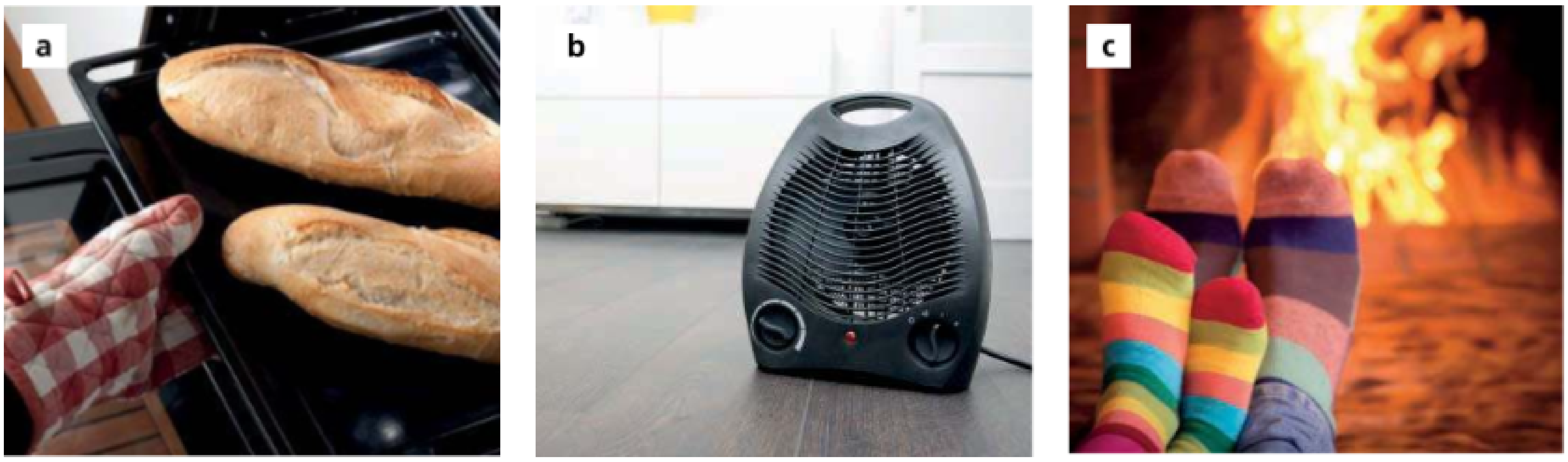
- In this activity you have practised skills that are assessed using Criterion C: Processing and evaluating.

When an object with a higher temperatures come into contact with an object at a lower temperature, the thermal energy from the high temperature object tends to flow into the lower temperature object. In other words, the kinetic energy of the particles in the two objects is shared between all their particles together. This causes the average temperature of the two objects taken together to decrease. When thermal energy is transferred or flows in this way, it is called **heat**. Of course, the amount of heat that flows will depend on the properties of the two objects – for example their material, their mass, or the surface area that they have in contact.

There are three ways in which the kinetic energy of particles can be transferred in Figure 4.14. In the handle of the pan, the thermal energy is being transferred between two solid objects that are touching each other – the metal of the handle, and the hand. Although the particles in a solid are fixed in place, the particles **vibrate**. The vibrations are transferred through the **bonds** that hold the particles together, and so spread to other particles. This process of transferring thermal energy is called **conduction**. (We will learn more about vibrations in *Sciences for the IB MYP 2: by Concept*.)

WHAT MAKES YOU SAY THAT?

Look at the images in Figure 4.13. All of the images show thermal energy being transferred in some way.



■ **Figure 4.13** (a) Using an oven glove, (b) a fan heater in a room, (c) hot feet

For each image, **discuss**:

- **What is going on in the image?**
- **What makes you say that?**

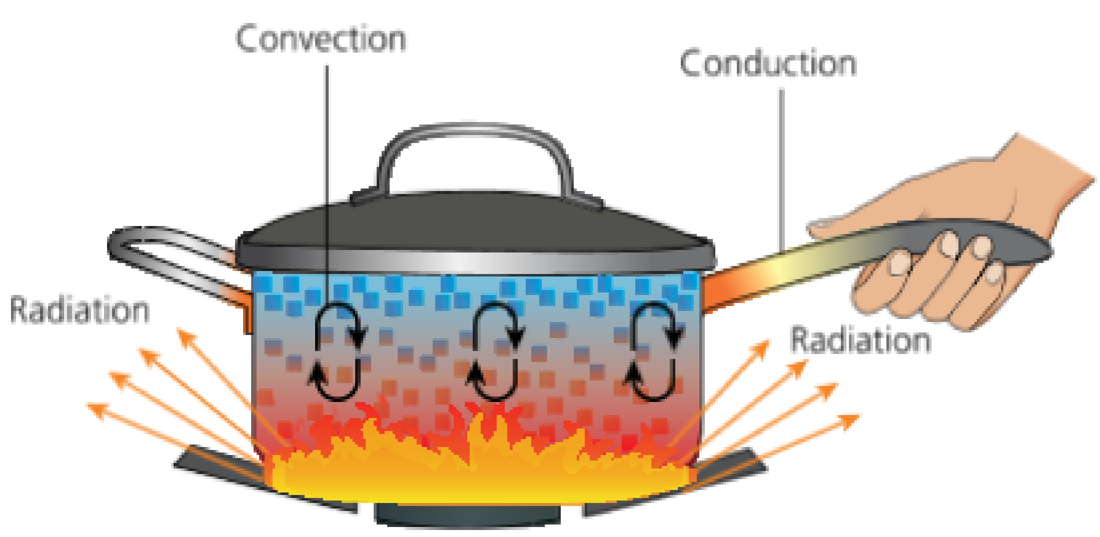


Figure 4.14 Thermal energy transfer by conduction, by convection and by radiation

Inside the pan, the thermal energy is transferring through a liquid. This time, the particles can move around within the liquid and as they do so they come into contact with other particles and so transfer some of their kinetic energy. Those particles in one part of the liquid that have more kinetic energy are more likely to spread out than particles with less kinetic energy, and this has the effect of causing the higher energy particles – those with more thermal energy – to rise, and in turn the particles with lower energy tend to fall. A circular **convection** current arises in the liquid until the thermal energy is spread through all the particles in the liquid more or less evenly.

In both of these last two examples, thermal energy is being spread by physical movement of particles in some way. In the third case, the particles cannot transfer their kinetic energy easily through physical contact – although some energy will be transferred through the particles of the air. This makes it relatively difficult for the thermal energy to transfer. However, as we saw in the 'energy rays' activity earlier, heat can be transferred through space without any need for physical contact. When this happens, the heat is transferred as **infra-red radiation** and this is known as radiant heat transfer. Although infra-red radiation is invisible to us, we can feel its effect on our skin as heat. When objects become hot, they often radiate red light along with invisible infra-red radiation, and this is why we tend to associate the colour red with warmth. It is important to note, however, that very hot objects produce light of all colours, and so are 'white hot'. (We will learn more about colours and light in *Sciences for the IB MYP 2: by Concept*.)

In Chapter 6, we will also find out how heat transfer processes in the atmosphere and in the oceans drive the weather on Earth.

ACTIVITY: Hot technology

ATL

- Transfer skills: Apply skills and knowledge in unfamiliar situations

In this activity we will make scientific judgments about heat transfer processes.

Interpret the information in Table 4.3 about heat transfer in different states of matter. **Outline** why different heat transfer processes occur only in certain states of matter.

Heat transfer process	Solids	Liquids	Gases
Conduction	Very effective	Moderately effective	Not effective
Convection	Not effective	Very effective	Very effective
Radiation	Not effective	Moderately effective	Very effective

Table 4.3 Heat transfer in different states of matter

The following list describes some examples of technological solutions to different problems of heat transfer. **Interpret** each of the technological solutions and **apply** what you know about heat transfer in order to **outline** the problem that they are solving, and how they work.

Hint

What would happen if the design were different?

Figure 4.15 NASA's Space Shuttle was coloured for heat transfer

1. **A refrigerator has the freezer compartment at the top of the refrigerator. This is where the refrigeration coils are located.**
2. **A space plane is exposed to the Sun's energy on its top side. When it re-enters the Earth's atmosphere, it becomes very hot on its bottom side. The top side of the space plane is coloured white, and the bottom side is coloured black.**
3. **A high-quality saucepan is made out of copper metal, but the handle is made from wood.**

Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding.

In this section we have **described** how average thermal energy in an object can be measured as temperature, and we have **outlined** how temperature scales are **defined**. We have **explained** how heat is transferred between objects with different amounts of thermal energy, and also we have **outlined** how heat transfer can be used to solve some different technological problems. How can we use this scientific knowledge to help us to use heat energy efficiently?

ACTIVITY: Capture the Sun's energy

ATL

- Creative-thinking skills: Design improvements to existing machines

In pairs or in groups, we will make a simple device for capturing the Sun's radiated heat energy.

SAFETY: Take care when cutting with knives – use gloves if necessary.

Inquiry: How can we use the Sun's energy to cook?

Background

Most of the time, the Sun's rays do not cause enough heating to raise temperature by more than ten or twenty degrees centigrade. However, the heating effect of the Sun's rays can be maximized if we gather and focus their energy. We can make a solar-powered oven to cook this way.

Method

To build your oven you will need:

- **Large, flat cardboard box: a pizza box is ideal**
- **Some black paper, or matt black paint**
- **Some aluminium foil, or silver paint**
- **Some plastic wrap, or thin plastic sheet**
- **Scissors, craft knife**
- **Glue, or sticky tape**

Figure 4.16 shows how to build the oven. First, cut a square flap in the centre of the box lid by cutting three sides of the square with the craft knife, and then folding the flap upwards along the fourth side. Cover the flap with aluminium foil, or paint it silver. Bend the flap back and prop it open, for example with a pencil. Cover the hole made by the flap with plastic wrap or plastic sheet. Finally, cover the bottom of the box with black paint or paper.

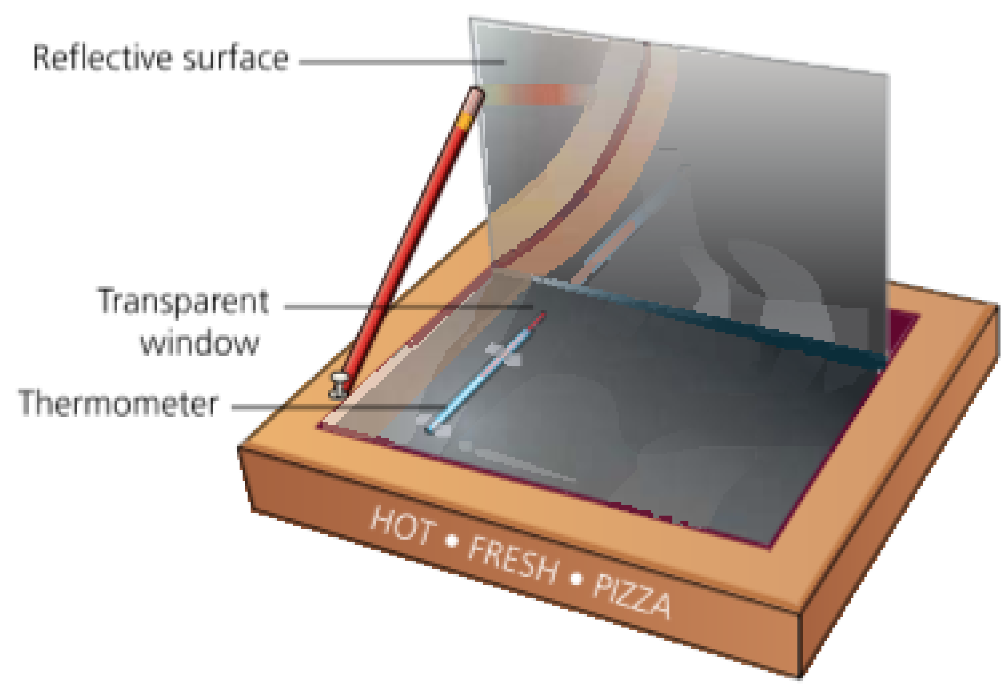


Figure 4.16 How to build your solar-powered oven

To try out your oven, you will first need a reasonably sunny day! (If this is unlikely where you live at this time of year, try using a very strong adjustable lamp with an incandescent light bulb as a heat source, placed quite close to the oven.) Position your oven so that the 'window' in the box lid captures the Sun's rays. Place the object to be 'cooked' on the black surface of the oven – it can be a small glass of water, some cookie dough or a marshmallow. Then wait …

Conclusion

Explain how your oven works, using the science of heat transfer we have explored in this section.

Evaluation

How well did your **prototype** oven work? Could the design be improved? **Outline** your ideas for an improved oven and **present** to the class.

As a class, **discuss** the ideas from the different design briefs presented. Which would have the greatest impact on the performance of the oven? What problems would you need to overcome to make them work? Make notes on your class discussion, and then produce a **design** brief for a super, improved pizza oven to beat all others!

How can we control energy?

THINK–PAIR–SHARE

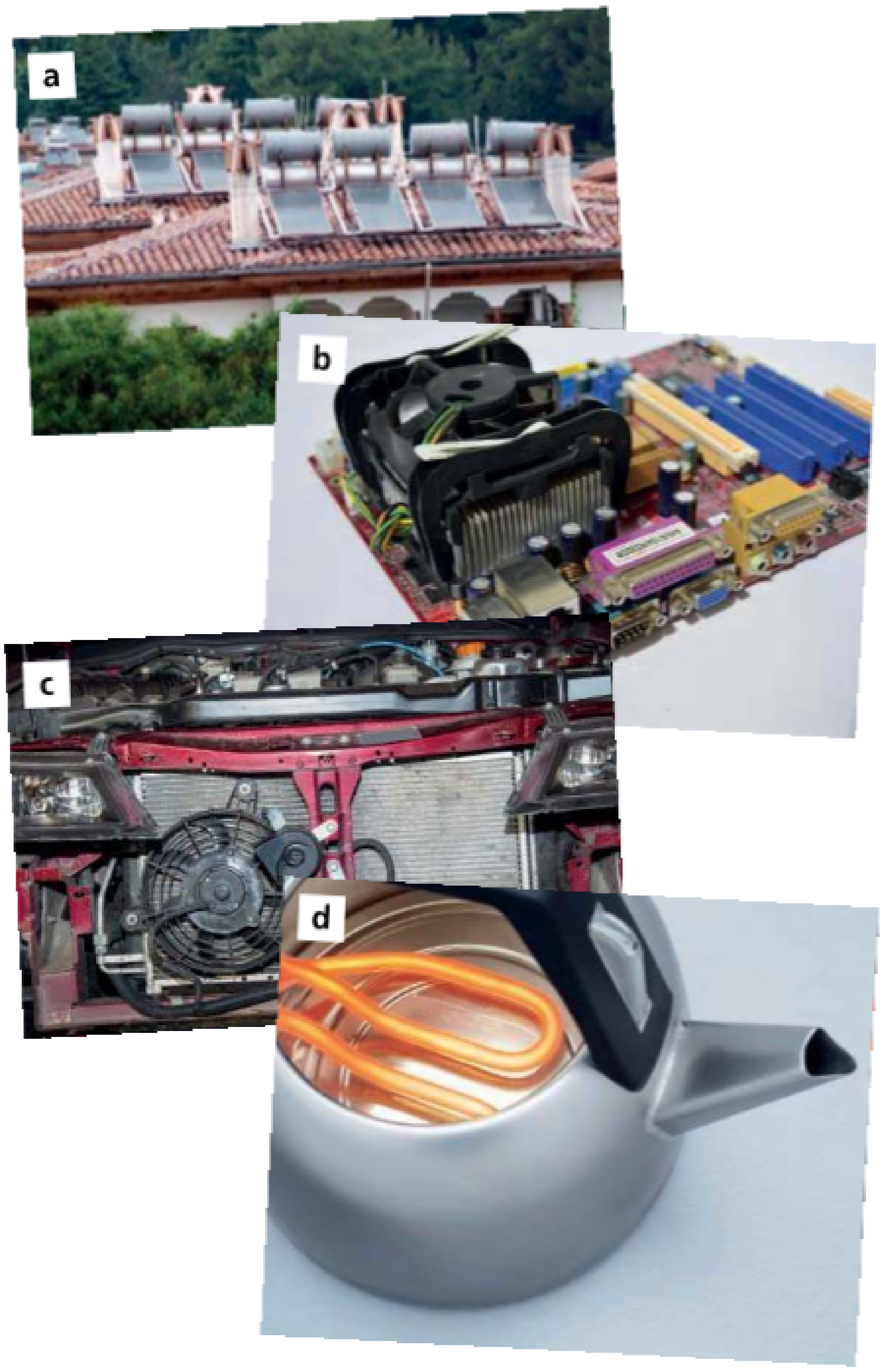
When is heat useful? When is heat a problem?

Look at the images in Figure 4.17.

On your own, think about the way heat is transferred in each of the objects. What is happening to the heat? Is the heat being used for something?

Then, in pairs, **discuss** your ideas and then write a brief **summary** of the way heat is being transferred in the objects.

In class, share your ideas. **Classify** the objects as 'heat users' or 'heat losers'.



■ **Figure 4.17** (a) Water heating solar panels, (b) a 'heat sink' on a microprocessor in a computer, (c) the radiator on a car engine (d) an electric kettle heating element

In the examples in Figure 4.17, energy is being either used or lost to the environment. It is important to realize that, even while we might 'lose' energy from a machine in the form of wasted heat, the energy does not disappear – it is just changed into another form (thermal energy). As far as nature is concerned, the energy is still out there, and has not been lost. If we could somehow add up the total amount of energy in the Universe at any moment since the start of time, we would expect to always find the same answer. Some will be potential energy – for example in the form of nuclear energy stored in the atoms in stars – and this energy was 'captured' inside atoms in the early moments of the Universe. The idea that the sum total of all the energy in the Universe remains the same is known as the principle of **conservation of energy**.

Controlling heat transfer enables us to make machines that make life easier. To control heat transfer, we need to carefully exploit the thermal properties of different materials. As we saw in the activity *Hot technology*, some materials are better than others at transferring heat by each of the three heat transfer processes. For example, materials that conduct heat well are called **thermal conductors**, while materials that do not conduct heat well are called **insulators**.

HOW CAN WE USE ENERGY EFFICIENTLY?

Making energy costs money, and has an impact on the natural environment (see *Sciences for the IB MYP 3: by Concept* and *Physics for the IB MYP 4 & 5: by Concept* for more information as to how energy production impacts on the climate). In the last five decades, we have become more aware of the need to control the way we use energy, in order to better conserve it.

ACTIVITY: Heat race

ATL

- Information-literacy skills: Collect and analyse data in order to identify solutions and make informed decisions

In pairs, we will explore the heat conduction properties of different materials.

Inquiry: Which material would be best to use for a saucepan handle?

SAFETY: This experiment uses hot liquids and hot objects. Make a safety assessment of your experiment before beginning. Use heatproof gloves and heatproof mats to prevent burns. Take care when pouring boiling water and take care when pouring melted candle-wax – avoid contact with your eyes. Wear safety glasses at all times.

Background

High-quality cooking utensils such as saucepans need to conduct heat very well. The better the conducting material used for the pan, the more control the cook has over the temperature of the food inside. However, this means that the handles of the saucepans will also become very hot very quickly – not such a good thing for the cook's hands.

Variables

In this experiment, we will change the material to be used for the handle. We will measure the time taken for heat to conduct through the material.

Prediction

Look at the list of materials below. Which will be best to use for a saucepan handle? **State** your choice and **explain** why you chose it.

Equipment

- **3 rods or sticks approximately 10 cm long: 1 copper or other metal, 1 Pyrex™ glass, 1 wood**
- **250 ml beaker**
- **Electric kettle, or other means to heat water**
- **Candle**
- **3 thumb-tacks**
- **Timer**
- **Safety glasses**

Procedure

1. **Light the candle. When some of the candle-wax has melted, pour a tiny drop onto the end of one of the rods.**
2. **Fix the thumb tack to the wax while it is still molten.**
3. **Repeat for all three rods. Try to ensure that you have more or less the same amount of wax on each rod, and that the wax is at the same position on each rod.**
4. **Boil some water in the kettle. Pour the water to half-fill the 250 ml beaker.**
5. **Quickly place the rods into the water, with the ends holding the thumb tacks out of the water.**
6. **Start the timer.**
7. **Wait until the wax melts and the thumb tacks fall off. Note down the time when this occurs for each rod.**

Results

Record your results and **organize** them so that they can be **interpreted**.

Conclusion

Summarize your results and **describe** what you observed. Was your prediction correct? What does this tell you about the conductive properties of the different materials?

Evaluation

State whether or not your experiment gave the results you needed to test your prediction. **Suggest** how the method could have been improved, and **suggest** how you could extend the experiment to obtain further information.

Discuss

What materials are actually used for saucepan handles? Why is this? What other factors affect the decisions saucepan manufacturers make when choosing the materials to use?

Assessment opportunities

- This activity can be assessed using Criterion C: Processing and evaluating.

ACTIVITY: Save money, save the planet

ATL

- Information literacy skills: Use critical-literacy skills to analyse and interpret media communications

Individually, read the following article from a popular science magazine.

Are energy savings the answer to climate change?

Climate change is always in the news – but what can we do about it? Many of the problems of climate change seem so big that there does not seem to be any point in individuals acting. However, research by the government Department for Energy and Climate Change shows that much of the energy we use to heat our homes is wasted immediately through heat losses in the home. It is important to realize that this heat does not itself contribute significantly to climate change. However, if this energy could be used to heat the home instead of being wasted, then households would be able to reduce their energy consumption. This would mean lower energy bills for homes, less energy production at the power stations, and so less impact on the global environment.

Of the heat wasted in most homes, 25% is lost through the roof. If the house is not surrounded by others (such as in an apartment), then 35% is lost through the walls and a further 15% through the floors. Meanwhile around 10% is lost through windows (even when closed!) and 15% through inadequate insulation around doors.

Think that warm weather would help reduce the problem? Not so – just as heat is lost during cold weather, when we turn on the air-conditioning in warm weather the heat comes back into the house in the opposite direction, reducing the effectiveness of that expensive air-con considerably.

So – time to cut out those chilly draughts and creeping heat loss. Save money, and save the planet.

Interpret the article to answer these questions:

- **Outline the main ways in which heat is lost from many homes.**
- **Explain why an apartment might be more energy efficient than a house.**

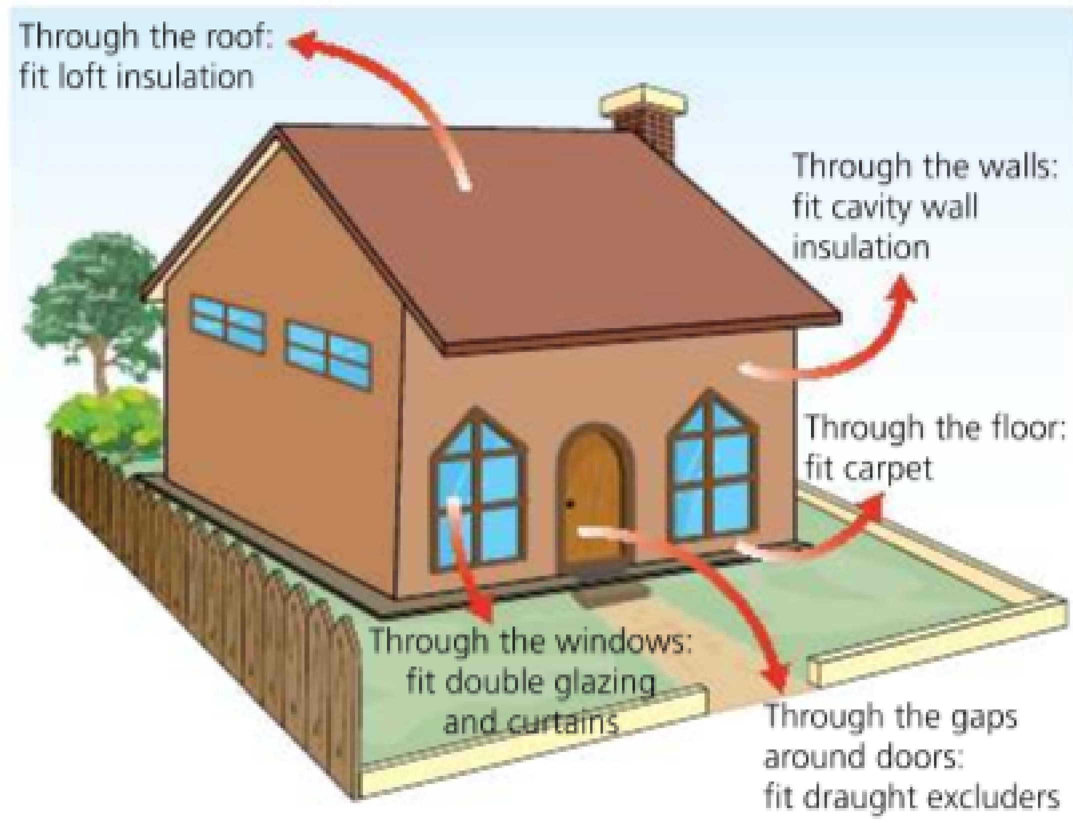
Now consider Figure 4.18.

Identify each of the heat loss prevention methods used in the house in Figure 4.18.

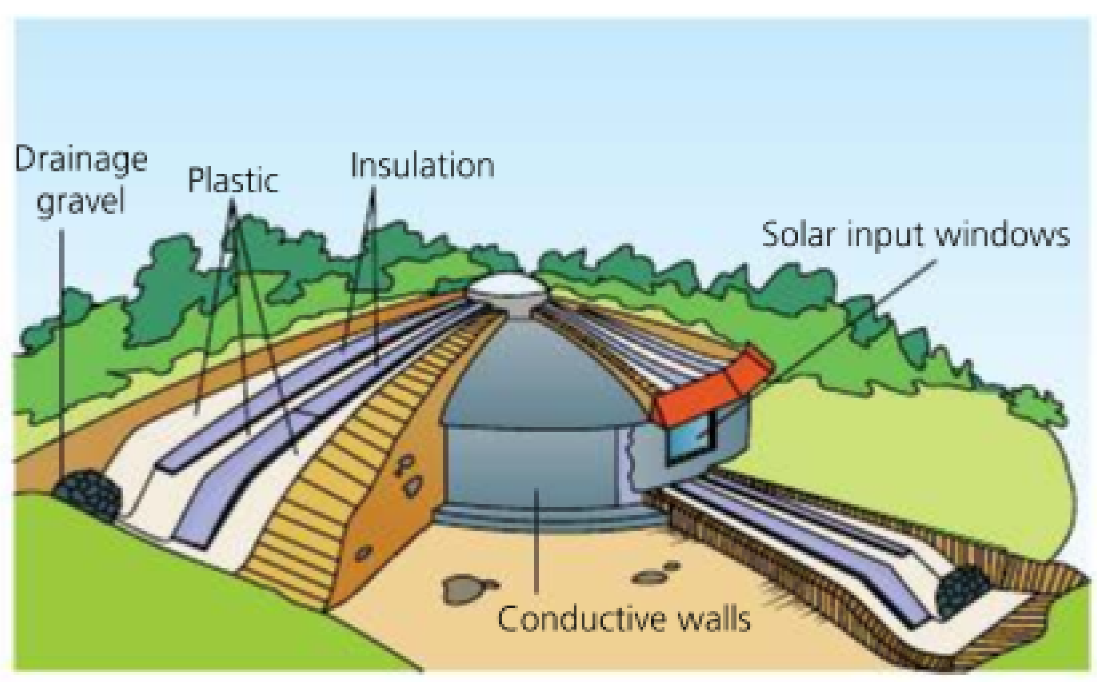
Compare the house in Figure 4.18 to the 'underground house' in Figure 4.19. How does the underground house deal with the problem of heat loss?

Choose one of the heat loss prevention methods shown. **Outline** how this method works to prevent heat loss, using the heat transfer processes we explored earlier. Use your own research to support your answer if required, but make sure you **document** all your sources correctly in the form of a bibliography.

Summarize the reasons why reducing heat loss from a home in this way could reduce our impact on climate change, and any other advantages it offers.



■ **Figure 4.18** Prevention of household heat loss



■ **Figure 4.19** Underground eco-house

◆ Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding and Criterion D: Reflecting on the impacts of science.

Of course, preventing heat loss is just one way we can reduce our energy consumption. Research: **CFL bulbs** to find out how we might also reduce our electricity consumption. We will find out more about energy conservation in *Sciences for the IB MYP 3: by Concept*.

Take action: Keeping cool to keep well

ATL

- Creative-thinking skills: Apply existing knowledge to generate new ideas or products

Background

- Many medicines need to be kept cool in order to be effective. In the more economically developed world, people can go to a doctor when they feel sick, and if required then go to a pharmacist to buy medicines over the counter. If the medicines need to be kept cool, they can be kept at home in a refrigerator. However, 1.3 billion people (18% of the world's population) live where there is no electricity supply[1], and so refrigerators are hard to find. Illnesses such as cholera, tuberculosis and typhoid can be cured by antibiotics, while others such as measles and yellow fever could be prevented with vaccination. These medicines are freely available to those in the more economically developed world, but these illnesses kill many people every year – especially children and the elderly.

  Data source: 1. World Energy Outlook 2014 database **www.worldenergyoutlook.org** accessed 09.08.15

- If the medicines can be transported safely to those who need them, many of those lives could be saved.
- You are scientists and engineers commissioned by the World Health Organization.

Task 1

- Your first task is to **design** a medicine carrier that will keep a medicine cool for the longest possible time. The medicine needs to be kept at a temperature no higher than 5°C for 24 hours.
- You should use what you have learnt about heat transfer processes and materials to design the medicine carrier. You should then build an experimental prototype and test it.
- You will then be expected to produce a scientific report, detailing your results. You may wish to use the scientific investigation cycle to plan your experiments and then write your report.
- You will be asked to **present** your conclusions to your class, stating whether or not your medicine carrier can meet the requirements for transportation of the medicine.

Task 2

- Your second task is to write a product brief for the World Health Organization which will help them decide whether or not to invest money in your project.
- **Summarize** the science behind the importance of temperature in medicine storage, and the way that your medicine carrier controls energy to maintain the temperature of the medicines. **Describe** the potential impact of developing your medicine carrier on people's lives. Remember to consider as many factors as you can: the effect on health, economic issues, and perhaps even political effects.
- In your product brief, **apply** the scientific vocabulary you have learnt clearly and precisely, making sure that you understand all the words you use.
- Be sure to **document** any research sources you used in writing your brief.

Assessment opportunities

- This activity can be assessed using Criterion B: Inquiring and designing, Criterion C: Processing and evaluating and Criterion D: Reflecting on the impacts of science.

Links to: Design

Testing and then reflecting on the design of a 'prototype', then using your findings to improve a design to making a better solution is an important part of the MYP Design Cycle, just as in MYP Sciences it is important to reflect on the outcome of an experiment and think of improvements.

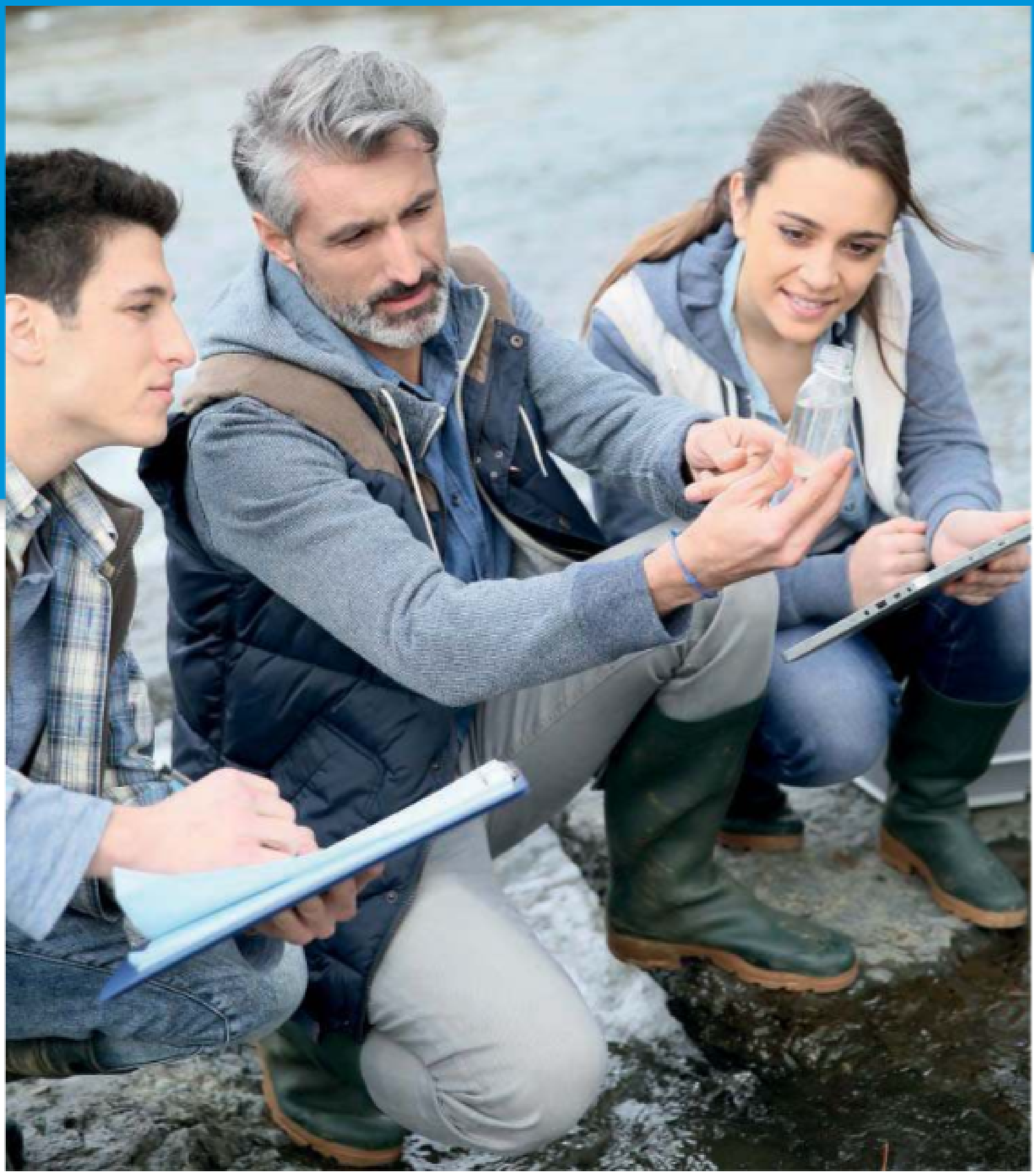
Reflection

In this chapter we have **described** energy changes in different situations, and **classified** energy types as potential or kinetic energy. We have **defined** temperature as a way to measure average thermal energy and **outlined** how temperature scales are defined. We have **described** three different states of matter in terms of the kinetic energy of particles, and **explained** how thermal energy transfers as heat between objects with different temperatures in different ways. We **identified** how energy can be useful or wasted in different situations, but **stated** that energy is never really destroyed, just changed into different types, such as heat in the environment. Finally, we **applied** our understanding of energy transfer to **outline** different ways in which heat loss could be controlled.

<table>
<tr><th colspan="6">Use this table to evaluate and reflect on your own learning in this chapter.</th></tr>
<tr><td>Questions we asked</td><td>Answers we found</td><td colspan="4">Any further questions now?</td></tr>
<tr><td>Factual: What types of energy are there? How can we classify energy? How can we measure energy? How can we control energy? How can we use energy efficiently?</td><td></td><td colspan="4"></td></tr>
<tr><td>Conceptual: How might our use of energy affect people's lives now, and in the future?</td><td></td><td colspan="4"></td></tr>
<tr><td>Debatable: Can individuals act to reduce energy consumption? Is there enough energy to go around?</td><td></td><td colspan="4"></td></tr>
<tr><td rowspan="2">Approaches to learning you used in this chapter:</td><td rowspan="2">Description – what new skills did you learn?</td><td colspan="4">How well did you master the skills?</td></tr>
<tr><td>Novice</td><td>Learner</td><td>Practitioner</td><td>Expert</td></tr>
<tr><td>Communication skills – we have discussed ideas to improve our understanding.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Collaboration skills – we have listened actively to others' explanations.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Critical-thinking skills – we have observed, gathered and organized information to formulate arguments and conclusions.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Information literacy skills – we have researched, analysed and identified solutions; we have read critically to interpret information.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Transfer skills – we have applied our knowledge in new and unfamiliar situations.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Creative-thinking skills – we have identified improvements to machines and applied our knowledge to create new solutions.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Learner profile attribute</td><td colspan="5">Reflect on the importance of being principled for your learning in this chapter.</td></tr>
<tr><td>Principled</td><td colspan="5"></td></tr>
</table>

5 How can we study the living world?

Scientists have developed methods and tools to understand and maintain the interactions that keep ecosystems in balance.



■ **Figure 5.1** Scientists study and make decisions to help natural systems stay healthy

CONSIDER THESE QUESTIONS:

Factual: How can we study ecosystems? What makes up an ecosystem? What makes an ecosystem healthy?

Conceptual: What can scientists and others do to understand ecosystems and what makes ecosystems healthy? How do scientific innovations and daily life decisions help to keep ecosystems healthy?

Debatable: To what extent will scientific innovations be able to keep ecosystems healthy? To what extent can we and should we rely on scientific advancements to 'fix' environmental damage that human activity has caused?

Now **share and compare** your thoughts and ideas with your partner, or with the whole class.

IN THIS CHAPTER WE WILL …

- **Find out** what an ecosystem is and what interactions between living and non-living things are necessary for balanced and healthy ecosystems.
- **Explore** how people influence the balance and health of ecosystems through scientific innovations as well as through their daily actions and decisions.
- **Take action** by designing and carrying out an experiment to test the effects of different factors on the health of an ecosystem.

We will reflect on this learner profile attribute …

- Thinkers – we will use creative-thinking skills to analyse complex situations and make reasoned, ethical decisions.

Assessment opportunities in this chapter:

- **Criterion A:** Knowing and understanding
- **Criterion B:** Inquiring and designing
- **Criterion C:** Processing and evaluating
- **Criterion D:** Reflecting on the impacts of science

These Approaches to Learning (ATL) skills will be useful …

- Organization skills
- Reflection skills
- Information literacy skills
- Creative-thinking skills

KEY WORDS

diversity	impact
ecologist	innovation
environment	maintain
factor	sustainability

Humans can and do live in different environments around the world. Every day, just like all other organisms, we have countless interactions with the living and non-living things that surround us. How many different living things do you come in contact with or see or use in a single day? Be creative … think carefully, and you can probably come up with a long list!

But how is it that so many different things can live in the same place and use the same resources, without all of us fighting or killing each other? Can all organisms live with each other? Is there any place that humans cannot live? What conditions make it better for life, and what conditions make it more difficult for life to exist? Are there any conditions and interactions that make life impossible? In this chapter, we will explore these questions. We will also look at what it means to be living, and the conditions and interactions that different types of living things need in order to survive in a balanced and healthy way.

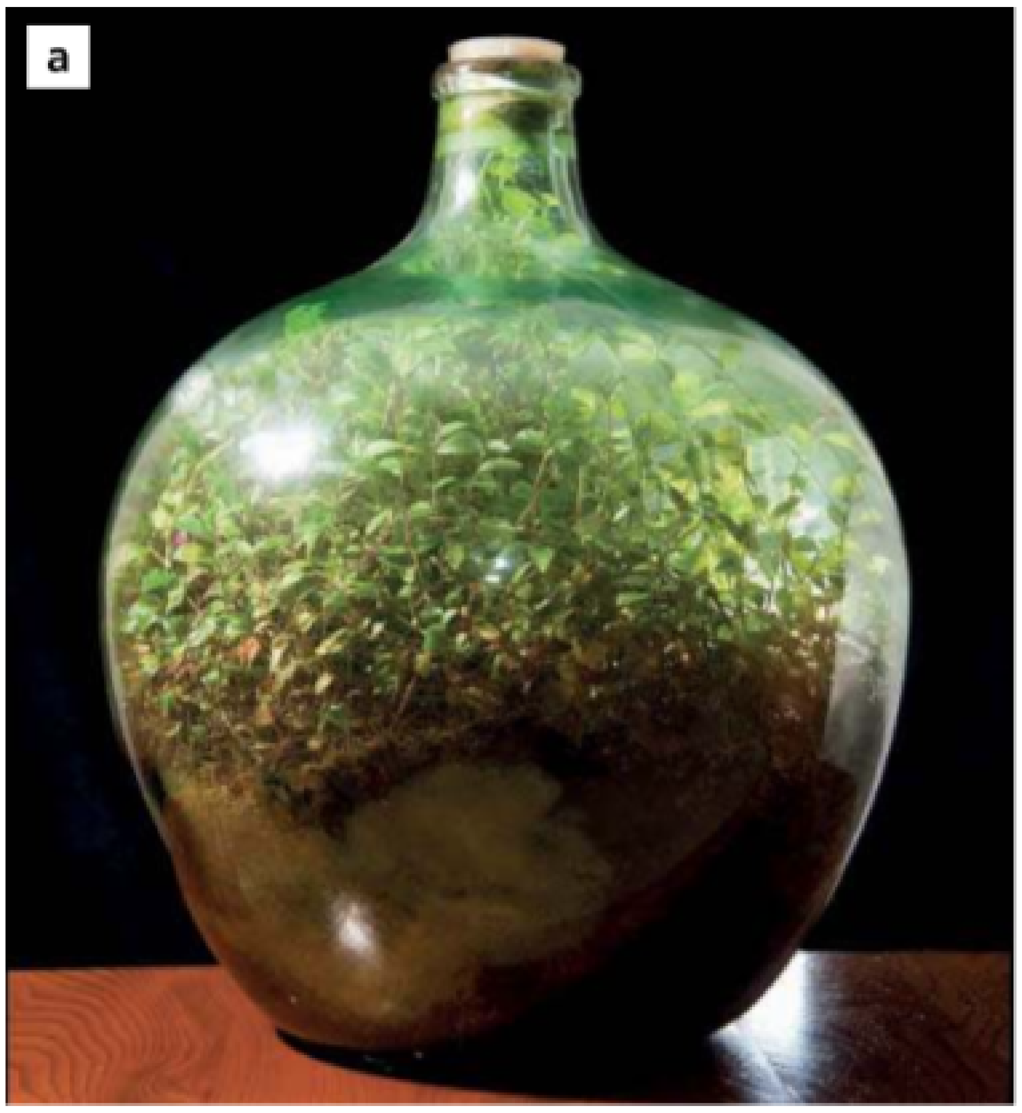
For this chapter, you will apply your knowledge and understanding as **ecologists** do. In fact, as you engage in learning the scientific concepts and principles, you should imagine you are an ecologist studying the **impacts** of different **factors** on the health and **sustainability** of an ecosystem.

For the summative assessment you will design and carry out an experiment by constructing a **mesocosm** to test how a factor of your choice affects the health of an ecosystem. Your experiment will run over a long period of time, so you will regularly make observations of your mesocosm, and organize those observations in a science journal. Towards the end of the course, you will write up a scientific article of your investigation, including a description of the investigation, the results, and your conclusions.

How can we study ecosystems?

A **mesocosm** is a **model**, or small-scale version of a real ecosystem. People create them to have conditions that are very close to conditions in nature. Some mesocosms, as we can see in Figure 5.2a, are designed and maintained by people in their homes to keep as a type of decoration, in what are often called 'bottle gardens'. Others, as in Figure 5.2b and c, are created by scientists, usually ecologists, in order to study and learn what can happen to different ecosystems under different conditions.

In both cases, if a mesocosm is created with the appropriate conditions necessary to create and keep a balance of the interactions necessary to sustain life, the organisms in it can survive on their own for years, without adding anything. In fact, the mesocosm pictured in Figure 5.2a was created in 1960, and has not been opened or watered since 1972!



■ **Figure 5.2** Different types of mesocosm

ACTIVITY: Understanding mesocosms

ATL

- Organization skills: Use appropriate strategies for organizing complex information

Use Table 5.1 to **organize** your observations of the mesocosms pictured in Figure 5.2. Work with your partners to make and **write down** as many observations and connections as possible. An example has been done for you.

Things we notice in ALL of the mesocosms	Things we notice in SOME of the mesocosms
All mesocosms are in strong and sturdy containers.	Some of the containers are glass, and some seem to be of plastic or another material.

Table 5.1 Characteristics of mesocosms

ACTIVITY: Sustainability

ATL

- Information literacy skills: Collect and analyse data to identify solutions and make informed decisions
- Creative-thinking skills: Apply existing knowledge to generate new ideas

Do an image search for the word **sustainability**. After looking at the images, **suggest** what you think 'sustainability' means.

Then share your ideas with your partner and the class. After hearing the ideas for 'sustainability' from the others, make some changes to your definition and write it underneath your first ideas.

Assessment opportunities

- In this activity, you have practised skills that are assessed using Criterion A: Knowing and understanding.

Figure 5.3 Sustainability is a key part of the study of ecosystems

ACTIVITY: Summative project

ATL

- Organization skills: Managing time and tasks effectively
- Reflection skills: (Re)considering the process of learning

! Take action

! Design and carry out an experiment to test the effects of different factors on the health of an ecosystem.

Planning your mesocosm

As we saw in the activity *Understanding mesocosms*, creating mesocosms is an effective method and tool for ecologists to get more of a 'real world' understanding of how different factors and conditions affect different ecosystems. Therefore, now that you are an 'ecologist' for the remainder of this chapter, your current professional goal is to design and construct a mesocosm. You will do this in order to identify the effects of a factor (that you will choose) on the health of an ecosystem over several months. You could keep your mesocosm and continue observing it through the school year, and write a scientific article about your findings.

Situation

Here is the situation for you to consider and to focus on for this project. Due to pressures from growing human populations, there are many factors that threaten to damage the natural conditions and natural balance in many different ecosystems.

As an ecologist, you are concerned about the possible consequences of increased and spreading human populations. You would like to investigate the impacts of one factor on an ecosystem over several months, and compare the results to a healthy ecosystem.

Part 1

You have decided that the best way to do this investigation is by planning and creating a mesocosm. However, before you begin your experiment, you must get approval for the investigation and ensure you have access to appropriate materials and equipment. In this case, 'approval' means that you are able to actually build your ecosystem and observe it in the laboratory (or your classroom).

Therefore, you will design a detailed plan for your investigation and mesocosm. You can use the activities throughout this chapter to help develop your plan. When you have finished your plan, you will submit it to the 'head scientist' in your laboratory (your teacher!). The head scientist will read your plan, and assess the plan for your investigation and mesocosm depending on how clearly you:

- **state or outline an appropriate problem or question that can be tested in a mesocosm**
- **outline a prediction of results that you can test through your investigation**
- **outline how you will manage all of the variables and collect relevant data**
- **design a complete and safe method, including appropriate materials and equipment.**

In order for the head scientist to approve your proposal, you must include adequate scientific information and evidence of planning. This means that you might have to re-submit your first proposal, or you might be assigned to assist another ecologist or team of ecologists (other students in your class) with a different mesocosm. In addition, you must remember that there may be some limitations in materials or equipment in the laboratory; for that reason, you must develop a plan that takes into consideration what is available in your laboratory so that you and the other ecologists (your classmates) can actually build your mesocosms.

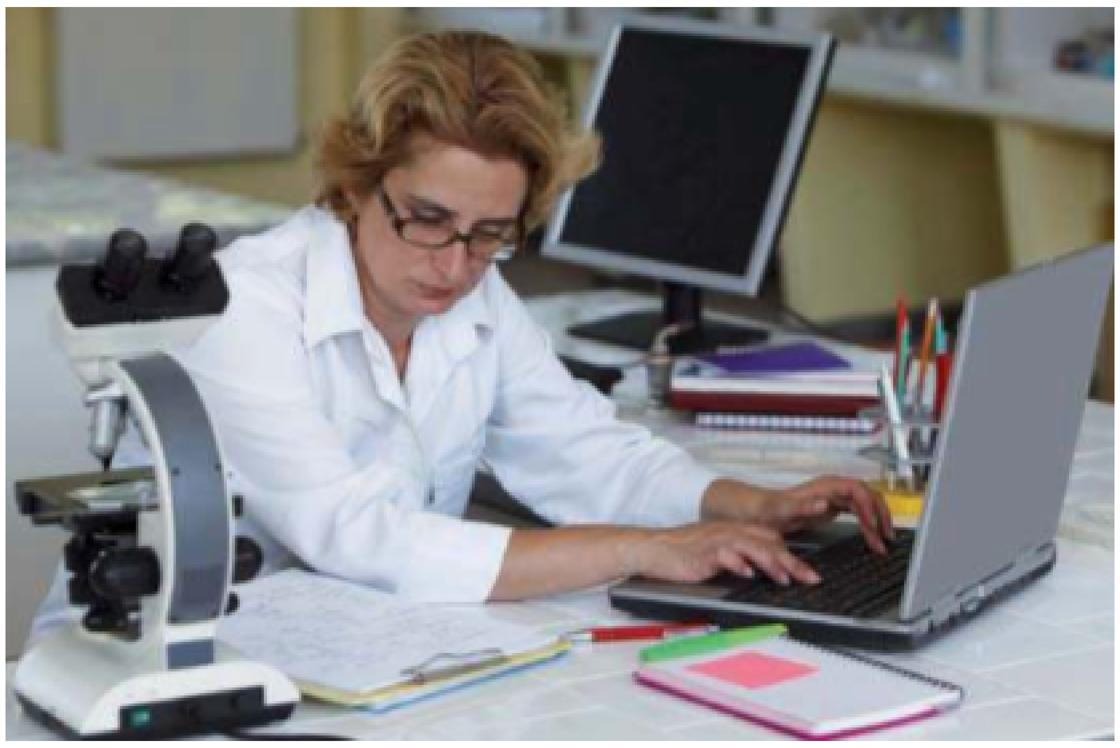
After you and your classmates build the mesocosms, you will regularly collect data and record what you observe. Remember to take pictures to **document** the progress of the mesocosms.

■ **Figure 5.4** Whether (a) 'in the field' or (b) in a laboratory, scientists give much time and attention to carefully making and documenting their observations

Part 2

After a few months of observing and writing down your observations of your mesocosm, you will write about your investigation because you would like your results to be published in a scientific journal. To do this, you will write an article to **describe** your investigation. Make sure you include:

- **the background of your investigation**
- **the plan**
- **your data**
- **your conclusions**
- **your evaluation of the results**
- **your suggestions for future research or actions to protect the ecosystem you studied in your mesocosm.**



■ **Figure 5.5** In addition to doing experiments, scientists spend time writing about their results to share their conclusions with others

You will then submit your article to the head scientist and the other ecologists from your laboratory, who will review your work and offer you suggestions for publication. You and the other ecologists from the laboratory could then write a blog or use an app to publish your articles.

This is a long-term project, one that requires a lot of organization and reflection. Throughout the chapter there will be activities to practise your scientific knowledge and understanding, and to practise the Organization and Reflection ATL skills you need to meet the expectations set by the head scientist (your teacher) as well as your personal goals as an ecologist. These activities should help you to:

- **plan short- and long-term tasks effectively to meet deadlines**
- **set challenging yet realistic goals**
- **develop a system to keep your notes and information organized**
- **focus on the process of learning by imitating and building from successful models**
- **keep a journal to record your reflections.**

◆ Assessment opportunities

- This activity can be assessed using Criterion B: Inquiring and designing and Criterion C: Processing and evaluating.

What makes up an ecosystem?

Humans are organisms. We are animals. We are living things. We are part of different ecosystems around the world. We use and depend on other living and non-living things in order to survive ... and other living things use and depend on *us* to survive. But what exactly is an ecosystem? What exactly are these other living and non-living things that we depend on in our daily lives? In the introduction to this chapter, you and your class talked about all of the different living things you come in contact with every day. Now, we will take a closer look to understand more about ecosystems, and how different types of interactions in ecosystems make life possible.

THINK–PAIR–SHARE

ATL

- Creative-thinking skills: Practise visible thinking strategies and techniques; Apply existing knowledge to generate new ideas

Look at the photos in Figures 5.6 to 5.9. Think about what they show about ecosystems and **write down** your observations using Table 5.2. Make sure you think about the things that are living and non-living in the ecosystem. You can also write things that you can't see but you *know* are there!

Then, **define** the word 'ecosystem' using your observations.

I notice that ALL of the ecosystems ...	... so, I think an ecosystem is ...
have living things of different sizes, such as ...	

Table 5.2 Individual thoughts about ecosystems

Figure 5.6 shows examples of four different ecosystems. You will use these examples to understand what is necessary for an ecosystem. Before you begin, look carefully at the pictures, and notice the similarities between all of the ecosystems. For example, you will notice that even though there are different types of animals in the ecosystems, all of the ecosystems have some animals.

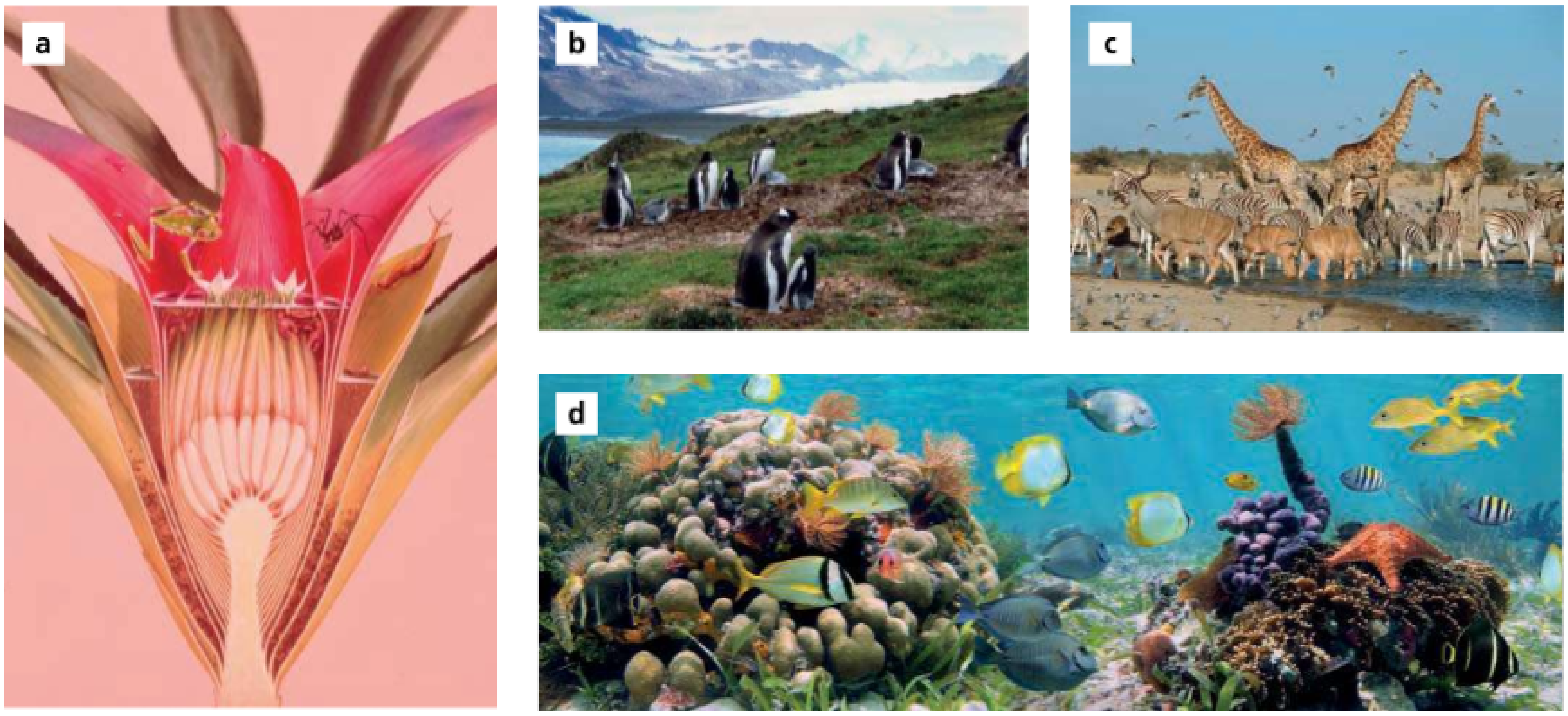


Figure 5.6 Different types of ecosystems: (a) a look at an ecosystem that exists inside the leaves of a kind of plant called a 'bromeliad', (b) the cold desert in the summer, (c) a watering hole in the African savanna, (d) a coral reef

Now, compare your thoughts and definition with your partner or group. Add any of their observations to your list if you did not have the same observations. Use each other's ideas and definitions of an ecosystem in order to come up with an even more complete and clear definition.

Share your observations and group definition with the class. Then, **discuss** and come to an agreement with the class about all of the different things that must be present in order for there to be an ecosystem. Use all of these 'must haves' in order to create a complete, detailed definition of what makes up an ecosystem. Copy Table 5.3 and use it to record the ideas from the class.

To be an ecosystem, there must be ...	... so, we think that an 'ecosystem' is ...

■ **Table 5.3** Class ideas and definition of ecosystems

■ **Figure 5.7** Acacia ants feed on nectar in, live in, and protect the Acacia trees in the African savanna

■ **Figure 5.8** A male and female mandarin fish mating in a tropical coral reef

■ **Figure 5.9** A moose, her calf, and several grey wolves in the tundra

You probably observed and noted that, in all of the **ecosystems**, there were different individuals of the same kinds – or **species** – of living thing in the same place, and at the same time. For example, in Figure 5.7 there are ants and a tree, in Figure 5.8 there are fish, and in Figure 5.9, there are moose and wolves. You might have also noticed that some individuals in the same species were **mating** or reproducing. When there are members of a species in the same place – or **habitat** – at the same time with the possibility to mate or reproduce, we call it a **population**. Therefore, we can say that all ecosystems are made up of different populations of living things in the same habitat.

Now that we have identified what a 'population' and a 'habitat' are, use your prior knowledge of different habitats you have seen in nature or from an Internet search to complete a copy of Table 5.4 with examples of different populations of living things and the habitats where they live.

Examples of different populations I have seen ...	Examples of different habitats I have seen ...
Ants and termites	A tree in the forest

■ **Table 5.4** Populations of living things in their habitats

You may have noticed that the living things are interacting with each other in different ways. For example, in Figure 5.7, the ants are feeding on plants (called **herbivory**), in Figure 5.8, the fish are mating, and in Figure 5.9 the wolf **predators** are hunting the moose **prey** (called **predation**). All of these interactions between living things are called **biotic** factors or interactions, because 'bio-' is a root word meaning 'life' or 'living'. Therefore, we can say that all ecosystems have different biotic factors or biotic interactions.

In addition, there are many different non-living things that the living things use and interact with. For example, in Figure 5.7, there is nectar inside the tree, in Figure 5.8, there is salt water, and in Figure 5.9, there is water in the pond. All of these interactions between living things and non-living things are called **abiotic** factors or abiotic interactions, because, as we just learnt, 'bio-' means 'life' or 'living', and 'a-' means 'not'. Therefore, we can say that all ecosystems have different abiotic factors or abiotic interactions.

ACTIVITY: Biotic and abiotic factors

Copy Table 5.5 and use it to **list** some of the biotic and abiotic factors and interactions in Figures 5.8 and 5.9.

Examples of biotic factors or interactions	Examples of abiotic factors or interactions
The number of plants where the moose live	How much water there is for the moose to drink

Table 5.5 Examples of biotic and abiotic factors and interactions

Organization skills: Keep an organized and logical system of information

All of these abiotic factors are ones that ecologists might test in a mesocosm. When you start to plan your own mesocosm, you might decide to test one of these factors.

In order to practise organizing information, develop a way to have easy access to your notes. For example, maybe you would like to copy these notes in your journal or make a labelled bookmark so you can easily locate this information about abiotic factors and interactions. Perhaps you prefer to use an electronic tool for creating, storing, and sharing documents.

So, if we put together all of these different parts of what makes up an ecosystem, we can say that an ecosystem is made of different populations that interact with biotic and abiotic factors in their shared habitat.

Looking back at Figures 5.6 to 5.9, what do you notice about the size of ecosystems? We can see that ecosystems can be very small, such as the one inside the tropical plant, or they can be very big, such as the tundra shown in Figure 5.6b. Really large ecosystems, such as the tundra (shown in purple in Figure 5.10), are known as **biomes**.

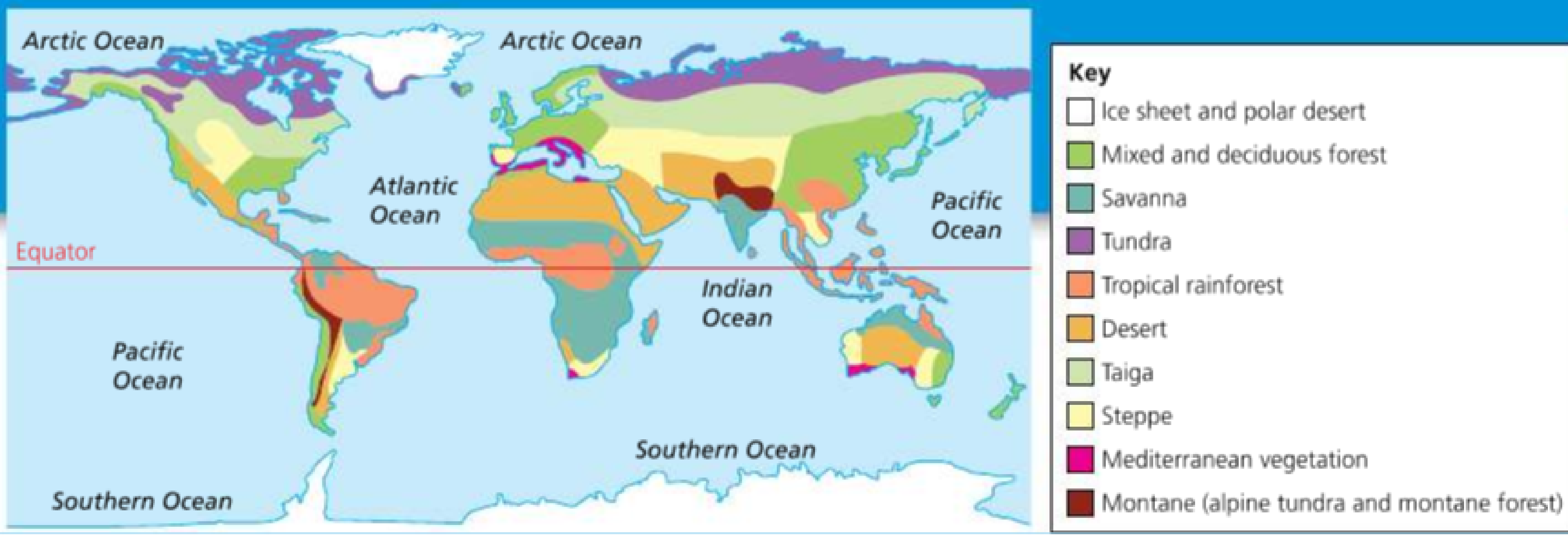


Figure 5.10 The main biomes in the world

ACTIVITY: My home biome

ATL

- Creative-thinking skills: Apply existing knowledge to generate new ideas

Do an image search for the word **biome**.

On your own or with your classmates, make a list of the major biomes in the world, and where they are located. An example has been given for you in Table 5.6.

Biome	Where it is located in the world
Tundra	In the furthest north parts of North America, Europe, and Asia

Table 5.6 Locations of some biomes

Next, **identify** characteristics or features of the biomes that are similar and characteristics that are different between all the biomes, and write them down in a copy of Table 5.7. Write an **A** next to each characteristic or feature that is abiotic and a **B** next to each characteristic or feature that is biotic.

All biomes have ...	Biomes have different ...

Table 5.7 Biomes: similarities and differences

Then, consider and talk about what makes an ecosystem a biome. Fill in your ideas in a copy of Table 5.8.

An ecosystem is a biome if it has BIOTIC factors, such as: ...	An ecosystem is a biome if it has ABIOTIC factors, such as: ...

Table 5.8 When is an ecosystem a biome?

What biome is your home in? Using the information about biomes from your Internet search, **identify** which biome you live in. You can think of 'home' as where you live now, where you were born, or any place where you feel a personal connection.

Make a short slideshow or video to share with your class. In your slideshow or video, be sure to include:

- **a map showing where your home is located**
- **the biome in which your home is located**
- **the biotic and abiotic characteristics of your home biome**
- **biotic factors or interactions that are important in your home biome**
- **abiotic factors or interactions that are important in your home biome**
- **what makes your home biome special to you and to others.**

Assessment opportunities

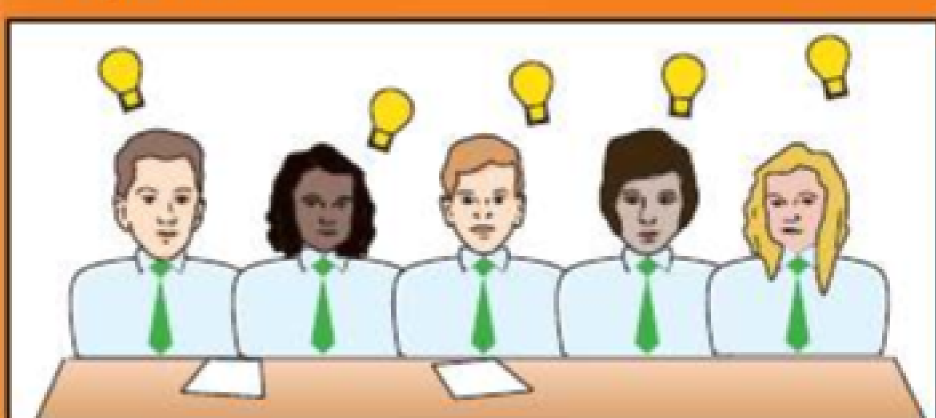
- In this activity, you have practised skills that are assessed using Criterion A: Knowing and understanding.

ACTIVITY: Characteristics of ecosystems

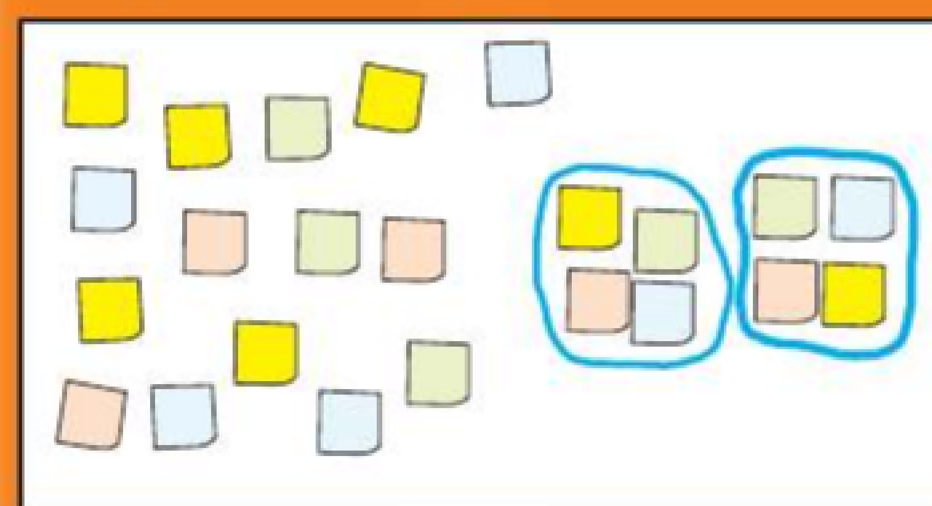
ATL

- Organization skills: Use appropriate strategies for organizing complex information

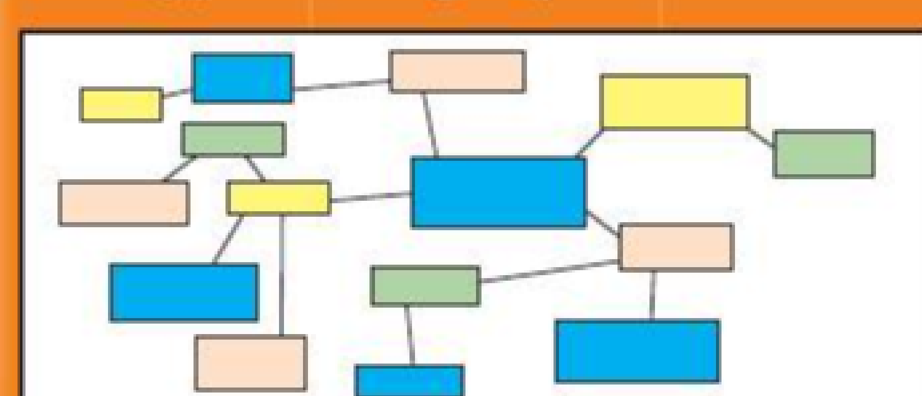
Step 1: Generate (think about and write down) a list of the characteristics of ecosystems, including the abiotic and biotic factors and interactions that we can find in ecosystems, as well as any examples and important scientific words related to ecosystems. You can think of this as making a 'vocabulary list' of all the important words for this section. It is helpful to brainstorm this list with a partner or as a whole class. You can generate your list on a piece of paper, on your electronic device, or on sticky notes.



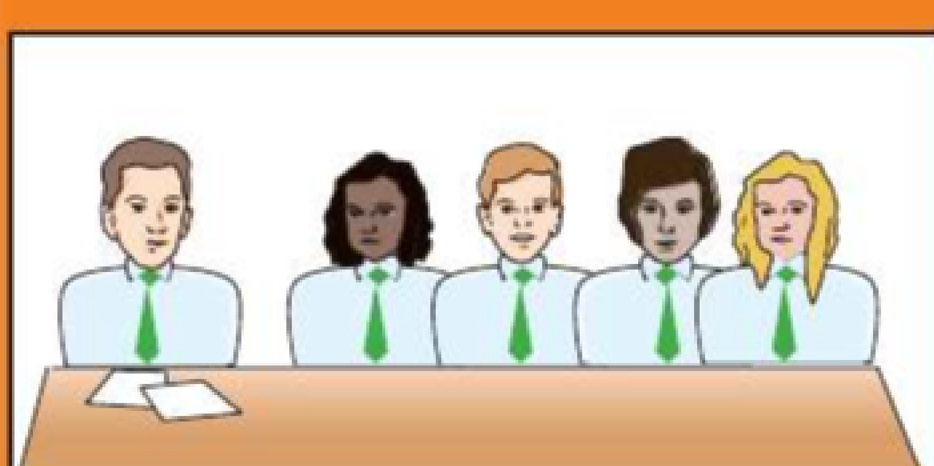
Step 2: Sort or **separate** the words into different categories or groups. Each category or group should have words that represent some sort of relationship or connection to the characteristics of ecosystems. You may want to sort the words by colour-coding or making lists. Please note there is not one 'right' way to sort the words, and you may find that some words can easily go in more than one category. Again, talking with your classmates can help to identify different categories of information.



Step 3: Connect the words within and between categories by drawing lines or arrows. You could use a piece of blank paper to draw a 'mind map' or 'concept map' so that it is easier to show the connections between the ideas. If you used sticky notes, you can stick them on a large piece of paper or on a whiteboard to draw lines between the ideas. You could also make a table if you prefer. Try explaining the connections out loud to your partner in order to clarify your thinking for yourself.



Step 4: Elaborate or **explain** the connections between the words. For example, write a sentence or phrase on the connecting lines in order to say in what way(s) the ideas are connected. You may also want to write a paragraph or make a voice recording to summarize the connections between all of the words.



■ **Figure 5.11** Thinking routine – Generate, Sort, Connect, Elaborate

ACTIVITY: Ecosystem examples

ATL

- Organization skills: Plan short- and long-term assignments; Keep an organized and logical system of information

In order to develop a detailed plan for your own mesocosm, you must first decide what ecosystem you would like to investigate.

Try using the word **ecosystems** as a search term to do an image search of different types of ecosystems. When you find a picture you like, click on it to find out what kind of ecosystem it is and where it is (you might have to do an additional web search for more information about where it is located). Then, use that information to fill in a copy of Table 5.9.

Type of ecosystem	Biotic factors	Abiotic factors

Table 5.9 Types of ecosystem

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Knowing and understanding.

DISCUSS

Discuss your responses to the following questions. These are important points that might help you with planning your own mesocosm, so make sure you keep your ideas well organized in your journal! You might want to create a table to record your ideas so you can easily find them later when you design your mesocosm.

- **What is the connection between a mesocosm and an ecosystem?**
- **What are the strengths or advantages of using a mesocosm to understand an ecosystem?**
- **What are the limitations of using a mesocosm to understand an ecosystem?**

Which of the ecosystems from the previous activity would be easily or effectively modelled in a mesocosm? What makes you say that? Highlight or put a * on the list of ecosystems that might make good mesocosms.

Think about whether you and your classmates will plan mesocosms that model the ecosystem you are currently living in, or whether you will plan mesocosms in different ecosystems. This is an important discussion to have with the 'head scientist' (your teacher!) for when you begin your mesocosm plan.

As we learnt in Chapter 1, 'inquiry' is the first step of the cycle for designing and carrying out scientific investigations. Asking questions, doing background research, brainstorming possible connections and making predictions are parts of the scientific cycle – they are skills that scientists practise often, and you will, too!

What makes an ecosystem healthy?

Ecosystems are all about interactions – interactions between different living things, and between living and non-living things. In order to have a healthy ecosystem, there have to be healthy interactions.

In order to understand what makes an ecosystem and its interactions healthy, it will help to first think about a group (such as a class, team, or club) that you are or were part of, and that worked really well or that you consider to be 'successful'. Then, you can make a connection between what makes a group of humans healthy and what makes an ecosystem healthy.

ACTIVITY: Building a successful group

ATL

- Reflection skills: Develop new skills, techniques and strategies for effective learning

Figure 5.12 There are different types of groups – what makes each of them successful?

First, think of the group that you are or were part of and that you considered successful. Then, answer the questions about that group in a copy of Table 5.10.

Who is part of the group? In other words, who are the *members*?	
What do the different group members do? In other words, what is each person's *role*?	
What does the group need and use in order to meet the purpose of the group? In other words, what *resources* do you need?	
How do you share information, help each other, cooperate, and collaborate? In other words, what are your *interactions* with each other?	
What are some things that you and the group members do so that your group works well or is successful? In other words, what *processes* do you carry out?	
What happens when there are challenges or when you face problems?	

Table 5.10 My successful group

ACTIVITY: 3–2–1 bridge!

We will use this activity to get a better understanding of what makes an ecosystem healthy. We will do this by making a connection between something we are familiar with – healthy groups of people – and something we are less familiar with – healthy ecosystems.

Step 1: Fill in the left side of the 'river' (column 1) in a copy of Table 5.11 using your answers to the questions about your healthy group.

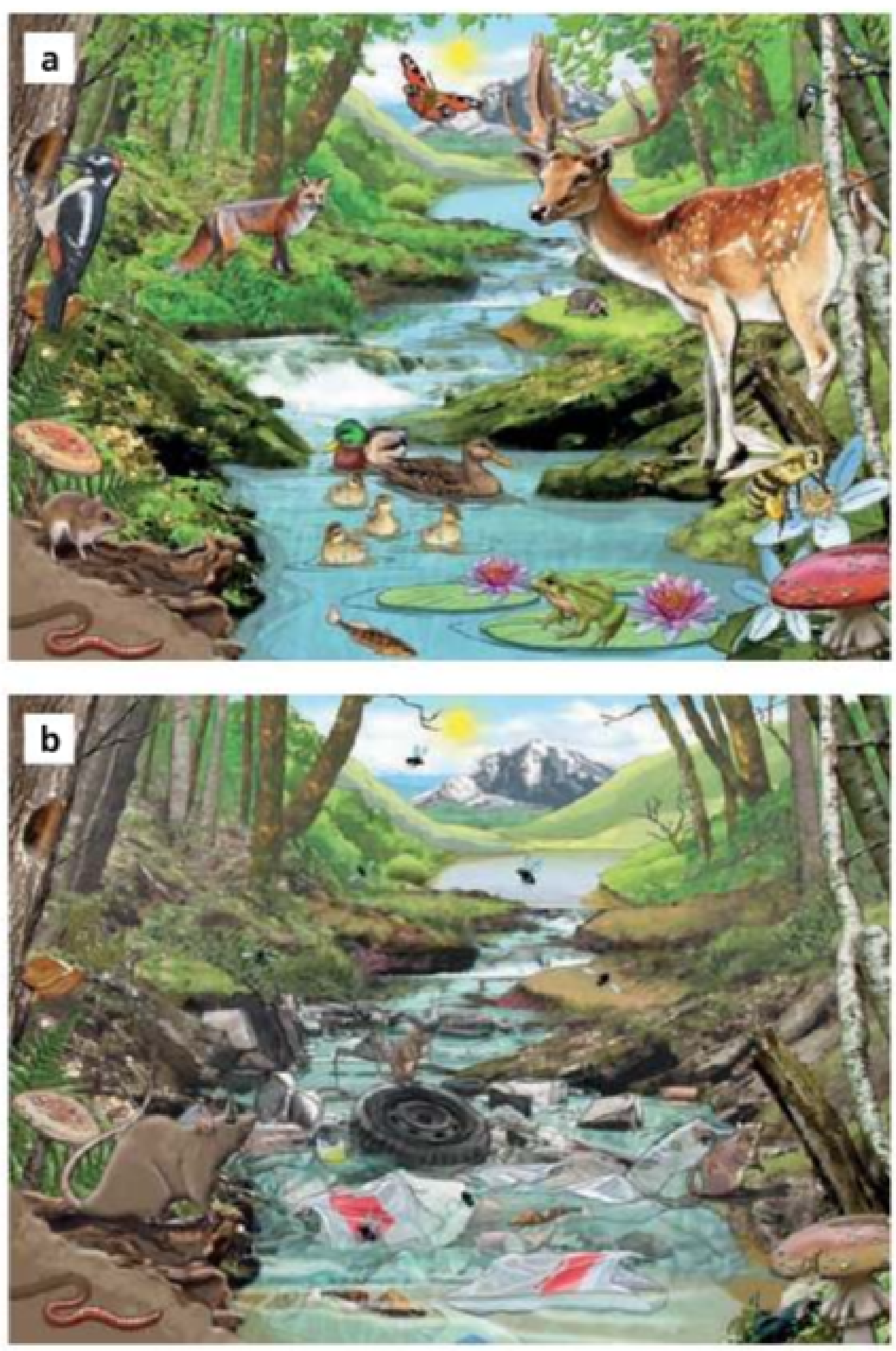
Step 2: Discuss the questions about healthy and unhealthy ecosystems in Tables 5.12 and 5.13. Then, fill in the right side about healthy ecosystems.

Step 3: Make a connection between the two sides by writing a sentence on the 'bridge' to summarize what it means to be a healthy, successful group or ecosystem.

Now, look at the example of a healthy ecosystem in Figure 5.13a. Using your personal experiences in your successful group and the guiding questions in Table 5.12 as a reference point, **identify** the features of this ecosystem that contribute to its being healthy. Some examples have been filled in to guide you.

Healthy group		Healthy ecosystem
3 thoughts or ideas of what makes a group healthy and successful: 1) … 2) … 3) …		**3 thoughts or ideas** of what makes an ecosystem healthy and successful: 1) … 2) … 3) …
2 questions about healthy and successful groups: 1) … 2) …	**Bridge** Healthy groups and healthy ecosystems are connected because …	**2 questions** about healthy and successful ecosystems: 1) … 2) …
1 analogy about healthy groups: A healthy group is like …		**1 analogy** about healthy ecosystems: A healthy ecosystem is like …

■ **Table 5.11** Healthy groups, healthy ecosystems



■ **Figure 5.13** Examples of (a) a healthy ecosystem, (b) an unhealthy ecosystem

Guiding questions	Features of healthy ecosystems
What do you notice about the number of different species that are *members* of the ecosystem?	There are many different species of living things, such as big and small animals, plants, and mushrooms. There are also things we can't see, like bacteria.
What is the *role* of the different *members*?	Big animals: Small animals: Insects: Plants: Worms: Mushrooms: Break down dead things and waste in the process of **decomposition** Bacteria: Break down dead things and waste in the process of decomposition
What *resources* do they use and have in their ecosystem in order to survive? Are there a lot of these resources, or a few?	
What are the *interactions* between the *members* of the ecosystem?	Male and female ducks: Deer or mice on plants: Fox and frog on smaller animals: Different kinds of birds with each other: Mosquitos and fleas on animals: Butterflies on flowers:
What *processes* are occurring?	Parents: Plant: Animals: Bacteria, mushrooms, and worms:
What would happen to the ecosystem if one species were killed? Would the whole ecosystem have problems, or would it recover?	

■ **Table 5.12** A healthy ecosystem

Now, look at the example of an ecosystem that is not healthy in Figure 5.13b and fill in your responses to the questions in Table 5.13. Think about how the unhealthy ecosystem differs from what you wrote for the healthy ecosystem to help you with your answers.

Guiding questions	Features of unhealthy ecosystems
What do you notice about the number of different species that are *members* of the ecosystem?	There are ...
What is the *role* of the different *members*?	Plants: Insects: Small animals: Bacteria:
What *resources* do they use and have in their ecosystem in order to survive? Are there a lot of these resources, or a few?	
What are the *interactions* between the *members* of the ecosystem?	Insects and plants: Small animals and insects: Small animals and plants: Bacteria:
What *processes* are occurring?	Plant: Animals: Bacteria:
What do would happen to the ecosystem if one of the species from the ecosystem, for example the grass, were damaged or removed? Would the whole ecosystem have problems, or would it be able to recover?	

■ **Table 5.13** An unhealthy ecosystem

Go back to Table 5.11 earlier in this activity and complete the right side of the 'river' (column 3) and make the bridge between healthy groups and healthy ecosystems.

From the previous activity, we have learnt that, like healthy and successful groups of people, healthy and successful ecosystems have certain characteristics. Table 5.14 explains the key characteristics with specific examples, using appropriate scientific terms to name and describe the characteristics.

Characteristics	Explanation	Examples
There are many different types, or *species*, of living things.	The different types, or species, of living things is called biodiversity. Healthy ecosystems have high biodiversity.	A healthy tropical rainforest has many different species of plants and animals living in it.
The different species and individuals within the same species have different roles or functions in the ecosystem.	The different species have different needs, abilities, and functions, which keeps the ecosystem in balance. **Producers** (plants) take energy from the sun and turn it into a form animals can eat, **primary consumers** eat producers, **secondary consumers** eat animals, and **decomposers** break down dead organisms into nutrients and other molecules.	Worms, bacteria, and insects need and can digest animal and plant waste as their food.
There are enough of the *resources* that are necessary for life.	Animals and plants do not have to **compete** too much for land, **nutrients**, or water; there are enough resources to supply parents and their young.	Plants have easy access to water so that they can grow.
All of the living things *interact* within the same species and between different species.	Animals eat plants and other animals; some animals compete for resources or mates; some organisms are **mutualistic** and help each other; other organisms are **parasitic**, and they actually do harm to other organisms while benefiting themselves.	Bees get nectar from flowers and spread the pollen to other plants so the plants can reproduce.
Different types of organisms can perform different *processes* that keep the ecosystem running.	Not all species have the same abilities; when the different species perform their life processes, they make it possible for other species to have access to their necessary resources.	Plants capture the Sun's energy to carry out **photosynthesis**.
Healthy ecosystems are **resilient**, so they recover from disruptions or challenges in the ecosystems.	Because there are so many different species, roles, and interactions, it is easier for the whole ecosystem to keep working even if some of the members are hurt or killed.	If some of the grass dies because of a small fire, there are other types of plants that animals can eat and use for food.

■ **Table 5.14** Some of the important characteristics of healthy ecosystems

THINK–PAIR–SHARE

Look at Table 5.14. Can you think of any more examples to go with the characteristics?

Share your examples with a partner.

ACTIVITY: Healthy mesocosms

ATL

- Organization skills: Plan short- and long-term assignments; Keep an organized and logical system of information

We have been learning about the characteristics of healthy ecosystems. But what does this mean for your mesocosm? Of course, because your mesocosm is small model of a natural ecosystem, you cannot include all of the ecosystem members that you would find in nature (for example, try to imagine squeezing animals into the bottle garden!).

However, there are certain things that you must be sure to provide your mesocosm with, so it has a chance to survive. Keep in mind as well that your mesocosm should be an ethical design – you must consider how you can avoid any animals dying as a result of your experiment. With your partner or on your own, complete a copy of Table 5.15 to help you develop your mesocosm plan even more.

Characteristics	What my mesocosm needs	Why my mesocosm needs it
Members		
Resources		So the plants can do photosynthesis
Processes	Decomposition	So the dead materials get broken down and can be used by the plants to grow.

■ **Table 5.15**

HOW DO SCIENTIFIC INNOVATIONS HELP TO KEEP ECOSYSTEMS HEALTHY?

Scientists have developed tools and processes that have helped them to understand how ecosystems work, what is necessary to keep them in balance, and how changes in and around an ecosystem can affect how healthy it is.

In addition to helping scientists better understand ecosystems, technology can help us in our daily lives to keep ecosystems healthy. The products we buy, the energy we use, the way we get from place to place, and the way we dispose of waste all impact on the environment.

EXTENSION

Working with a partner, do an image search for ecology equipment. Choose two different types of equipment that come up in the search; go to the website associated with the image to identify the name of the equipment and how scientists use it to monitor ecosystems. Make a slideshow with a picture of the different types of equipment and an explanation of how they are used. Share what you have discovered with your class.

DISCUSS

With your partner or as class, brainstorm two lists:

- **Our daily activities and choices**
- **The effect that our actions and choices have on the environment.**

To organize your lists, draw a two-column chart, with one column for each list.

Some things you can consider in your discussion and lists are:

- **What foods do you eat, and where do they come from?**

Hint

You might have to do some research online to find out where different types of food are grown or produced.

- **What do you use to communicate with people?**
- **What do you use to clean yourself and clean your surroundings?**
- **How do you travel from place to place?**

Now, if we consider that these actions and choices relating to technology are necessary parts of our life, is there any way that technology can help to decrease the environmental impacts? Scientists have created and continue to create new products and systems that can help reduce our **ecological footprint**. Which products exist that could help you, your family, and school to be more environmentally friendly?

EXTENSION

To learn more about the technological developments that can help us take more environmentally friendly actions and decisions, do an Internet search using the search term: eco-friendly technology.
You might also try searching for: cleantech; green tech; environmental tech.

What did you find? Share your search results with the class. Add a third column to your list of activities and choices that impact on the environment so that you can document how we can use technology to reduce the environmental impacts of our decisions.

EXTENSION

Now that you will put together the plan and design for your mesocosm, it will be helpful for you to see some examples of other mesocosms. Do an image search: mesocosm examples. Keep a list of ideas or examples of what you can do in your planning notes.

EXTENSION

What is an 'ecological footprint'? Try a web and image search of: ecological footprint to understand better what this term means. Where in the world are there larger ecological footprints? Where are they smaller? What do you understand makes ecological footprints larger or smaller?

ACTIVITY: Designing and constructing your own mesocosm

Now that we have learnt about ecosystems, what they need to be balanced, and how technology is used to keep them balanced, it is time to create your official proposal for your mesocosm.

Go back to the *Take action* box on page 96 to remind yourself of the expectations and goals of your investigation. In addition, you should open all the notes you have kept throughout the chapter, as well as all of the activities, discussions and research you have done.

You can also use the checklist in Table 5.16 to help you meet all of the expectations of designing and carrying out a complete scientific investigation. Another way to help yourself meet all the expectations for the assessment is to look at Criterion B: Inquiring and designing and Criterion C: Processing and evaluating, and fill in the right side of the checklist with the specific learning objective for each step of the checklist. Use the example and your teacher to help.

Once you have built your mesocosm and collected enough data (or alternatively if your mesocosm is no longer alive), you can use the checklist to write the article to submit to the scientific journal.

Assessment opportunities

- This activity can be assessed using criterion B: Inquiring and designing and Criterion C: Analysing and evaluating.

Links to: Design

The MYP design cycle is a similar process to the investigation cycle in science. In addition, one of the related concepts of design is 'sustainability.' How can you use what you have learnt in your Design class to design products in a sustainable way to help you design and build a sustainable mesocosm?

Step	Things to consider	Criterion B or C	Learning objective
Explain the question or problem to be tested	To write a question, use this format: How does X affect Y? To describe a problem, use 'effect' or 'affect'.	B	**i)** outline a problem or question to be tested by a scientific investigation
Formulate and **explain** a testable hypothesis	If [*write in a short way what you will do in your experiment*] then [*what you think the results of your experiment will be*] because [*the scientific reason why you think it will happen*].	B	**ii)** outline a testable prediction using scientific reasoning
Explain how to manipulate the variables/how to collect the data	Independent variable: Thing ('variable') that I change or make different in each 'trial' or test group. Dependent variable: Thing (variable) that I will measure, count, or calculate. Controlled variables: Things (variables) that are the same in each 'trial' or test group.		
Design a complete, logical, and safe method	Include the variables you wrote in the previous step. Underline or highlight the variables so that you are sure you include them. What safety considerations, if any, might you need to make in doing this experiment?		
Collect and **organize** data	Remember to include appropriate titles, headings, and units.		
Transform and **present** data	What mathematical calculations will you do with your data? What type of graph is most appropriate to give a visual summary of your results? What will you put on your *x*-axis? Hint: This is the variable you changed in your experiment. What will you put on your *y*-axis? Hint: This is the variable you measured or counted in your experiment. Remember to include the units!		
Interpret and **explain** results	What are your conclusions from the experiment? What is the 'answer' to your question? What are the results from the investigation that support your conclusion or 'answer' to your question?		
Evaluate the hypothesis	In what way(s) did the results of the experiment support or not support your hypothesis?		
Evaluate the hypothesis	Which step(s) of the method could have been the source of an error or inaccurate results? Why?		
Discuss the improvements and extensions to the method	Considering the steps that were possible sources of error, what could you do differently in order to avoid the error or inaccurate result in a future experiment? What do you still wonder about your problem/research question? What would you do in order to test the thing you are still wondering about?		
Document your sources	Use easybib.com or another website to help.	D	Completely document sources

Table 5.16 A checklist, things to consider, and learning objectives for an investigation

ACTIVITY: Technology in nature

For this assessment, you will consider our debatable questions:

To what extent will scientific innovations be able to keep ecosystems healthy?

To what extent can we and should we rely on scientific advancements to 'fix' environmental damage that human activity has caused?

In an essay, presentation, interview, video, or another format of your choice, use evidence of your learning from this chapter, your research, and the results of your mesocosm investigation to respond to the debatable questions.

Be sure to do the following in your response:

- **Outline** your scientific knowledge about ecosystems, and what they need to be healthy and in balance.
- **Summarize** the ways science is applied and used to keep ecosystems healthy and in balance.
- **Interpret** the ways science is used to keep ecosystems healthy in order to decide how effective the scientific applications and solutions are.
- **Suggest** solutions of how scientific knowledge can be used to solve the problem of keeping ecosystems healthy and in balance.
- **Describe** and **summarize** how cultural, economic, ethical, political, or social factors might influence how we use science to solve the problem of keeping ecosystems healthy and in balance.
- Consistently use scientific language in clear and accurate ways.
- **Document** your sources completely.

Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding and Criterion D: Reflecting on the impacts of science.

THINK–PAIR–SHARE

ATL

- Reflection skills: Develop new skills, techniques and strategies for effective learning; Focus on the process of creating by imitating the work of others

Throughout this chapter, you have practised different techniques or strategies for learning new information. Reflect with a partner by asking each other and answering these questions:

- What are some of the techniques and strategies for learning that we practised?
- Which ones do you find to be the most helpful for your learning? What makes you say that?
- Which ones were least helpful? What makes you say that?
- In what types of situations could you use those techniques or strategies again?

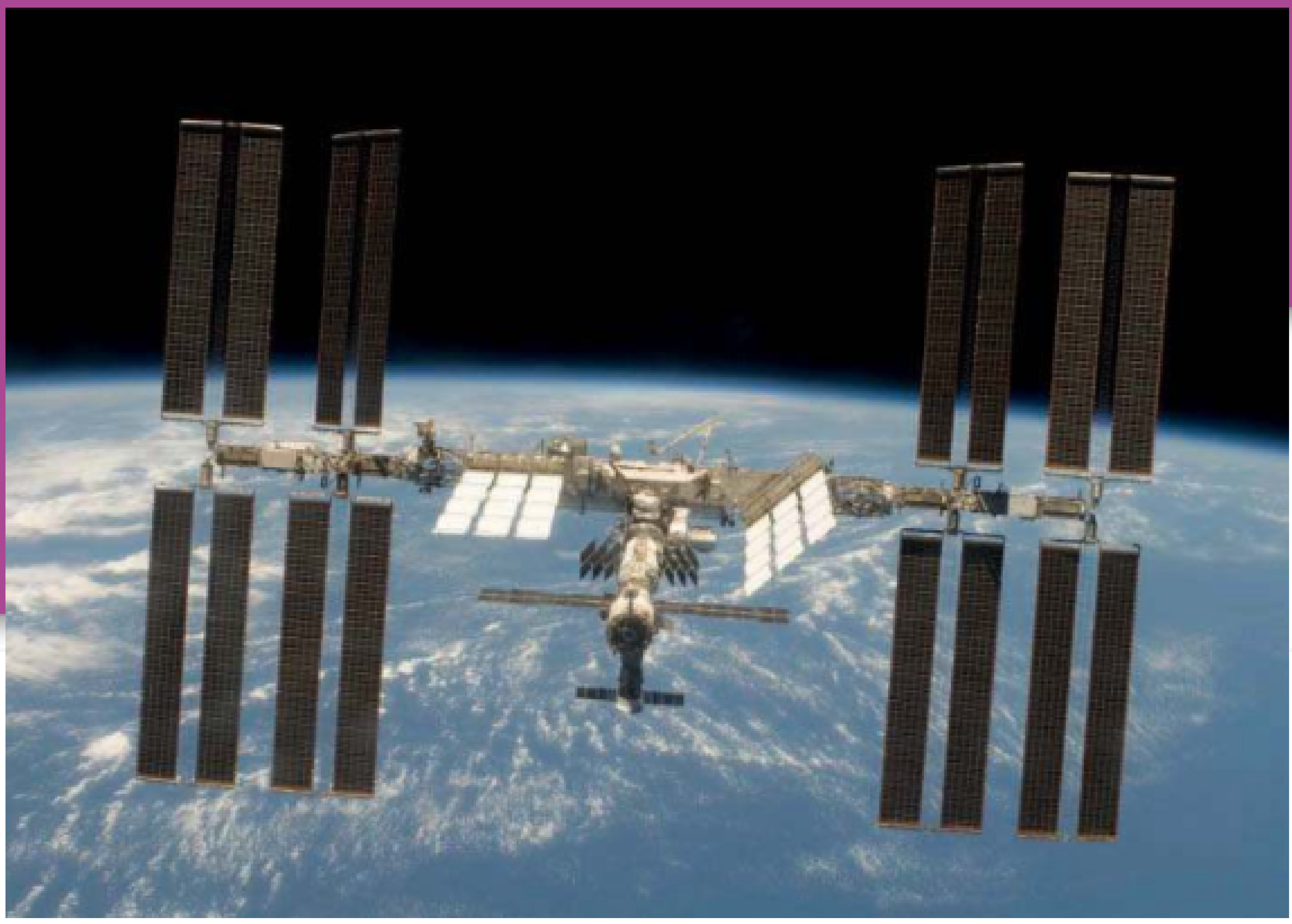
Reflection

In this chapter, we have described what makes up a healthy ecosystem. We described the different characteristics of a balanced ecosystem. In addition, we have inquired into the technology that exists to help scientists understand ecosystems and to help us take actions and decisions in our daily lives that will support healthier and more balanced ecosystems.

Use this table to evaluate and reflect on your own learning in this chapter.					
Questions we asked	Answers we found	Any further questions now?			
Factual: How can we study ecosystems? What makes up an ecosystem? What makes an ecosystem healthy?					
Conceptual: What can scientists and others do to understand ecosystems and what makes ecosystems healthy? How do scientific innovations and daily life decisions help to keep ecosystems healthy?					
Debatable: To what extent will scientific innovations be able to keep ecosystems healthy? To what extent can we and should we rely on scientific advancements to 'fix' environmental damage that human activity has caused?					
Approaches to learning you used in this chapter:	Description – what new skills did you learn?	How well did you master the skills?			
		Novice	Learner	Practitioner	Expert
Organization skills – we have used appropriate strategies for organizing complex information; we have kept an organized and logical system of information and we have planned short- and long-term assignments.					
Reflection skills – we have developed new skills, techniques and strategies for effective learning and we have focused on the process of creating by imitating the work of others.					
Information literacy skills – we have collected and analysed data to identify solutions and make informed decisions.					
Creative-thinking skills – we have practised visible thinking strategies and techniques and we have applied existing knowledge to generate new ideas.					
Learner profile attribute	How did you demonstrate your skills as a thinker in this chapter?				
Thinker					

6 Where do we fit into the world?

We have learnt about **our place** in the **systems** that affect **life on Earth** through looking beyond into **space** and making **models**.



■ **Figure 6.1** The first section of the International Space Station (ISS) was launched in 1998 and the current station is the result of collaboration by many countries

CONSIDER THESE QUESTIONS:

Factual: What is in the Solar System? Where is the Earth? What is the structure of our planet?

Conceptual: How do different systems of the Earth affect each other? How do models help us to understand Earth's systems? How does knowledge from space exploration help us to understand the Earth?

Debatable: To what extent does looking into space help us to improve our models of Earth's systems?

Now **share and compare** your thoughts and ideas with your partner, or with the whole class.

IN THIS CHAPTER WE WILL ...

- **Find out** how the Earth's systems work together to make it a place we can live, how those systems have changed, and how the Earth came to be the way it is now.
- **Explore** the ways in which scientists have researched and discovered the Earth's systems, and the role of space technology in helping us to understand more about the Earth.
- **Take action** to evaluate the costs and the benefits of space research, and form an opinion about its value.

These Approaches to Learning (ATL) skills will be useful ...

- Collaboration skills
- Organization skills
- Communication skills
- Information literacy skills
- Critical-thinking skills
- Creative-thinking skills

■ **Figure 6.2** Inside the ISS

● We will reflect on this learner profile attribute …

- Reflective – we will reflect on the impact of science on our understanding of our place on Earth, and in the Universe.

◆ Assessment opportunities in this chapter:

- ◆ **Criterion A:** Knowing and understanding
- ◆ **Criterion B:** Inquiring and designing
- ◆ **Criterion C:** Processing and evaluating
- ◆ **Criterion D:** Reflecting on the impacts of science

KEY WORDS

orbit	radius	satellite
probe	rotate	system

SEE–THINK–WONDER

Look at Figures 6.1 and 6.2.

The first section of the International Space Station (ISS) was launched in 1998, and the station has been occupied by humans since 2000 – the longest period of continuous human occupation beyond the Earth! The station is the result of collaboration between the United States, Russia, Japan and the European Union.

- **What do you see?**
- **What does it make you think?**
- **What does it make you wonder?**

You can find out more about the ISS here:

www.nasa.gov/mission_pages/station/main/index.html

If you want to try to spot the ISS, you can track its orbit at these sites:

http://spotthestation.nasa.gov/home.cfm

www.isstracker.com

The ISS is an artificial world away from Earth. The station is designed for experimentation, to help us learn more about the possibility of living away from Earth, but also to learn about the Earth itself. We can see that life on the ISS is very different from life on our own planet. Our own planet – apart from being considerably larger – is a much more varied and diverse place to live.

What is in the Solar System?

■ **Figure 6.3** ISS streak

WHERE IS THE EARTH?

For millennia, looking up into the night sky has prompted humans to ponder where we are, and to think about our place in whatever universe they understood. On a dark night, a long way from a town or city and when there is no moon, the human eye can see around 4500 stars. This is – of course – the tiniest fraction of the total number of stars in our galaxy alone, which is estimated at between 100 and 400 billion. With powerful telescopes it is possible to see beyond our own galaxy to millions more. Stars are not the only things we can see when we look up in the night sky. Figure 6.3 shows part of the night sky taken from the northern hemisphere over a few minutes.

You can see the stars in the image as clear, still points of light. But the white streak is caused by something much closer to home – it is the light trail left by the International Space Station (ISS) as it moves in orbit over the Earth. Similarly, at different times of the year and from different parts of the Earth we can see our nearest neighbours, the planets, moving through the night as Earth turns on its axis.

The very first images of the Earth from space were taken using high **altitude** rockets as long ago as 1946. These images were black and white and showed only part of the Earth. When the United States began its Moon programme, humans were for the first time able to turn around and look back at our planet in its entirety, and the famous 'Blue Marble' photograph (see Figure 6.6 on page 119) had a huge impact. We now take images of the Earth for granted, so it is hard to imagine what it was like to have seen our home in this way for the first time.

Links to: Individuals and societies: History

If we are to have a better understanding of the impact of an image such as the Blue Marble in its own time, we need to try to forget what we know now, and imagine ourselves back in 1972. Of course, this is hard for us to do, but use of historical sources from the time can help us place the image in its own context. Historians might use media sources from the period – such as newspapers and magazines that first published the image – or they might interview people who were alive at the time for their own memories. Your grandparents may remember the first Apollo Moon missions. Why not interview them about the images taken of the Earth, and about the Moon missions?

The system of objects that **orbit** the Sun is known as the **Solar System**. Some of these objects are, in turn, orbiting others – for example moons, or human-made objects such as the ISS. These are termed **satellites**. The number of known artificial (human-made) satellite launches is around 4000, although only about 1000 of these are still operational. The Solar System is our neighbourhood in space, and we have been actively exploring the neighbourhood since the late twentieth century. The first exploratory **space probes** were sent out into the Solar System in the late 1950s.

ACTIVITY: The sky in an app

ATL

- Information literacy skills: Understand and use technology systems

For this activity you will need access to a tablet computer or smartphone.

Use the tablet or smartphone to download a night sky observatory app.

Figure 6.4 Smartphone sky view

Point the smartphone or tablet at the sky (you will probably need to enable GPS global positioning for this). Look around the sky and see if you can **identify** the locations of:

- **a constellation**
- **a planet**
- **the Moon.**

DISCUSS

Which of these is not in fact an object? **Explain** your answer.

Which of these will appear to move most quickly in the night sky? **Explain** your answer.

ACTIVITY: Sorting the Solar System

ATL

- Information literacy skills: Access information to be informed and inform others

The schematic diagram in Figure 6.5 shows the principal objects in the Solar System. The labels for the diagram are in Table 6.1, mixed up.
In pairs, **research** and **discuss** which label goes with which object.

Note: Some objects may have more than one label!

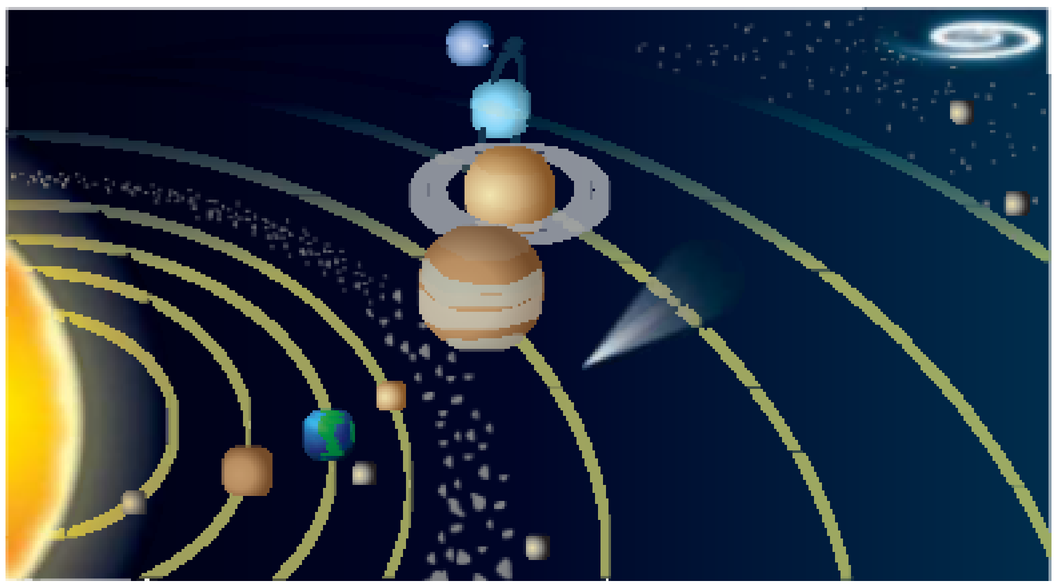


Figure 6.5 Solar System schematic

Inner planets	Planetoids
Asteroid belt	Satellites / moons
Outer planets	Rocky planets
Satellites	Gas giant planets
Comets	Stars
Oort cloud	

Table 6.1 Labels

Use your research to **describe** the properties of the different objects. What are they like? What do they consist of?

How did the Solar System come to be? Science provides us with a few clues. Firstly, all the planets in the Solar System orbit the Sun in the same direction. Secondly, most planets spin on their own axes in the same direction – with the exception of Venus and Uranus. Thirdly, all the planets except the dwarf planet Pluto orbit within 7° of the **plane** of the Sun's equator. Finally, the moons of most planets orbit the planet in the direction of the planet's rotation – with the exception of the moons of Uranus, and Triton, the largest of Neptune's moons. All of this evidence is consistent with the idea that the principal objects in the Solar System were formed around the same time from a great cloud of gas and dust which was spinning as it collapsed inwards towards its centre, rather like water draining from a bath. Scientists think that the cloud originally came from the explosion of an earlier star, more than 5 billion years ago. The material from the original explosion then began to collapse inwards because the matter in the cloud was attracted by **gravity**.

At the centre of the cloud, the gravitational attraction was so great that hydrogen gas began to undergo the process of **nuclear fusion** to form our star, the Sun, and this generated enormous quantities of heat and radiation. The heat and radiation that erupted from the Sun 'swept' through the remaining material in the Solar System, leaving just rocky planets and their satellites near to the centre. The first planets – including the Earth – began to form around 4.5 billion years ago. Further out, the force of the explosion was spread over a greater volume of space and so the planets were able to hang onto gaseous material as well, leaving the large gas giants of Jupiter, Saturn, Uranus and Neptune.

It is thought that the 'backwards' or **retrograde rotation** of Venus is the result of a collision with another large object early in the formation of the Solar System. Similarly, it is thought that Uranus was 'knocked over' on its side and so rotates at almost 90° to the plane of the other planetary orbits. The 'odd' moon of Neptune, Triton, was probably captured by Neptune's gravity later in the formation of the Solar System.

ACTIVITY: Spinning through space

ATL

- Critical-thinking skills: Gather and organize relevant information to formulate an argument

Research to find out more, using the search term: formation of the Solar System.

Outline the evidence that the Solar System was formed from a spinning cloud of material.

Describe the following exceptions to the hypothesis, and **explain** how these can be included in the model:

- **Uranus' tilted rotation**
- **Venus' retrograde rotation**
- **orbit of Triton around Neptune**
- **orbits of comets.**

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Knowing and understanding.

DISCUSS

Look at Figure 6.6. What different colours can you see?

What is causing the different colours?

THE EARTH'S SYSTEMS

The Apollo images of Earth were also the first time that the continent of Antarctica had been seen on a complete image of one hemisphere of the Earth. When we look at Figure 6.6, we begin to gain a sense of the diversity of the Earth's environment.

Earth scientists see the Earth as a system, and human beings are a part of that system. Since the Earth is so large and its systems are so complex, we can **analyse** the Earth as a system in order to distinguish the smaller processes and systems which make it all work together. Earth scientists start by distinguishing four main 'spheres' or systems that work together to form the environment in which we live.

■ **Figure 6.6** *'The Blue Marble'* – Earth as seen from Apollo 17 in 1972

ACTIVITY: Identifying the spheres

ATL

- Information literacy skills: Make connections between various sources of information
- Critical-thinking skills: Gather and organize relevant information to formulate an argument

■ **Figure 6.7** What different ecosystems are we part of?

Individually, look at these descriptions of the four main 'Earth systems':

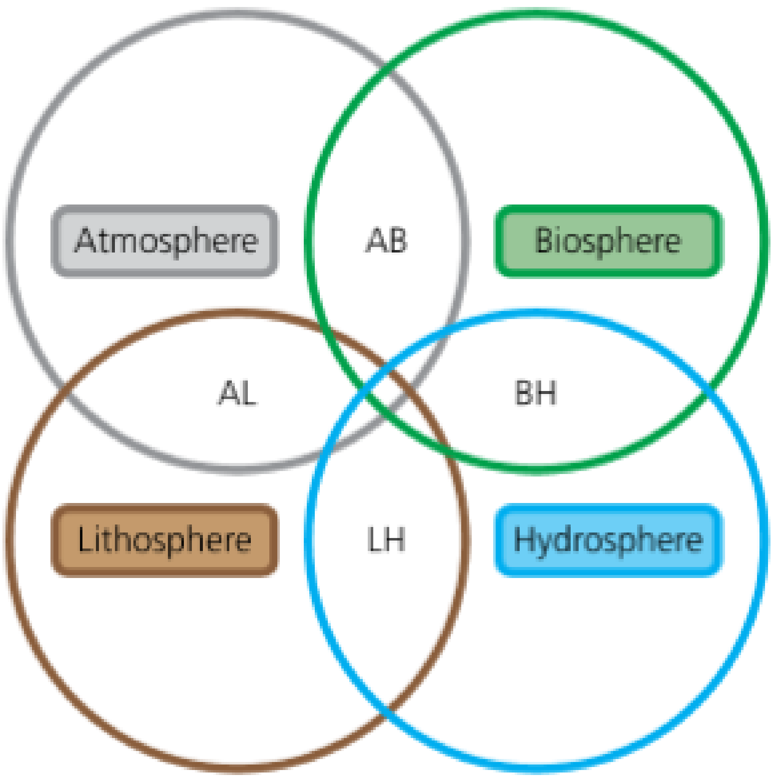
1. **The layer of gases that surround the Earth's surface**
2. **The solid, mineral part of the Earth that is formed by the upper mantle and crust of the planet**
3. **The system formed by living things on the Earth**
4. **The system formed by the Earth's water in all of its forms.**

Use these search terms or your own knowledge to match the descriptions to the names of the systems: lithosphere; hydrosphere; atmosphere; biosphere.

Identify the systems shown in Figure 6.7.

Make a poster or chart to illustrate the different Earth systems. **Organize** your understanding using a Venn diagram as shown in Figure 6.8.

Add pictures or drawings of the kinds of object found in each Earth system to the appropriate part of the diagram.



■ **Figure 6.8** Venn diagram

Consider what you might put in the 'overlap' parts of the diagram:

AB = Atmosphere/Biosphere

AL = Atmosphere/Lithosphere

BH = Biosphere/Hydrosphere

LH = Lithosphere/Hydrosphere

If you are not sure right now, add to your poster as you work through this chapter.

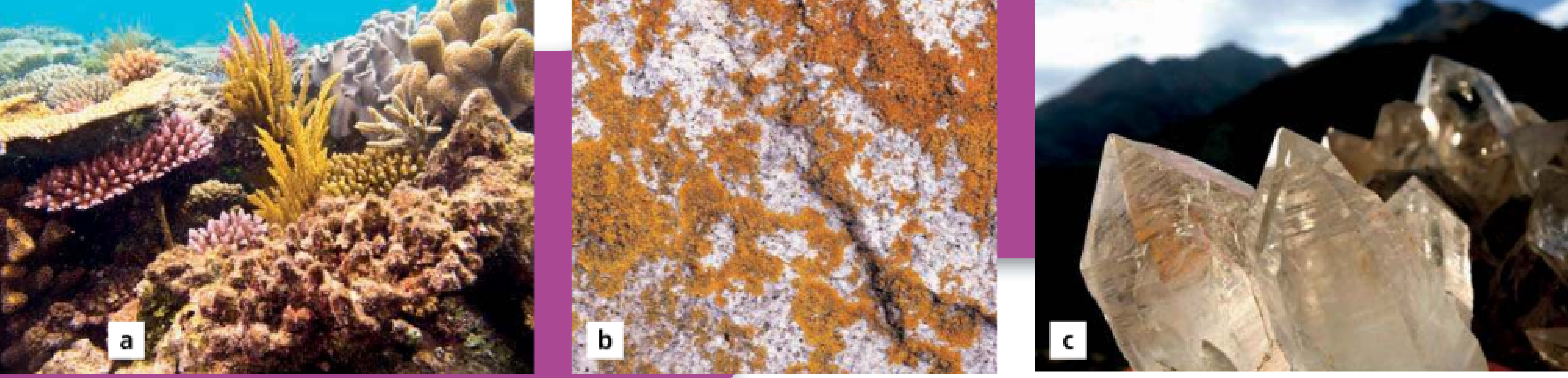
EXTENSION

The following have been suggested as other possible Earth systems (use as search terms to find out more): **geosphere**; **cryosphere**; **androsphere**.

Modify your Venn chart to include these systems as well. Are they different to the four main Earth systems of lithosphere, hydrosphere, atmosphere and biosphere? Do they overlap?

Visual organizers

In this activity we have used a chart or diagram to help us to organize our thinking about the Earth systems. Using 'visual organizers' in this way can help us to clarify our ideas and make our understanding of categories and distinctions more precise. It can also show us how different ideas might overlap or relate to each other, just as the Earth systems do.



■ **Figure 6.9** (a) Coral, (b) lichen on a rock, (c) crystals

It is not always immediately obvious which 'system' something belongs to. The coral in Figure 6.9a looks like a rock formation but is a living thing, and coral reefs such as the Great Barrier Reef near Australia are an important habitat for marine life. Lichen (Figure 6.9b) lives on the surface of rocks and is a micro-organism, although it can be hard to distinguish from the rock itself. Similarly crystals (Figure 6.9c) can grow quite rapidly in certain environments, but consist only of minerals.

Human beings are part of the Earth's systems, and we rely on them. At the same time, our actions affect those systems.

In this section we have explored the way that our home planet can be **described** as a system, and how in turn we can break down or **analyse** the large, complex system of the Earth into smaller systems that interact with each other. In the next section we will explore the four systems in greater detail.

ACTIVITY: Evaluating our impact

ATL

- Critical-thinking skills: Evaluate evidence and arguments

In pairs, look at the images in Figure 6.10. Each image shows human activity and its effect on an Earth system. **State** which systems the images show and **describe** what is happening in the images. **Outline** the effects of the human impact shown.

Research further into the human impacts shown using these search terms: **deforestation**; **oil pollution**; **strip mining**; **air pollution**.

In some cases, the human impact may only be local – as it does not have an effect on the Earth system beyond the immediate surroundings, or the bigger Earth system can absorb or accommodate the human impact. In other cases, the impact may potentially be global, since the Earth system concerned might be affected across the whole planet.

Using your research, categorize and **evaluate** the impacts shown in Figure 6.10 according to whether you think they are local, or global, or both. **Explain** your answers, **applying** your scientific understanding of the way the Earth systems relate.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Knowing and understanding.

■ **Figure 6.10** Human impacts on natural systems

What is the structure of our planet?

WHAT'S BENEATH OUR FEET?

What could be more reliable than the Earth beneath our feet? As Figure 6.11 shows, we cannot always take the stability of the Earth for granted. Throughout history, major events in the lithosphere have been interpreted as the anger of gods, as punishment for human wrongdoing. This is easy to understand if you have ever experienced an earthquake or been near to a volcanic eruption. The size of the forces released makes our own human activities seem puny by comparison, and without an understanding of the science that helps us to explain these events it might make sense to imagine that they are caused by the actions of mighty, supernatural beings.

We now understand that major events in the lithosphere are the result of activity deep beneath the Earth's surface. In the early twentieth century scientists began to suggest that the shapes of the Earth's continents looked as if they may have once fitted together. Furthermore, geologists (scientists who study the lithosphere) had noticed that very similar kinds of rock, of similar age, could be found in places that were very far apart – across different continents even. It was not until the 1960s that scientists measuring the direction of the magnetic field in bedrock at the bottom of the oceans were able to show that rock now found in different places had originated far away. So how could we explain the observation that the ground beneath our feet appeared, in fact, to have moved? To answer this question, we need to go deep into the centre of the Earth to find out about the structure of our planet.

Links to: Mathematics

In the activity *Chocolate Earth* on page 124 we will estimate values for the thicknesses using a mean average. This is a common technique to provide useful data when we have a range of different measurements for the same thing.

Figure 6.11 (a) Earthquakes such as that which devastated Nepal in 2015 and (b) volcanic eruptions such as Krakatau in 1883 are both reminders that the Earth beneath our feet is sometimes moving

Figure 6.12 The Lisbon earthquake of 1755 was interpreted by many as being punishment from God, and was the first earthquake to be studied scientifically

ACTIVITY: Chocolate Earth

ATL

- Critical-thinking skills: Use models and simulations to explore complex systems and issues

In pairs, we can use chocolate treats to visualize and 'model' the structure of the Earth.

Equipment

To model the structure of the Earth, you will need:

- **Round chocolate containing caramel with a hard centre**
- **Sharp cutter, such as a surgical scalpel**
- **Cutting mat**
- **Thick rubber gloves or similar**
- **Transparent ruler, sharp pencil and paper**

SAFETY: Although we are using chocolate treats – which are good to eat – we should never put anything in our mouths in the science laboratory, in case it is contaminated or contains a poison or other toxic substance. We will also be using sharp knives. Use a glove on the hand holding the chocolate while cutting. Always cut carefully on a cutting mat. If you are not confident about using the knife, ask a teacher for help.

Method

Take a sharp knife or surgical scalpel and cut the chocolate in two. Make sure you cut through a **diameter** of the chocolate. If you can't cut through the hard centre, that's fine – just cut around it.

Can you **identify** the core, mantle and crust?

Measure the thickness of the crust, mantle and core in your model, and **record** the measurements.

Hint

How easy is it to measure across the chocolate? You may find it easier to use the paper and sharp pencil to mark the thicknesses of each part of the chocolate, and then take measurements from the paper using the ruler.

Now turn the chocolate through 90°, and measure again. **Record** these measurements.

Figure 6.13 Chocolate Earth

Processing results

The thickness of the layers in the chocolate will vary – they may be thicker in some places than in others. This is why we took two sets of measurements, at 90° to each other.

One way to give a general measurement is to find the mean average of the results, like this:

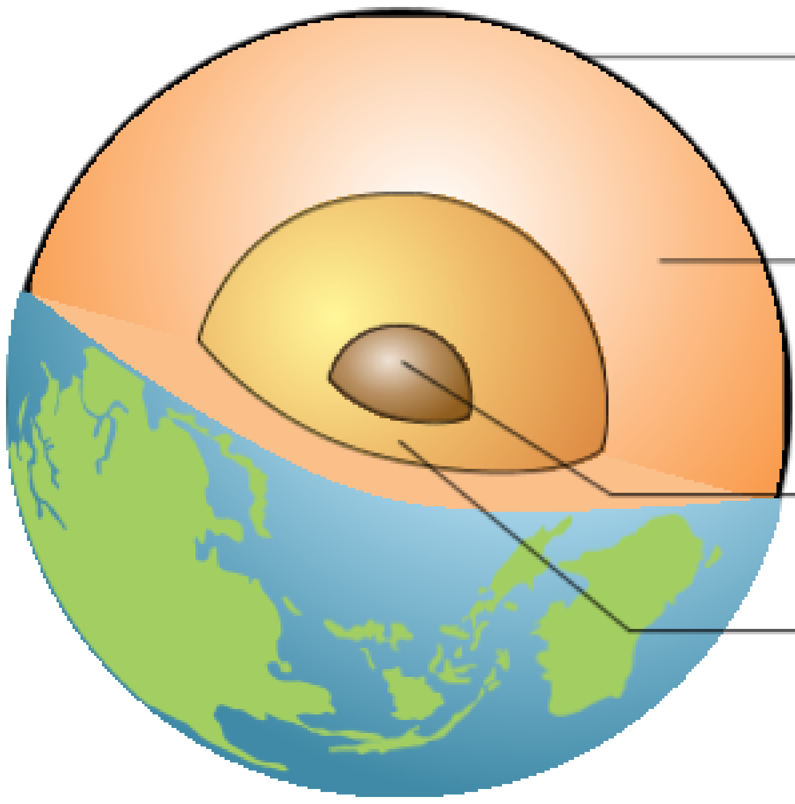
$$\text{Mean} = \frac{\text{sum of measurements}}{\text{number of measurements made } (= 2)}$$

Now **design** a table to show all your measurements and the average measurements.

Sketch your model, showing the measurements you made. We will use these later.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion C: Processing and evaluating.



■ **Figure 6.14** The Earth in section

What happens when we have a brittle skin over a liquid or jelly-like middle? Have you ever eaten a soft-boiled egg? One fun way is to take off the shell by breaking it up into pieces with the back of your spoon! If you have ever eaten European food, you might also have come across the French dessert *crème brûlée*. Crème brûlée is made from a vanilla sauce or custard with sugar that has been melted (caramelized) and allowed to cool over the surface. What happens when we hit the caramelized skin with the back of our spoon?

It is thanks to earthquakes that we do know something about what lies beneath our feet. Using highly sensitive vibration detectors called **seismometers**, geologists can measure the way that the vibrations from an earthquake spread out or **propagate** through the Earth's centre and out the other side. The energy of the earthquake is carried in vibrations in different directions, principally as **S-waves** or **P-waves**. Through analysing the ways that the seismic waves are affected by their journey through the Earth, geologists can then make hypotheses about the material that they have travelled through.

The Earth's structure can be roughly divided into three sections. From the centre outwards, these are the **core**, the **mantle** and the **crust** (see Figure 6.14).

■ **Figure 6.15** Eggshell and crème brûlée: tectonic food!

The core begins some 2890 km beneath the Earth's surface. It is mostly made from iron, and it is thought to be the cause of the Earth's **magnetic field**. The outer part of the core is thought to be liquid, while the innermost core is a solid sphere of iron and nickel.

The mantle is a very dense region of rock containing magnesium, iron and silicates. While the mantle is solid, the huge pressures in this part of the Earth can force the rock of the mantle to behave like a very, very slow moving fluid.

The crust is a very thin layer, thinner even than the chocolate on our chocolate treat. Under continents, the crust is 26–60 km thick, while under the oceans it can be as thin as only 4 km. The crust is the region of the lithosphere and it contains many different kinds of rock.

ACTIVITY: How thin is the crust?

ATL

- Information literacy skills: Process data and report results
- Critical-thinking skills: Use models and simulations to explore complex systems and issues

To have some idea of the relative thicknesses of the different layers in the structure of the Earth, we can calculate what percentage of the Earth's radius they represent.

Individually, use the following data and the information from the box on the previous page to **calculate** and complete Table 6.2.

Hint

For the crust, the thickness varies so you will need to work out an average value for the thickness. You can do this by subtracting the smallest from the largest thickness and dividing by 2 then adding to the smallest (this gives a 'median' value).

Hint

For the mantle, you will need to subtract the thickness of the core and the crust from the radius of the Earth.

Radius of Earth = 6371 km

Part of Earth structure	Average thickness (km)	% of Earth's radius
Crust		
Mantle		
Core		

■ **Table 6.2**

Now refer to the measurements you made for the chocolate model of the Earth in activity *Chocolate Earth*. **Calculate** the percentage thickness of the crust, mantle and core in your chocolate model in the same way as you did for the actual Earth. **Compare** your measurements for the model to the real values.

Evaluate your model – how accurate is it as a representation of the structure of the Earth? **Comment** on the differences and similarities.

EXTENSION

We can now use the actual calculated values for the thicknesses to make a better model than the chocolate Earth model! Use modelling clay of three different colours and calculate the relative thicknesses of each of the layers so that they are the same percentage values as you have just calculated.

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion A: Knowing and understanding.

Models

In this activity we have used a model to visualize the structure of the Earth, then compared the model to the actual structure. Models can be very effective tools to help us understand scientific ideas. However, we must be able to **evaluate** their limitations, to be clear about how accurate they really are, so that the model does not mislead us.

A **tectonic plate** is a region of the Earth's crust that is broken away from others. At the edges of the plates, two things can happen. At a **constructive boundary** the plates are moving apart, and new rock is being made as liquid **magma** is pushed through the crack to the surface and cools. At a **destructive boundary** the plates are pushing together and rock is being forced down beneath the surface.

ACTIVITY: The Earth is moving

ATL

- Information literacy skills: Understand and use technology systems

Individually or in pairs you will need a device connected to the Internet. We will be using a map provided by ESRI Geographical Information Systems which you can locate at this URL: **http://bit.ly/earthgeoinquiry9**

Open the map on your device.

State what is represented by the purple regions shown on the map.

Now click on the 'content' box on the map. Check the box for 'Tectonic Boundaries'.

Compare the locations of the tectonic boundaries to the mountain ranges. What do you notice?

Now click on the 'Show legend' icon beneath the 'Tectonic Boundaries' check box.

If you are not sure what the words mean, research these search terms: **convergent** and **divergent tectonic boundaries**.

Compare the map to Figure 6.16, which shows the age of rock in the Earth's crust, and **outline** the similarities.

Finally, check the box 'Plate Motions'. **Discuss** what this new information tells you about the tectonic plates of the Earth's crust.

Summarize the relationship between tectonic boundaries and mountain ranges.

Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding.

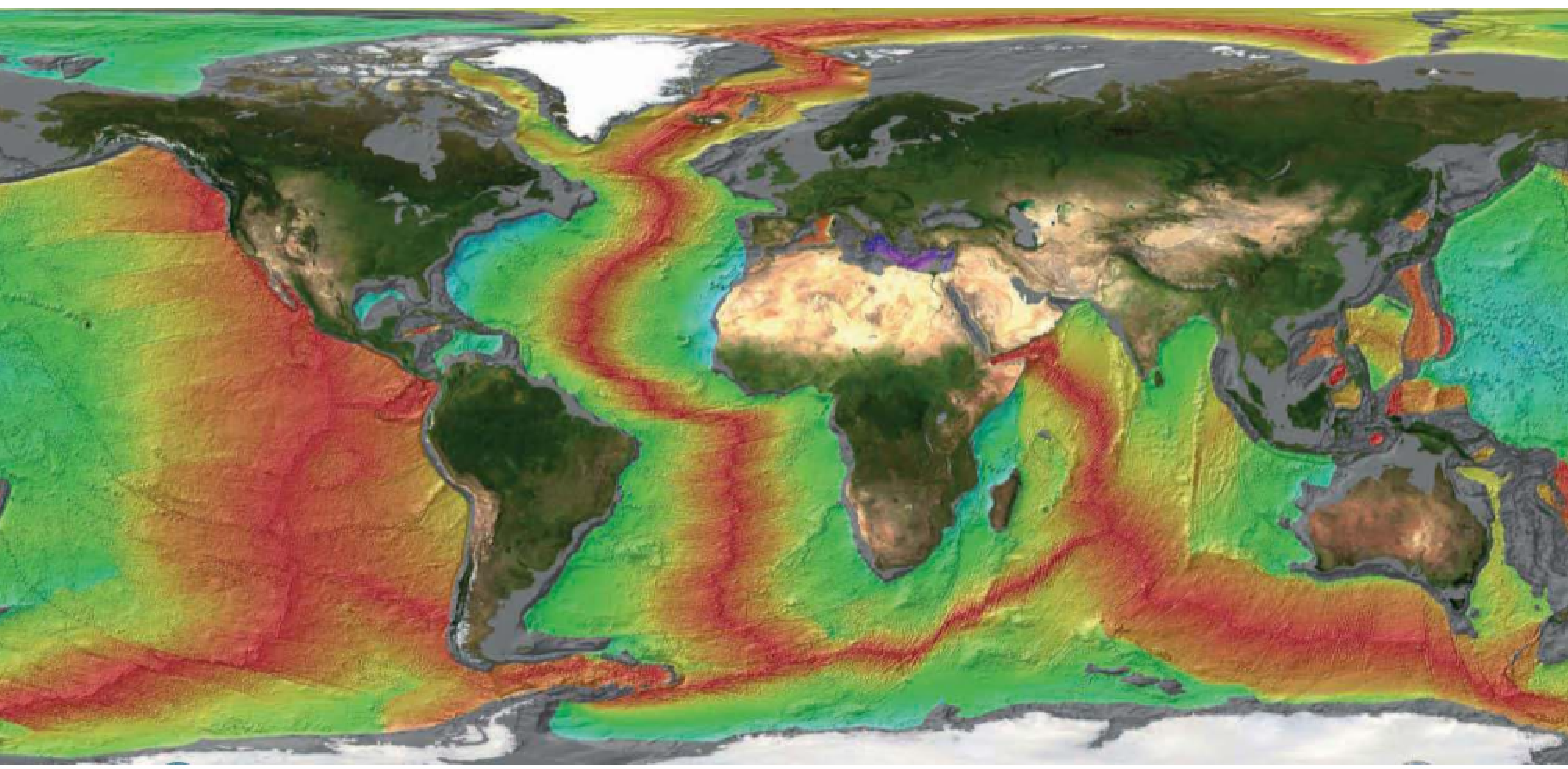


Figure 6.16 Map of the Earth showing the age of rock, where red is young rock and purple is rock over 280 million years old.

■ **Figure 6.17** Sedimentary rock

■ **Figure 6.18** Metamorphic rock

■ **Figure 6.19** Igneous rock

The rock in the Earth's crust seems very solid to us – unless we are unfortunate enough to be caught in an earthquake. But the lithosphere is constantly changing – it is just that usually the changes are very slow, so that we short-lived human beings do not observe them happening.

Geologists classify rocks into three different types, according to the way they are formed.

Sedimentary rock is made from smaller particles such as sand or pieces of stone that have been deposited – perhaps at the bottom of an ocean – and then **compressed** under huge pressure and very long periods of time, over millions of years. When sand is compressed in this way it forms **sandstone**. Sometimes the pieces can be shells from sea creatures, forming a kind of sedimentary rock called **limestone**. Sedimentary rock is formed by a physical process and tends to be brittle and crumbles relatively easily.

Sedimentary rock that has been subjected to heat and pressure can change in form. The rock undergoes chemical change (see Chapter 2 if you need a reminder about what this means). Since metamorphic rock has undergone chemical change it tends to be stronger than sedimentary rock.

When rock is caught up in the extreme heat of volcanic activity, it can melt completely to form **lava**. When lava cools, it forms igneous rock. Igneous rock tends to be quite **uniform** in appearance, since it was formed relatively rapidly. It can sometimes be very light, such as pumice stone, due to the air trapped inside it.

We have seen that geological processes can take a very long time indeed. But how do we know this, if we cannot see the processes happening over millions of years? How long did the rock in the Earth take to form? In fact, how old *is* the Earth?

Before Earth scientists began to make measurements and carry out experimental models to investigate geological processes, people had to make their own estimates of the age of the Earth. One sensible way to do this seemed to be to date the Earth according to memory. If we knew, for example, how many ancestors we had, we could use this information to estimate how long human beings had been around. Of course this assumes that the Earth did not exist before the first human beings, but people had no reason to believe that it did. For this reason, most people believed in a creation story of one kind or another. Creation stories are explanations of how the Earth came to be, and since the answer to this question seemed very mysterious – just as mysterious as the power of earthquakes or volcanoes, in fact – the explanations people gave were usually supernatural. All human cultures have creation stories which explain the origin of the Earth as a supernatural event.

ACTIVITY: Rock and roll!

ATL

- Critical-thinking skills: Use models and simulations to explore complex systems and issues

Sedimentary and metamorphic rock can take millions of years to form, while igneous rock is formed more rapidly, though we have to be near a volcanic event to witness it. In this activity, working individually or in pairs, we will model these processes using something much easier to manipulate than rock – chocolate!

Equipment

- **Pieces of white and dark chocolate**
- **1 kg masses**
- **Butter knife or scraping implement**
- **Aluminium foil**
- **Large beaker (500 ml)**
- **Thermometer**
- **Some hot water from an electric kettle**

SAFETY: Remember not to put anything in your mouth in the laboratory. When using water that has recently been boiled, take care not to spill the water on yourself as this can cause scalding. Always pour hot water slowly and with care. Wear safety glasses to prevent droplets of hot water getting into your eyes.

Making 'sedimentary rock'

Scrape some of the white and dark chocolate into 'shavings' and then place them in a piece of aluminium foil. Roll up the foil into a ball so the chocolate is all trapped inside. Place one or two of the 1 kg masses on top of your ball of chocolate and leave for a few moments. Now remove the masses and unwrap the chocolate.

Observe the chocolate inside – take a picture if you can. How have the chocolate scrapings changed? Make a note of your observations.

Making 'metamorphic rock'

Pour some of the boiled water into the beaker. Stir with a scraper for one or two minutes – **measure** the temperature with the thermometer. When the temperature of the water is between 30–32°C, take your sedimentary chocolate and place it in a small 'boat' made from the foil. Place the foil in the water.

Observe the chocolate in the foil boat – take a picture if you can. How does it change? Make a note of your observations.

Making 'igneous rock'

Now boil the water in the kettle again. Take your foil boat with the metamorphic chocolate out of the beaker and pour away the warm water. When the water in the kettle has boiled, pour some into the empty beaker. (Take care!) Place your foil boat and chocolate into the very hot water.

Observe the chocolate in the foil boat – take a picture if you can. How does it change? Make a note of your observations.

Conclusion

Write a conclusion about your experiment. **Outline** the changes that take place in the chocolate 'rock' for each stage of the experiment. **Compare** to the three main kinds of rock formation.

Assessment opportunities

- This activity can be assessed using Criterion C: Processing and evaluating.

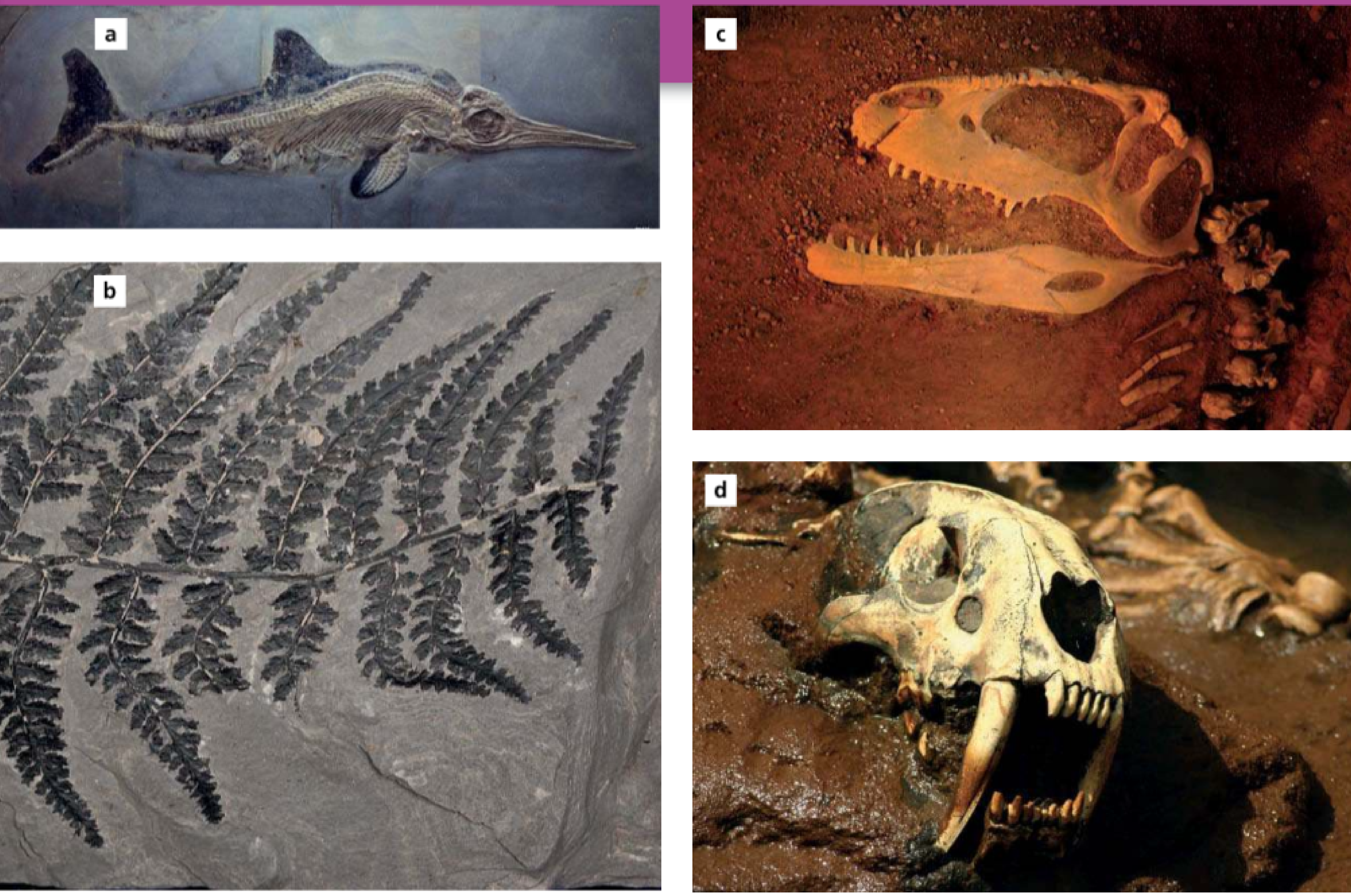
■ **Figure 6.20** Mary Anning (1799–1847), early and influential fossil-hunter

EXTENSION

Earth scientists can find the age of rock and other objects found in the ground directly using **radioactive dating**. This technique uses changes in the natural **radioactivity** of objects to work out their age. Use the search term: **radioactive dating** to find out more about how this works. One kind of radioactive dating uses the radioactive carbon found in living things – you can find an online simulation at https://phet.colorado.edu/en/simulation/legacy/radioactive-dating-game and a more detailed explanation in *Physics for the IB MYP 4 & 5: by Concept*, Chapter 11.

With the advent of scientific experimentation and research in Western Europe during the seventeenth and eighteenth centuries CE, Europeans began to question the creation story they had inherited from the Bible. Biblical scholars had dated the age of the Earth using the description in the books of the Old Testament to be around 6000 years old. In the 1830s a Scottish geologist called Charles Lyell (1797–1875) published a book called *Principles of Geology* in which he suggested that the slow, tiny geological changes that could be observed in nature might – over very long periods of time – explain the way the Earth came to look as it does. Of course these changes needed far more than 6000 years to take place.

Charles Lyell and his friend Charles Darwin were able to draw on a long history of the discovery of the remains of strange creatures buried sometimes deep in the bedrock. Fossils have been described since the earliest times in many cultures – indeed, many historians believe that the stories of mythical and fantastical beasts in many cultures all over the world (such as dragons, minotaurs or ogres) might in fact originate in the discovery by early people of fossils. As Lyell was writing his *Principles of Geology*, the science of fossils – **palaeontology** – was also becoming very important. Mary Anning (1799–1847) was a renowned fossil-hunter from a coastal part of England near to Lyme Regis where the sea has



■ **Figure 6.21** Fossils revealed that life on Earth long pre-dated the existence of human beings: (a) a fossil ichthyosaur, like the one found by Mary Anning, (b) fossil ferns, (c) a fossil of a dinosaur predator; (d) early mammals such as this predator are also found as fossils

eroded the rock of the cliffs to reveal many fossils, even to this day. In 1810 Mary and her brother discovered a complete skeleton of what we now know to be a marine dinosaur, which was named an ichthyosaur. This discovery was followed rapidly by a full plesiosaur or 'sea-dragon' in 1823 and a pterodactyl in 1828. At this time, women were not admitted to the scientific societies that discussed and decided on the importance of new discoveries, so it was male scientists who gained the credit for identifying dinosaurs and placing them in the Earth's pre-history. But Mary Anning's contributions to palaeontology were so important that she was recognized by the British Association for the Advancement of Science and the Geological Society of London, and she was paid for her fossil-hunting explorations.

As we saw earlier in this chapter, the Earth is now estimated to be around 4.5 *billion* years old. For at least the first billion years of the Earth's lifetime, it was lifeless – the first cellular lifeforms perhaps appeared around 3–4 billion years ago. Geologists divide the Earth's timeline into **eons** and **eras** of billions of years. On this scale, humanity has existed for only the last 0.004% of the Earth's life. We are very much a recent event.

ACTIVITY: Tracks of the past

ATL

- Critical-thinking skills: Use models and simulations to explore complex systems and issues

Fossils are not – as many people believe – the actual remains of living things. In this activity, individually or in pairs, we will 'model' the process by which fossils are formed.

Search and find descriptions of the following stages using the search terms: **sedimentation**; **dissolving**; **crystallization**.

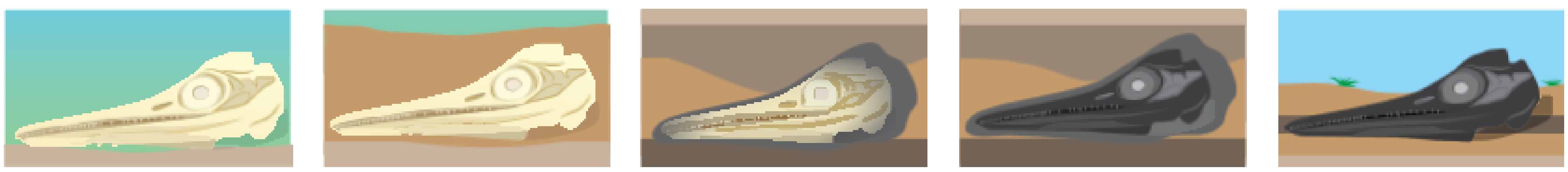


Figure 6.22 How fossils are formed

Equipment

- **Tray or other shallow container, around 20 cm × 30 cm**
- **Fine sand**
- **Drinking straws**
- **Dropper pipette**
- **Plaster of Paris (fine modelling plaster)**
- **Sugar cubes**

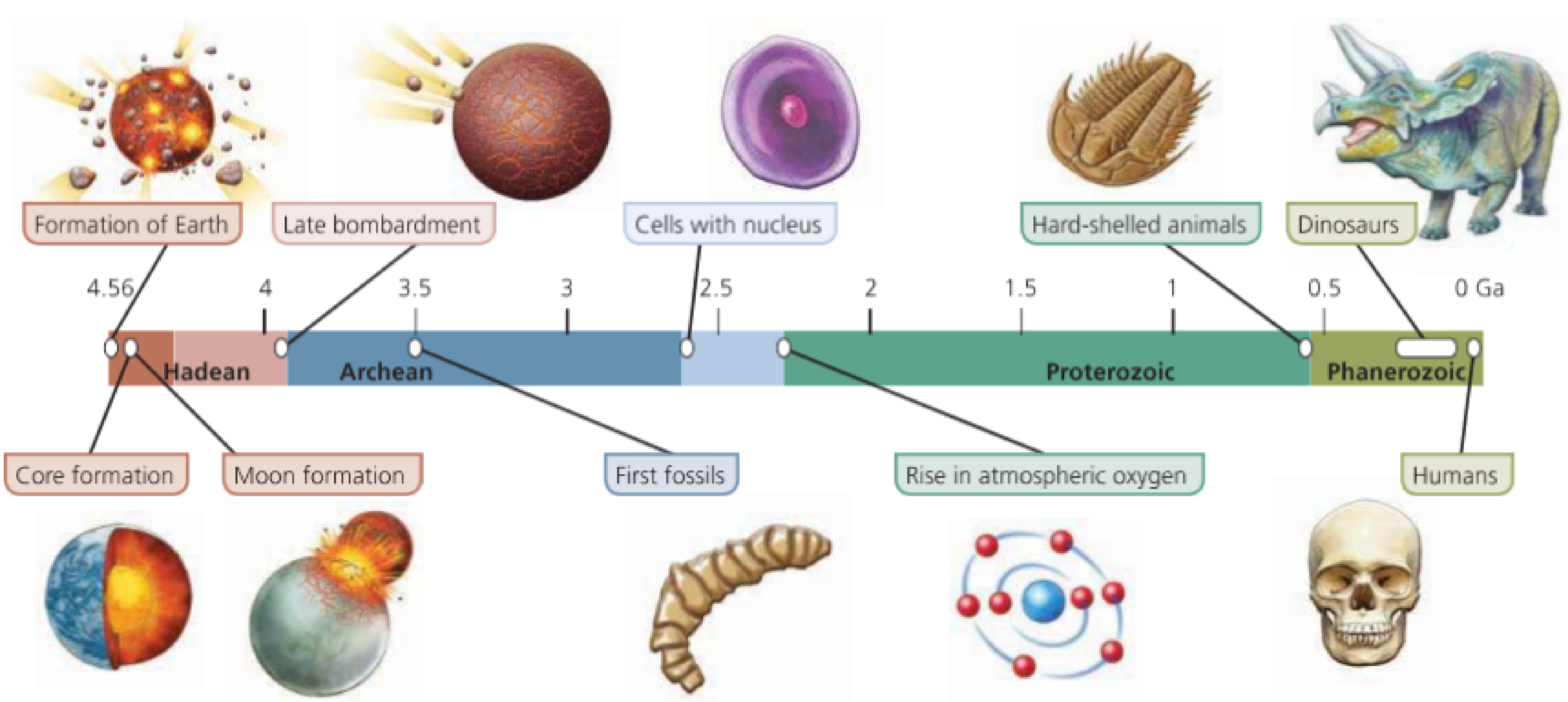


Figure 6.23 The Earth's timeline (not to scale), 1 Ga = 1 billion years

SAFETY: Sugar is edible but we should never put anything in our mouths in the science laboratory, in case it is contaminated or contains a poison or other toxic substance.

Procedure

In the first stage of fossilization, the remains of a living thing are buried in sediment.

Pour sand into the bottom of the tray in a thin layer, then position a sugar cube in the sand. Continue to fill the tray with sand until the sugar cube is nearly covered. Just before you cover the sugar cube over, insert the drinking straw vertically on top of the cube and then cover with more sand.

Now use your hands to press the sand down firmly all around the sugar cube.

In the second stage of fossilization, water dissolves the living remains to leave a mould.

Using the dropper pipette, drip warm water into the drinking straw. Keep adding water for as long as possible to dissolve away the sugar cube under the sand.

Leave your model to dry out for a few hours.

In the third stage of fossilization, minerals dissolved in water fill the hole left by the living remains and crystallize inside.

Prepare a solution of Plaster of Paris. The solution should be as thick as possible, but not so thick that you cannot pour it down the drinking straw. Stir well to make sure there are no lumps in the solution.

Now gently pour Plaster of Paris through the drinking straw until it fills the mould underneath. Remove the drinking straw.

Leave the Plaster of Paris to set for a few hours.

The fossil is revealed when erosion and other natural processes remove the rock around it.

Carefully excavate (dig out) the sand around your fossil. How well did your fossilization work?

Evaluate the success of your fossilization model. What information can we obtain from 'fossils' produced in this way? What can we not find out?

Hint

What if there was something inside the sugar cube?

In this section, we have **summarized** the properties of the lithosphere, and **described** how rocks are formed and changed. We have also **described** how geologists use scientific evidence to **explain** the formation of the Earth over time.

How do different systems of the Earth affect each other?

INTO THE AIR!

Figure 6.24 shows a high-altitude balloon launched by NASA. Balloon flight was the first success achieved by humans who wanted to leave the ground and escape the clutches of gravity, and passenger balloon flights were achieved as early as the eighteenth century CE. High-altitude balloons filled with **helium** gas have been used since the 1950s, when the United States and the Soviet Union both conducted experiments to find out what would happen when human beings travelled into space. They are still regularly used to carry out research into the atmosphere and weather.

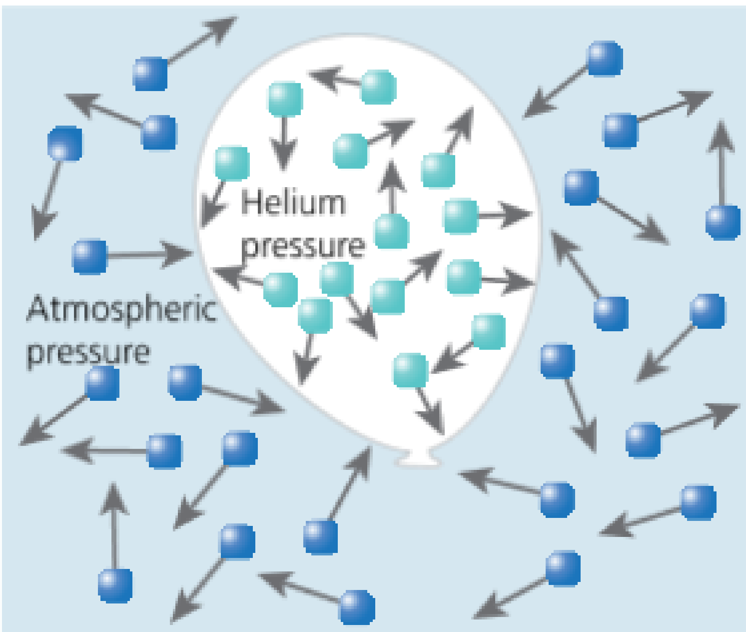
Now use the search term: **NASA balloon launch NZ** to watch a high-altitude balloon being launched from New Zealand.

SEE–THINK–WONDER

- **What do you see? Carry out an image search for: high altitude balloon. How do balloons at high altitude look different to the balloon in Figure 6.24?**
- **What does it make you think?**
- **What does it make you wonder?**

The balloon near to the ground looks very different to the balloon at high altitude. At high altitude, the pressure of the gases in the atmosphere around the balloon is much lower than it is near to the surface of the Earth. Pressure is a measure of the amount of force pressing over a certain surface area and is measured in **pascals (Pa)**. Since atmospheric pressure is so large near the surface of the Earth, atmosphere scientists sometimes use a different unit for atmospheric pressure called the **bar**, where 1 bar = 100 000 Pa.

■ **Figure 6.24** A 'near-space' balloon at launch



■ **Figure 6.25** Pressure inside and outside a gas balloon

The balloon contains gas on the inside which pushes out on the fabric or 'envelope' of the balloon. As the pressure outside the balloon decreases, the gas inside can push the balloon envelope out to a greater size. This is why the balloon looks larger at high altitude than it does near to the ground.

The Earth is wrapped in a blanket of gases that we call the atmosphere. But where does the pressure of the atmosphere come from? We are used to living at ground level, and so we don't notice air pressure much. In fact, the Earth's atmosphere is very deep indeed – it would be more accurate for us to imagine that we are walking around at the bottom of a deep ocean of gas.

Atmosphere scientists divide the atmosphere into 'layers' according to the properties of the gases at different altitudes. The atmosphere is not really 'layered' – the different layers blend into each other – but it is a useful way to understand how the gases behave at different heights. As Figure 6.26 shows, the part of the atmosphere we know best is called the **troposphere**, which is an average of 12 km thick (9 km at the poles, 17 km at the equator). This is where weather happens. If you have ever flown a long distance in a commercial airliner, you will have flown 10–12 km high – at the upper edge of the troposphere. The **stratosphere** extends out to around 50 km.

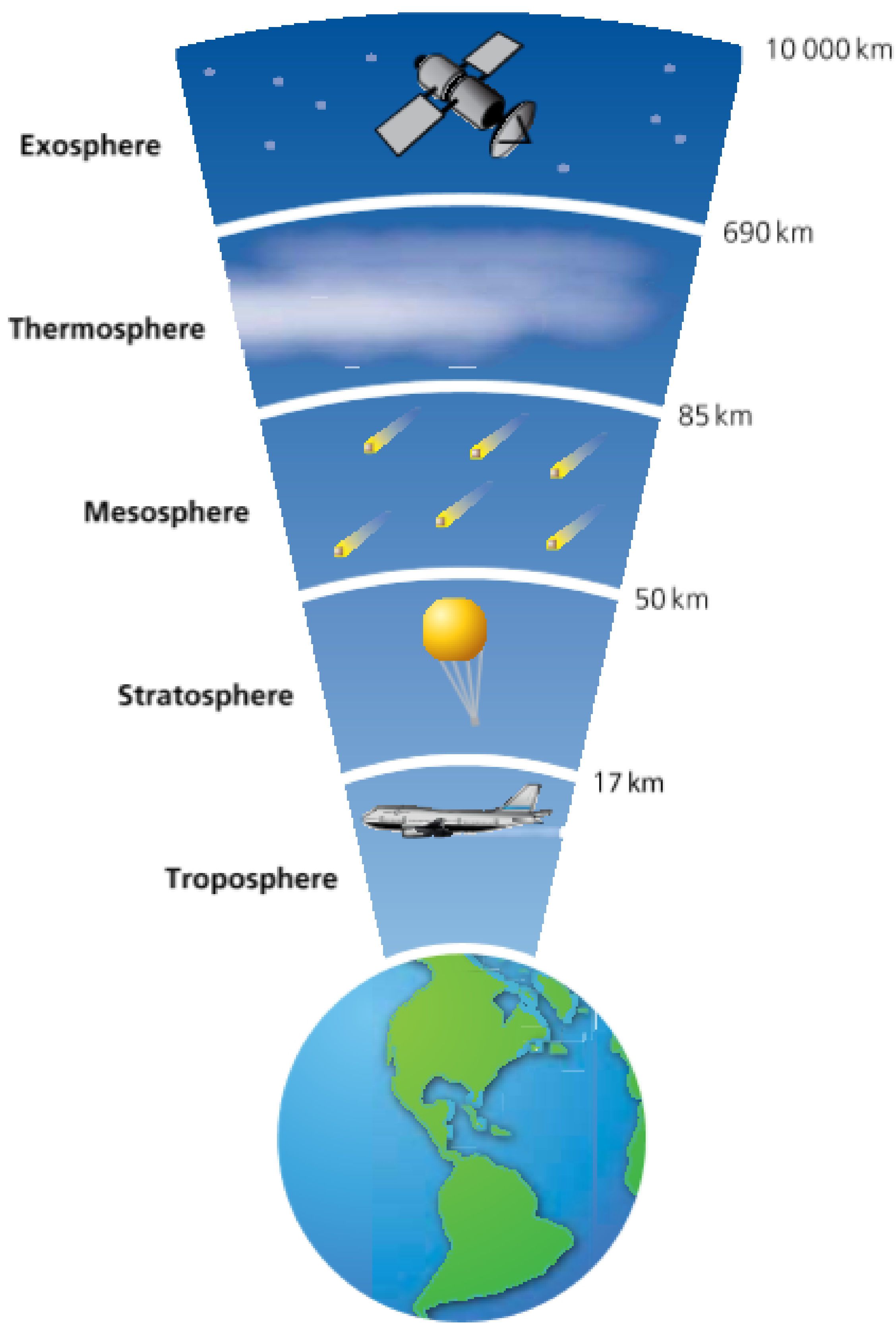


Figure 6.26 Layers of the Earth's atmosphere (not to scale)

■ **Figure 6.27** SpaceShipOne

■ **Figure 6.28** Aurorae occur in the thermosphere; they are caused by energetic particles from the Sun that are trapped by the Earth's magnetic field and which react with atoms in the thermosphere to produce light

The Concorde supersonic airliner (which is no longer in use) flew at a height of around 18 km, while the highest-flying jet aircraft are military planes that can fly well into the stratosphere, at up to 36 km. The record for altitude by an aircraft (not including spacecraft such as the Space Shuttle) is currently held by a rocket-powered aircraft called SpaceShipOne, which reached an altitude of 112 km in 2004.

Use the search term: **Alan Eustace record** to find out about a record-breaking parachute jump from the very edge of the stratosphere.

The stratosphere is important as it contains the **ozone layer** which filters out (removes) **ultra-violet radiation** in the Sun's rays that could be dangerous to life on the surface. As we climb higher into the atmosphere, the air pressure decreases, and at first so does the temperature. This region is known as the **mesosphere** and it extends out to around 80 km of altitude. The gas in the mesosphere is very thin, but just dense enough to cause meteors to burn up as they enter from space.

Beyond the mesosphere the gas is so thin that it would be very hard to measure any temperature at all using a conventional thermometer. However, the gas particles in the **thermosphere** are moving very fast and this means they carry a lot of thermal energy. The speeds of the particles – if near the surface – would result in temperatures of hundreds of degrees centigrade. The thermosphere extends out to 600 km or more.

ACTIVITY: What a great atmosphere!

ATL

- Information literacy skills: Process data and report results

Table 6.3 shows data gathered from scientific instruments on board a high-altitude balloon.

Discuss the data in the table. What does it show?

Make a **copy** of the data table, either in your notebook or using a computer **spreadsheet**. In your copy of the data, **identify** the layers of the Earth's atmosphere we have described.

Plot the data on two graphs as follows:

- **first graph showing pressure on the *x*-axis and altitude on the *y*-axis**
- **second graph showing temperature on the *x*-axis and altitude on the *y*-axis.**

On your graphs, **show** where some of these might occur:

- **the highest mountains**
- **clouds**
- **meteors**
- **aurorae**
- **high-altitude balloon**
- **commercial airliners**
- **spacecraft.**

Now **interpret** and **summarize** the data in the form of a **conclusion.** You may use these sentence starters to help:

Altitude (kilometres km)	Pressure (kilopascals kPa)	Temperature (centigrade °C)
0	101.3	15
10	69.64	−30
20	46.61	−56
30	30.13	−46
40	18.82	−22
50	11.65	−2
60	7.24	−28
70	4.49	−55
80	2.8	−75
90	1.76	−85
100	1.12	−80
110	1	−25
120	0.92	58
130	0.8	110
140	0.68	190
150	0.5	230

Table 6.3 Data from high altitude

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion C: Processing and evaluating.

As altitude increases, the air pressure …

However, the air temperature …

At ground level the pressure of the atmosphere is around … and …

The troposphere extends to an altitude of …
The air in the troposphere contains water vapour which can form …

The stratosphere extends to an altitude of … The temperature in the stratosphere …
The stratosphere is important to us because …

The mesosphere extends to an altitude of … In the mesosphere, the temperature …

The thermosphere extends out into space to an altitude around … In the thermosphere, the pressure is …
The temperature of the thermosphere …

We saw earlier in this book how living things use gases from the atmosphere, and also produce those gases themselves. Figure 6.29 and Table 6.4 show the composition of the atmosphere – how much of each different gas is present.

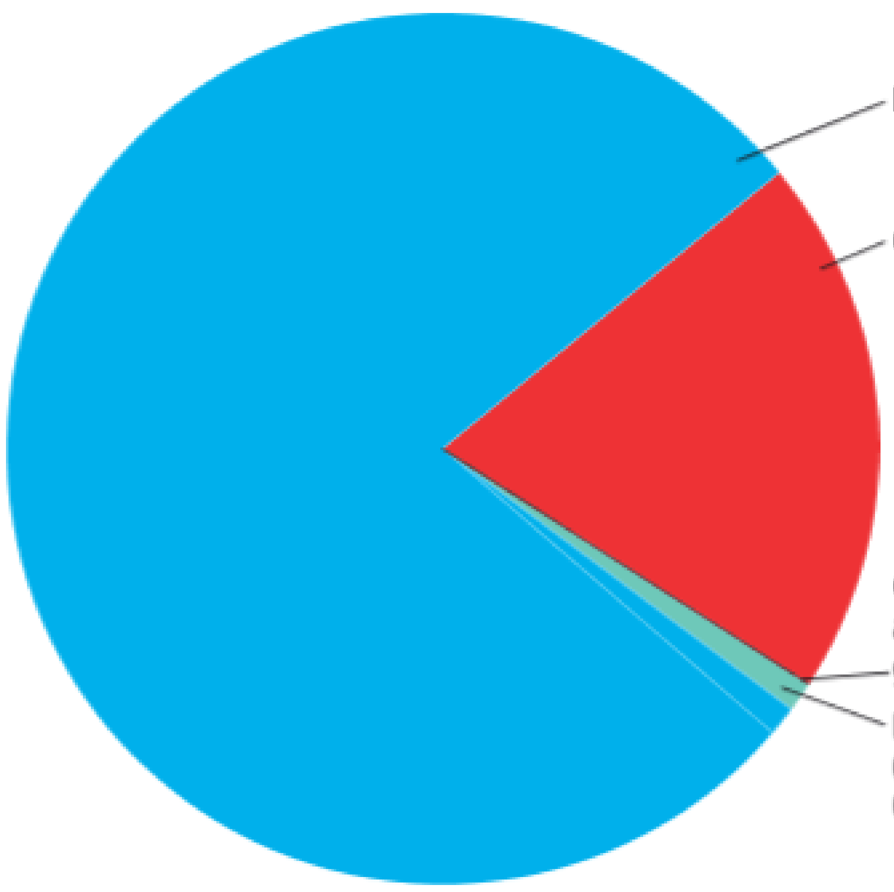


Figure 6.29 Composition of the atmosphere

Substance	% by volume
Nitrogen, N_2	78.08
Oxygen, O_2	20.95
Argon, Ar	0.93
Carbon dioxide, CO_2	0.033
Neon, Ne	0.0018
Helium, He	0.00052
Methane, CH_4	0.0002
Krypton, Kr	0.00011
Nitrogen(I) oxide, N_2O	0.00005
Hydrogen, H_2	0.00005
Xenon, Xe	0.0000087
Ozone, O_3	0.000001

Table 6.4

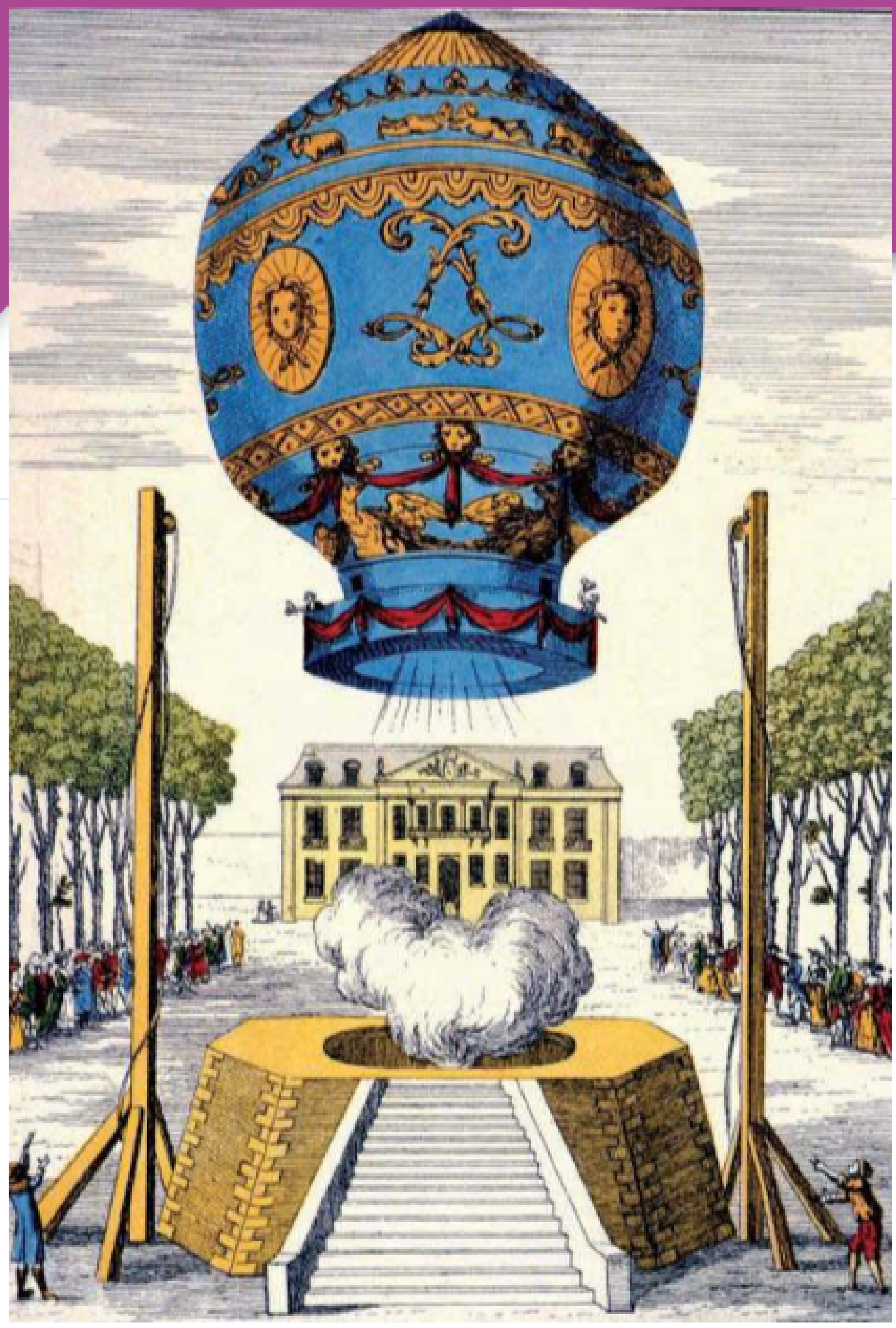


Figure 6.30 The first balloons used hot air to produce lift. This picture shows the first manned flight in a hot-air balloon by the Montgolfier brothers near Paris in 1783

Which is the most important gas to us? If your reply is 'oxygen' then that makes sense, since we rely on available oxygen for our **metabolic processes**. However, the other gases play important parts too – especially carbon dioxide, as we will see.

Modern high-altitude balloons use helium gas, which is much less dense than air at ground level. Less dense gases will tend to rise above more dense gases, and so the balloon lifts. When a gas is warmed, it also becomes less dense. (Why? Chapter 4 for more detail!) For this reason, the first balloons used heated air to produce the lift required – hot-air balloons. The first records of hot-air balloons are for Kongming lanterns (孔明灯) which were made in the third century CE in China.

ACTIVITY: Being dense

ATL

- Information literacy skills: Process data and report results
- Critical-thinking skills: Use models and simulations to explore complex systems and issues

We have seen how the gases in the different 'layers' of the Earth's atmosphere have different temperatures and pressures. Another way to think of the amount of gas – or any substance – we have in a certain volume is given by the **density**.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

where mass is measured in kilograms (kg) and volume is measured in cubic metres (m^3), so the units of density are written $kg\,m^{-3}$.

Density determines what floats, and what does not. In this activity we will see how liquids of different densities behave when mixed.

Equipment

- **Large beaker (500 ml)**
- **4 measuring cylinders**
- **Electronic top-pan balance**
- **Small 1 cm^3 blocks of different materials, such as plastic, wood, metal, modelling putty**
- **Samples of around 100 ml of each of these liquids: glycerine (glycol), sunflower or olive oil, water, ethanol**

SAFETY: Ethanol is an alcohol. It is therefore potentially toxic if drunk. If you are not allowed to use alcohols in your school laboratories, you may be able to use acetone (propanone) as a substitute. Acetone and ethanol are both volatile, meaning they give off fumes which you should not inhale for long periods of time, so use them in a well ventilated area. They are also both flammable, do not use them near to a flame.

State the problem or question we are investigating as an experimental inquiry question.

Method

Look at the different liquids – move them around in their containers or stir them. Predict what will happen when the liquids are poured together. **Explain** your prediction using scientific reasoning.

We will begin by making measurements to determine the density of each liquid:

1. **Place a measuring cylinder on the top-pan balance. Press the TARE button. This should set the reading on the balance to zero, with the measuring cylinder on top.**
2. **Remove the measuring cylinder from the balance, and pour 100 ml of liquid into the cylinder.**
3. **Use the balance to measure the mass of the liquid.**
4. **Pour the liquid into the large beaker, and repeat for the other liquids. Use a clean measuring cylinder each time.**

Record your measurements in a table. Add a column to the table for the density of the liquids. **Calculate** the densities using the formula. Note that:

$100\,ml = 0.0001\,m^3$

Observe what happens to the liquids as you add them to the beaker. Leave the liquids for some time to settle. Now drop the small blocks of different materials into the liquid mixture. **Observe** what happens as they enter the liquids.

Conclusion

Summarize your observations in the form of a conclusion. Use your calculated values for liquid densities to **explain** your observations.

Evaluation

How successful was your experiment at allowing you to compare liquids of different densities? **Evaluate** the experiment, suggesting what errors there might have been, and improvements you could make. What else could you have done to extend your experiment?

Assessment opportunities

- In this activity you have practised skills that are assessed using Criterion B: Inquiring and designing and Criterion C: Processing and evaluating.

The tendency of warmer gases to rise due to their lower density is very important in the troposphere. Equally, cooler air has higher relative density and so tends to sink. This process of rising and falling is called **convection** and it causes heat and water vapour to be transported through the atmosphere. Without it, we would have no weather – and the Earth's surface would be a very different place. You can observe convection taking place when birds seem to glide stationary in the air, and gliders use the same technique. The birds and gliders are exploiting rising columns of warm air called **thermals** to maintain their lift.

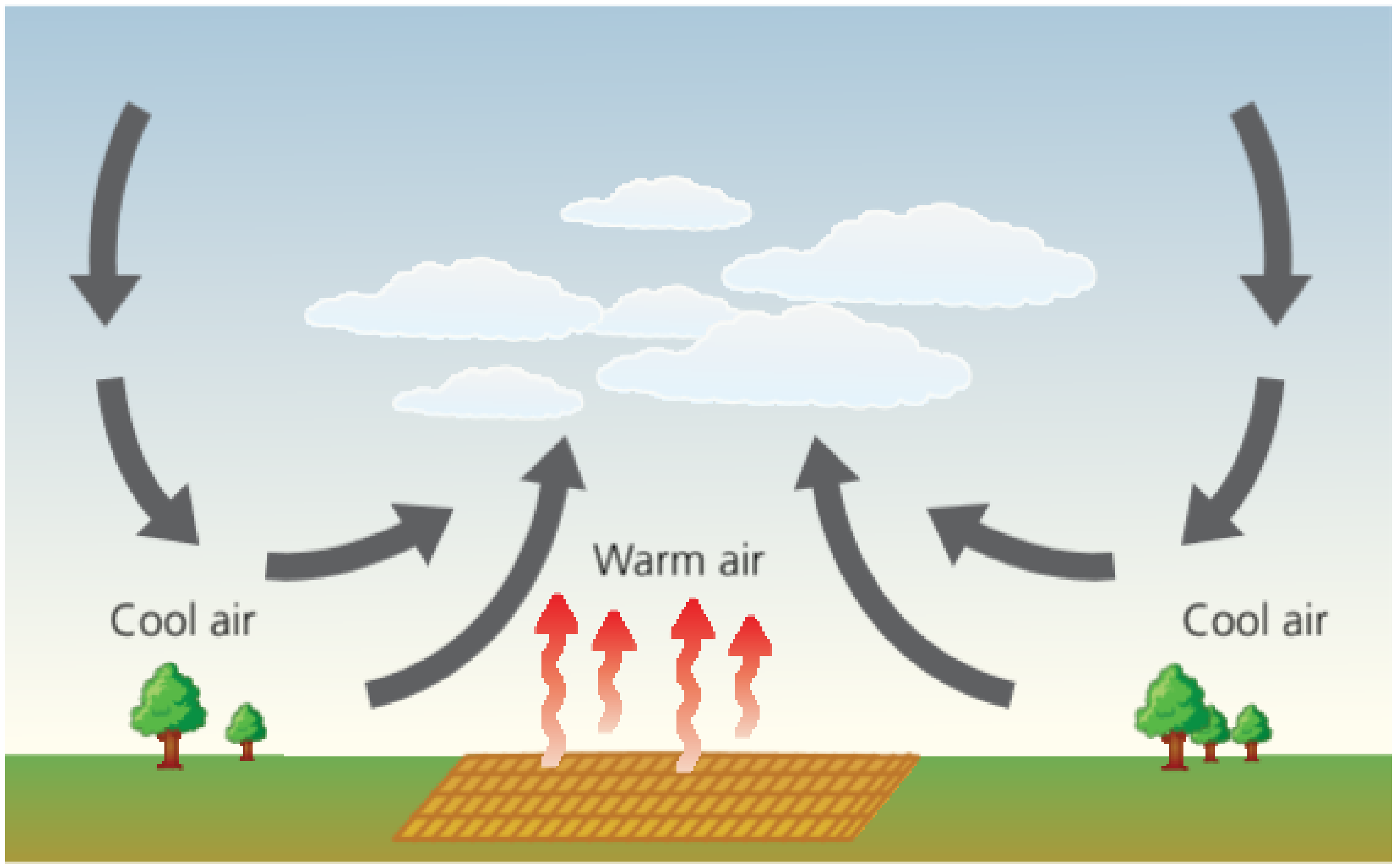


Figure 6.31 Rising warm air drives our weather systems; birds and gliders often use this effect to stay in the air with no effort

ACTIVITY: Hot air rising

ATL

- Creative-thinking skills: Apply existing knowledge to generate new ideas, products or processes
- Critical-thinking skills: Evaluate and manage risk

In pairs, we will make a simple hot-air balloon.

Equipment

- **Very light plastic bag – those used by dry-cleaners are perfect.**
- **Some light wire – for example from a wire coathanger**
- **Wire cutter**
- **Aluminium foil**
- **3 or 4 birthday cake candles**
- **Sticky tape**
- **Glue**

SAFETY: Coathanger wire can be sharp when cut – ask for help if you need it and take care when manipulating the ends of the wire.

Ensure the candle flames cannot contact the envelope of the balloon, as this will melt the balloon plastic and produce toxic fumes.

Take care when melting wax from the candles. Avoid getting the molten wax on your skin.

ENVIRONMENTAL IMPACT: Do not allow your balloon to float away, as the plastic of the balloon causes environmental damage and may harm animals or birds.

Method

1. **Tie four knots in the opening at the bottom of the dry-cleaning bag.**
2. **Unbend the coathanger and cut the wire into two straight lengths.**
3. **Twist these two lengths of wire into an X-shape.**
4. **Use the aluminium foil to make a small 'cup' which is about the same depth as the candles.**
5. **Twist or tape the ends of the wire 'X' to the knots you made in the bag.**
6. **Fix the cup to the centre of the wire 'X' using tape or glue. Adjust the wire so that there is a small gap between the top of the cup and the opening formed in the bottom of the bag.**
7. **Light the candles and carefully drip molten wax into the bottom of the cup. Use this melted wax to position the candles vertically in the cup.**
8. **Now hold the balloon by pinching the top between your fingers. Light the candles carefully (take care not to burn or melt the balloon envelope!).**
9. **Wait for the balloon to begin to fill with hot air from the candles.**
10. **Release your balloon!**

Evaluate the design of your hot-air balloon. What problems did you encounter while constructing it? How could it be improved?

How do models help us to understand Earth's systems?

TO WHAT EXTENT DOES LOOKING INTO SPACE HELP US TO IMPROVE OUR MODELS OF EARTH'S SYSTEMS?

When we compare the 'blue marble' photographs of the Earth to pictures of our nearest planetary neighbours, one colour stands out.

SEE–THINK–WONDER

Compare the images of Earth at the beginning of this chapter to those of Venus and Mars in Figure 6.32.

- **What colours do you see?**
- **What do the colours of the planets suggest to you?**
- **What do you imagine it would be like to stand on the surface of these planets?**

Figure 6.32 Venus and Mars

The single substance that makes our planet so special is one that we take for granted: H_2O, dihydrogen monoxide or oxidane, more commonly known as water.

71% of the Earth's surface is covered with water, and about 96.5% of all the water on Earth is salt water solution in the oceans and seas (see Table 6.5). Water also exists as water vapour in the air, and as fresh (or less salty) water in lakes and rivers, frozen as ice in **glaciers** and in the polar caps, and hidden underground in large natural reservoirs called **aquifers**. In turn, our own bodies are between 50% and 65% water – it would not be inaccurate to see ourselves as mobile bags of water! Water is truly the stuff of life, as it is the solvent for our biological processes.

Venus is similar in size to the Earth, and is a rocky planet like ours. But Venus is covered in thick clouds of carbon dioxide, with pressures nine times those of the Earth's atmosphere, while the temperature at the surface is around 450°C. Mars is only about half the size of the Earth, and its atmosphere is about a hundred times thinner than ours, again made mostly of carbon dioxide. Mars does have polar caps, which can be seen to grow during Martian winter time and shrink during Martian summer. This had led some early astronomers to speculate that Mars might have water like Earth, and therefore life. We now know that the polar caps of Mars are actually made from frozen carbon dioxide ('dry ice'). Although recent visits to Mars by robot explorers from Earth have suggested there may in fact be evidence of water under the surface of Mars, the scientific community is still divided on this.

If all the Earth's water were collected into a single bubble, the bubble would contain 1386 million cubic kilometres (km^3) of water, and its diameter would be around 1384 km. But how much of *this* water is available for us to use?

Water is abundant and commonplace on Earth, but it is not equally distributed everywhere on Earth. In some places, fresh water is so valuable that it becomes economically **viable** to extract it from salty sea water using industrial processes.

■ **Figure 6.33** In countries such as Saudi Arabia where fresh water is very scarce, water is extracted from sea water using desalination plants. However, this is a very expensive way to make fresh water

■ **Figure 6.34** Icebergs float on seawater. Why should this surprise us?

The oceans are **saline** because mineral salts from the Earth are easily soluble in water. It might seem that this is a problem for life on Earth – until we remember that the hydrosphere contains the most extensive and varied ecosystems on our planet. Salt water also plays a key role in transporting heat energy around the planet, and so the salinity of the oceans has a significant effect on our weather systems.

Water may seem innocuous and very ordinary. However, a little scientific investigation can reveal that it has some quite unusual properties, especially when we compare liquid water to solid water ice. You may recall from Chapter 2 that when a substance is in the form of a solid, its particles are closely packed together, whereas in the liquid state particles are more loosely bonded and less closely packed. This means that usually the density of any substance in the solid state is greater than its density in the liquid state. Logically, this suggests that solids tend to sink in their liquids – for example, we might expect solid candle wax to sink in melted candle wax.

DISCUSS

Research the densities of water and of ice.

What might surprise you about these values? What does this suggest about the behaviour of ice in liquid water?

Water is very unusual in that the density of its solid state – ice – is *lower* than the density of its liquid state. This means that ice floats on water – which a mind experiment can confirm, when we think about the North Pole ice shelf and icebergs!

About 1.7% of the Earth's water is trapped in the form of ice, whether floating as sea ice in the seas over the North Pole or lying on the ground as freshwater snow, such as over the continent of Antarctica or elsewhere in the polar regions. Polar snow and ice has a key influence on the Earth's environment.

Polar ice plays a key role in our climate since it acts as a 'heat sink', cooling the air above it even when the local temperatures are warm. What would happen to the Earth if the ice caps melted? As we will see in the activity *Salty ice*, floating ice actually occupies a larger volume than liquid water. Most of the volume of an iceberg is beneath the surface of the sea, so when floating North Pole ice melts in the summertime it does not significantly change the volume of the oceans. Any ice or snow that lies on land, however, is not contributing to the volume of the oceans, and should it melt the liquid water would run off and increase the volume of the oceans. The Greenland and Antarctic ice sheets together account for 99% of the freshwater ice on Earth. The Greenland ice sheet covers about 1.7 million square kilometres (km^2), and if it melted the estimated rise in sea level would be about 6 metres. Still worse, the Antarctic ice sheet covers 14 million square kilometres (km^2), and if all of this ice were to melt the sea levels would rise by 60 metres. This means that a major global warming event could result in anywhere lower than 60 or 70 metres above current sea level being flooded. Of course, this would not be the only consequence of such an event – the Earth's climate patterns would change radically. What evidence is there that the ice caps might be melting?

ACTIVITY: Water, water everywhere – but how much to drink?

■ ATL

- Critical-thinking skills: Interpret data; Gather and organize relevant information to formulate an argument

The data in Table 6.5 shows the volume of water held in different forms on Earth.

Water source	Volume in cubic kilometres (km^3)
Oceans, seas and bays	1 338 000 000
Ice caps, glaciers and permanent snow	24 060 000
Groundwater	23 716 500
Freshwater lakes	91 000
Saline lakes	85 400
Swamp water	11 470
Rivers	2 120
Atmospheric water	12 900

■ **Table 6.5** Volume of water in different forms on Earth

We are going to **interpret** this data to work out how much water is available for each person on the Earth.

To do this, we will need to make some assumptions:

- **We will assume that only water in liquid form is easily accessible to humans.**
- **We will assume that only fresh water is useful to humans.**

How valid are our assumptions? **Outline** the science that supports these assumptions. For each assumption, **write down** a FOR and an AGAINST statement, then make a judgment about their validity.

Identify the sources of water that are both fresh and liquid.

Now **calculate** the volume in cubic kilometres of this water.

The world's population is currently estimated at around 7 billion people, where 1 billion is 1 000 000 000.

Use this fact to **estimate** the amount of fresh water available to each person on Earth, in cubic kilometres.

A cubic kilometre is a lot of water – in fact it would weigh a billion or 1 000 000 000 tonnes! It will help to express this number as a volume we can understand, as follows:

1 litre is the volume of a large bottle of drinking water.

1 litre (l) = 0.001 m^3

So 1 m^3 = 1000 litres

Now **calculate** how many cubic metres (m^3) of water are available to each human being, and so how many litre bottles this would represent.

Did you include the value for groundwater in your calculations? Unfortunately, most groundwater is trapped in the Earth and is not accessible to humans either!

If necessary, revise your **estimate** of the amount of fresh, liquid water that is easily accessible to each person on Earth.

In 2008, a documentary movie about water scarcity was made called *Blue Gold: World Water Wars*. Use: Blue gold: world water wars as a search term to find out more about this.

Evaluate your calculation and **interpret** its validity. How realistic is your value likely to be, in your opinion? Does each person on Earth have the same access to fresh water? Why might water be 'blue gold'?

◆ Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding.

ACTIVITY: Salty ice

ATL

- Critical-thinking skills: Use models and simulations to explore complex systems and issues; Draw reasonable conclusions and generalizations

SAFETY: Before beginning any investigation be sure to make a safety/risk assessment and an environmental impact assessment. Make sure that your teacher has checked your design before you begin.

In pairs, imagine you are Earth scientists working for the United Nations Intergovernmental Panel on Climate Change (IPCC, www.ipcc.ch) who are trying to work out the effect of climate change on the polar caps. What effect might global warming have on the amount of ice in the Earth's polar regions? Does it matter how much salt is dissolved in the sea water? In this activity we will design an investigation to explore the properties of salty water and fresh water, as liquid and as solid, and write a report for the United Nations.

Background

Ice formed from salt water covers all of the North Pole and forms great ice shelves in both polar regions. Water that has fallen as precipitation is fresh water since when it evaporates it loses any dissolved solute.

Discuss: What is the freezing point of fresh water? Do you think adding salt to water would make a difference to the freezing point?

Outline an inquiry question for your experiment about salinity and freezing point.

Outline the variables for your investigation:

- **an independent variable that you will change**
- **a dependent variable that you will measure**
- **other independent variables that you will need to control and keep the same.**

Write a prediction about the effect of changing the independent variable on the dependent variable. **Explain** your prediction using your knowledge of solutions and solutes.

Design an investigation to make measurements that allow you to test your prediction and answer your inquiry question.

Record your results clearly in a table or spreadsheet, making sure to show units of measurement.

Present your data as a chart or graph that makes the effect you are looking at clear.

Interpret your data – what does it suggest about the effect of the independent variable on the dependent variable? Write a conclusion that **outlines** your findings.

Evaluate your investigation. Did you fully test the prediction? Did you answer the inquiry question? How confident are you that your results were reliable and valid? **Describe** any improvements you could make to the investigation to make it more reliable.

Assessment opportunities

- This activity can be assessed using Criterion B: Inquiring and designing and Criterion C: Processing and evaluating.

EXTENSION

The NASA Aquarius satellite monitors the Earth's oceans and measures their salinity. Use this website to observe the Earth's salty seas in real time: http://aquarius.nasa.gov/

Discuss: Why is it important to know how much salt the sea contains? Find out by researching: sea salinity.

EXTENSION

Find out more about water and ice density. The shape of the water molecule means that liquid water contains unusual additional forces of attraction. Use the search term: hydrogen bonding to explore and then **explain** to your classmates.

ACTIVITY: ICESat and the polar ice cap

ATL

- Critical-thinking skills: Interpret data; Evaluate evidence and arguments

From 2003 to 2010, a NASA satellite mission called ICESat monitored the North Pole ice cap.

Figure 6.35a shows composite images of the Arctic ice in November through January, in 1980 and in 2012. Figure 6.35b shows the average extent (surface area) of Arctic ice over the period 1980–2012.

Individually, **describe** the shape of the graph in Figure 6.35b. **Explain** why the line on the graph is not straight, or is not a simple curve. **Explain** why it might be important to measure the ice extent at the same time of year.

Interpret the graph to **estimate** the change in average surface area over 1980–2012. **Calculate** this change as a percentage change in surface area.

Use the evidence from the graph and your calculations to make a scientific judgment and **summarize** what evidence is presented here that Arctic ice is melting. **Outline** what other evidence we might expect to find that this is happening.

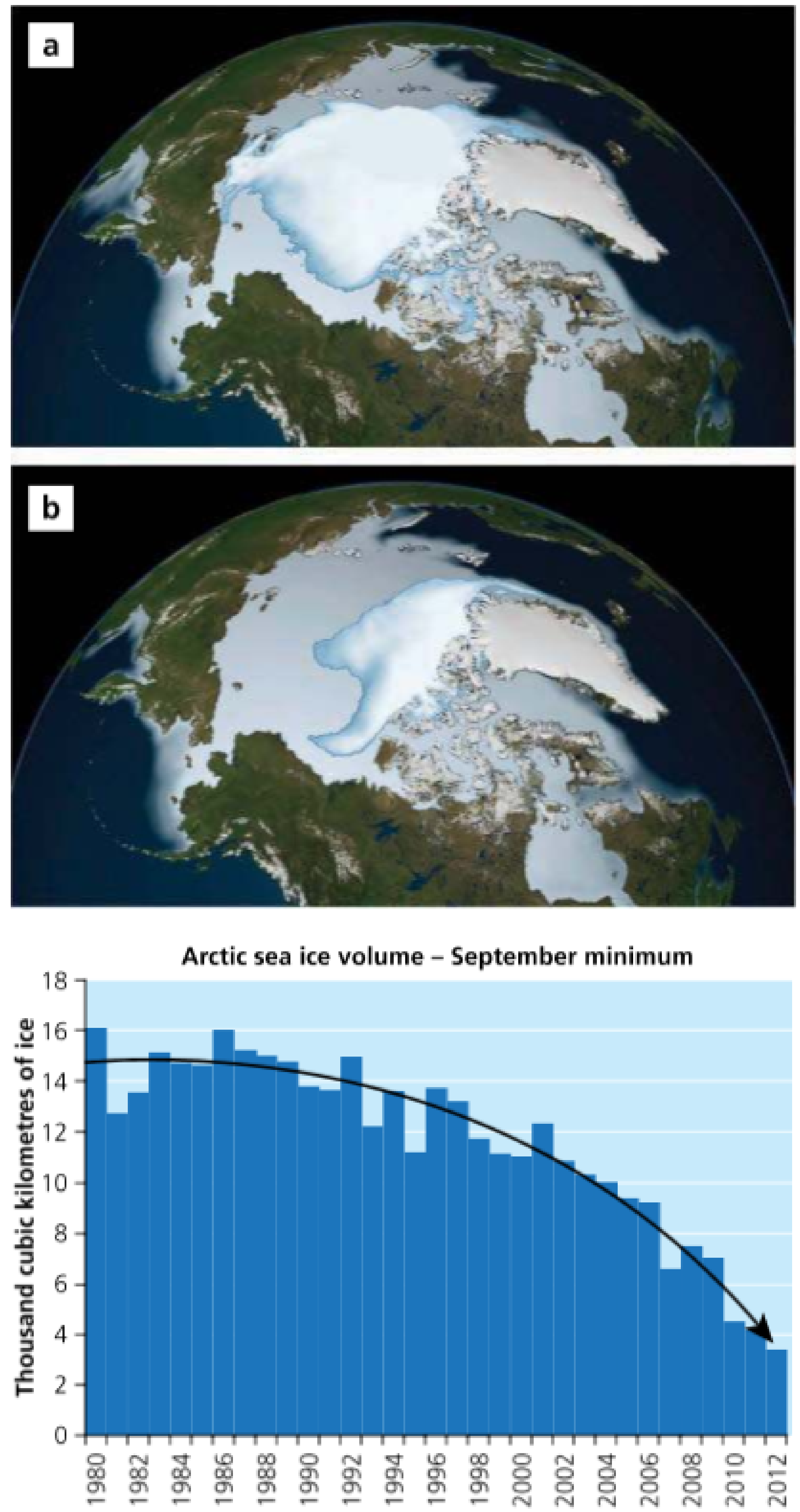


Figure 6.35 Evidence of receding polar caps; data for North Pole ice surface area to 2015

Assessment opportunities

- This activity can be assessed using Criterion A: Knowing and understanding.

EXTENSION

Other evidence has been offered that ice coverage all over the Earth is reducing, including a reduction in size of glaciers. Find out more about this evidence using the search term: glacier reduction.

EXTENSION

NASA has also been monitoring global sea levels from 1997 with a number of satellites. You can find out more about this scientific project at http://sealevel.jpl.nasa.gov/

NASA also provides a stream of data every 15 days showing global sea level variation: http://climate.nasa.gov/interactives/sea_level_viewer (requires Shockwave Flash).

Discuss: What does this information tell us? **Evaluate** the usefulness of this data and **outline** what it may be used for.

How does knowledge from space exploration help us to understand the Earth?

THE LIVING EARTH

In Chapter 2 we saw how the water cycle – sometimes called the **hydrological cycle** – recycles water from the oceans and transports it to land regions. The hydrological cycle is driven by heat transfer due to temperature difference, so a change in the temperature differences over the Earth would result in a change in the hydrological cycle that sustains our weather patterns. This is one of the key concerns about global warming and what is meant by climate change more generally.

After the formation of the Earth around 4.5 billion years ago, the planet was a rather barren, unpleasant place to be. The Earth's surface was very hot and the only atmosphere consisted of hydrogen and helium gas. These are very light gases and at high temperature the hydrogen and helium particles were able to escape from the Earth's gravity, and were lost in space. As the Earth was still cooling, there was much volcanic activity, and the eruption of volcanoes released water as steam, and carbon dioxide (CO_2) and ammonia (NH_3). These molecules are rather heavier, and the Earth was continuing to cool, so the Earth's first real atmosphere was formed. Much of the carbon dioxide would have dissolved in the water forming new oceans, while the Sun's energy broke up the ammonia to form nitrogen and hydrogen. Although this environment was not hospitable to life as we now know it, it did allow for the formation of simple bacteria in the oceans, as energy from the Sun caused the chemicals in the oceans to react. The bacteria in turn consumed the carbon dioxide in the water and produced oxygen (O_2) as a waste product, and so the Earth's atmosphere began to change.

As we saw in Chapter 5, ecosystems form where living things live in symbiotic relationships, depending on each other for the things they need to survive. On the

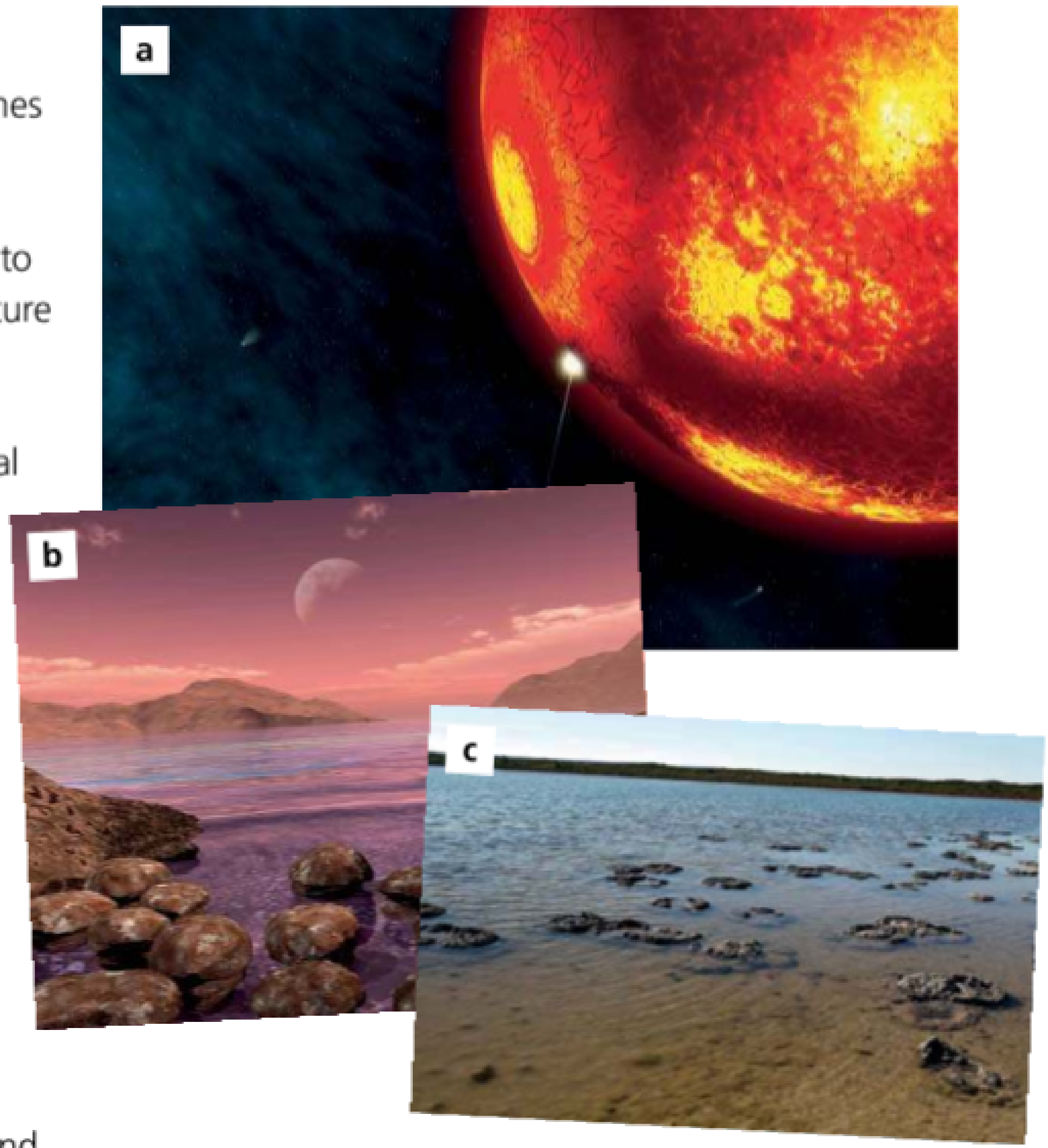


Figure 6.36 Three stages in the formation of the early Earth, known as the Precambrian Eon. (a) the Hadean era, where rocks were forming and the Earth had no stable atmosphere, (b) the Archaean era, when volcanic activity formed an early atmosphere of gaseous H_2O, CO_2 and NH_3 (c) the Proterozoic, when primitive bacteria began to produce O_2

early Earth, through the process of photosynthesis, plant life consumed carbon dioxide and produced oxygen, while early animal life did exactly the opposite – developing respiration to breathe oxygen and expel carbon dioxide. Plant and animal life rely on each other to this day.

We can see how the Earth and its environment are not just welcoming to life by coincidence – it is better to think of the Earth as a living system that created the conditions for itself.

! Take action: Into space?

ATL

- Collaboration skills: Delegate and share responsibility for decision-making
- Organization skills: Select and use technology effectively and productively
- Communication skills: Use a variety of media to communicate with a range of audiences; Organize and depict information logically

! In this chapter we have seen how scientists have been able to learn more about our home planet, the Earth, by looking back from space. Space research has provided scientific data to help us to develop models and so better understand Earth's environmental systems.

! How important has the contribution of space research been? Has it been worthwhile? With time, space missions have become more collaborative, perhaps culminating in the international collaboration of the ISS. What problems have been overcome in achieving this?

! **In pairs or groups:** In this activity you will research a space mission and **present** your findings to a United Nations commission on space research. You will need to **justify** the mission in terms of its costs, and its benefits. Should the United Nations be more involved in space research?

! **Before you begin:** Plan out your project. What kind of presentation will you make? Consider different forms of media such as video, slide presentation, posters, online. Is somebody in your group skilled with your chosen kind of media? Who in your group will be responsible for each stage of the project? What deadlines do you need to meet, and how will you each organize your time so as to meet the deadlines?

! **Research:** Carry out background research on space missions that have been used to find out about Earth systems. You may find the search terms: Earth observing system and International Space Station useful as starting points.

! Choose ONE research mission to investigate in more detail, and prepare a presentation about it. In your presentation, make sure that you:

- **Summarize** the ways in which your chosen space mission has contributed to our scientific understanding of Earth's systems.
- **Describe** the advantages and disadvantages of carrying out research in this way. What other factors must be considered? What problems or obstacles might there be?
- **State** your conclusion on the question: should the United Nations support more international space research?
- **Apply** the scientific vocabulary you have learnt in this chapter and throughout the book to **explain** your understanding of the mission clearly.
- Make sure that you **document** sources you use, with a bibliography and in-text citation as appropriate.

! When you have finished your presentation, **evaluate** your participation. Did you contribute effectively to the group work? What could you have done better? You may wish to share your self-evaluation with the other members of your group.

Assessment opportunities

- This activity can be assessed using Criterion D: Reflecting on the impacts of science.

Reflection

In this chapter we have **outlined** and **summarized** our local neighbourhood in space, the Solar System. We have **described** a theory for the formation of the Solar System, and **outlined** the main Earth systems. We have **evaluated** evidence produced from space missions and from research on the Earth, and explored how this evidence has been **applied** to build a scientific model of the way the Earth works and supports life. We have **applied** our understanding of these systems to see how they are inter-related.

Use this table to evaluate and reflect on your own learning in this chapter.					
Questions we asked	Answers we found	Any further questions now?			
Factual: What is in the Solar System? Where is the Earth? What is the structure of our planet?					
Conceptual: How do different systems of the Earth affect each other? How do models help us to understand Earth's systems? How does knowledge from space exploration help us to understand the Earth?					
Debatable: To what extent does looking into space help us to improve our models of Earth's systems?					
Approaches to learning you used in this chapter:	Description – what new skills did you learn?	How well did you master the skills?			
		Novice	Learner	Practitioner	Expert
Communication skills – we have used different media to communicate and to depict and organize information					
Organization skills – we have selected and used appropriate technology.					
Collaboration skills – we have worked collaboratively to share decision-making.					
Information literacy skills – we have used online technology to find information and inform others.					
Critical-thinking skills – we have organized information, evaluated evidence, formulated arguments, interpreted data and drawn conclusions, and we have managed risk to work safely.					
Creative-thinking skills – we have thought creatively to apply knowledge to generate new ideas.					
Learner profile attribute	How did you demonstrate your skills of being reflective in this chapter?				
Reflective					

Glossary

abiotic The non-living components of an ecosystem

absorb Process by which a liquid is taken up or physically trapped within the structure of a solid

adaptations Changes in the structures or functions of an organism that make it better suited to survive in its environment

altitude Height above sea level on Earth, or ground level elsewhere

analytical To take an object or idea apart and examine its components or pieces to see how they work

apparatus Any equipment used in a scientific experiment

aquifer Liquid water held in rocks under the ground

archaeologist A scientist and historian who uses evidence from relics found in the Earth to learn about the past

artificial material A material that has been manipulated or created by humans

asexual reproduction Reproduction that occurs without the combination of male and female genetic information; only one 'parent' organism is involved

bar Non-SI unit of gas pressure

biome A complex ecosystem that is characterized by climate and the plants and animals that live there

biotic The living components of an ecosystem

biotic change A change caused by the action of living organisms

bonds Joints or connections between atoms

capillary action The ability of liquids to move through a thin tube without external force due to the action of forces of adhesion and surface tension

cellular respiration A chemical process that occurs inside the cells of all living things, and which produces energy for the cells and organism to survive

chemical change A change resulting in a new chemical substance

chemical neutralization A reaction between an acidic and a basic substance that results in neutral products

chemical reaction Process by which two substances or reactants undergo chemical change to form new substances or products

chromatography Separation process that utilizes the different solubilities of liquids in different solvents

clone A cell or organism that has the same genetic information as another one

combustion Burning, or the rapid oxidation of a substance, producing heat

competition The struggle between different organisms over the same resources

compress To put under pressure

conduction Process by which energy is transferred through contact between particles, by vibration or translation, such as heat, sound or electricity

conservation of energy The principle that energy cannot be created or destroyed, only transferred from one form to another

constructive boundary Boundary between tectonic plates that are moving apart, such that magma is forced to the surface to make new rock

controlled variable A variable that is expected to be affected by the independent variable, but whose effect is not being investigated, so it is kept constant

convection Process by which energy is transferred through the bulk motion of particles

core The centre of the Earth, around 3000 km beneath the surface, consisting largely of iron and nickel

crust Thin, rocky layer on the surface of the Earth

crystal A solid substance that has a regular geometrical physical structure

decomposer An organism, such as bacteria or mushrooms, that breaks down dead organisms into smaller, more simple substances

decomposition Chemical breakdown of a substance by living organisms; rotting or decay (see also fermentation)

density The mass of a substance per unit volume

dependent variable A variable that is expected to be affected by the independent variable, usually measured

destructive boundary Boundary between tectonic plates that are moving together, such that rock is forced down beneath the surface

diameter Line splitting a circle into two semicircles

diet The food eaten by an organism

dissolve Process whereby the particles of one substance are physically trapped within the structure of another, without chemical bonding

distillation Process of evaporating then condensing a liquid, such that all dissolved substances are removed or separated

distilled water Water that has been evaporated and condensed to remove all dissolved impurities

DNA Deoxyribonucleic acid; a large molecule inside each cell that has the genetic information for the characteristics of the organism

ecological footprint A measurement of the effects that people have on the natural balance in ecosystems around the world

ecosystem Different populations that interact with biotic and abiotic factors in their shared habitat

environmental impact evaluation Assessment or evaluation of the effect of our actions on the living or non-living environment

eon The longest geological time period: billions of years, comprising geological eras

era The second longest geological time period: many millions of years

erode The gradual wearing away of rock by natural processes

evolution A change in the genetic and physical characteristics of a species over many generations

experiment A procedure carried out under controlled conditions to provide observations that will test a hypothesis or demonstrate something known or new

fermentation Chemical breakdown of a substance by living organisms to give new chemical substances, such as alcohols (see also decomposition)

filtration Process of removing particulates from a suspension

fixed point A physical change that is used to specify a particular point on a temperature scale

fossil fuel A substance formed in the ground that has energy stored in its chemical bonds, such as coal, oil or natural gas

gas A physical state of matter where particles are arranged and only very weakly bonded, or not bonded at all, so that the material fills a containing volume

genetic information The molecules in a cell (DNA) that direct the functions and characteristics of the cell and the organism

glacier Large mass of ice on the land

gravity Force of attraction between any two masses; a fundamental force of nature

habitat The environment or surroundings where an organism lives

harness To use to do work

heat Thermal energy that is transferred between regions at different temperature

helium The second lightest element (hydrogen is the lightest)

herbivory The process of eating plants

homeostasis The tendency of an organism to maintain itself in a stable, healthy balance

hydrological cycle Process by which water is recycled in the Earth's environment

independent variable The variable that is changed under controlled conditions

infra-red radiation Energy transferred as a wave with wavelength a little longer than that of visible red light

ingest To swallow or take a substance into the body

inheritable A characteristic or trait that is able to be passed to new generations through DNA and the process of reproduction

insulator A poor conductor of heat

kinetic energy Energy due to physical motion

kingdom A large category of living things, for example plants, animals, bacteria and fungi

lava Molten rock

limestone Sedimentary rock formed by the compression of the shells of prehistoric sea creatures

linear scale A scale that increases by unit amounts, as in a straight line

liquid A physical state of matter where particles are arranged and weakly bonded so that the material remains in one piece but can flow

magma A mixture of molten (melted) and semi-molten rock found beneath the surface of the Earth

magnetic field A region of space where magnetic forces can be detected

mantle A region inside the Earth consisting of a thick, slow-moving liquid of magnesium, iron and silicates

mating The process of sexual reproduction

mesocosm An experimental system that models an ecosystem

mesosphere Region of the Earth's atmosphere above the stratosphere, extending to around 80 km of altitude

metabolic process Process in an organism that supports life

metabolism The chemical reactions that occur in the cells of living things to process molecules and produce energy for the organism

methodical To follow a procedure carefully

microscopic Requiring a microscope or other magnifying device to see – typically less than a millimetre in size

model A representation of a natural phenomenon so that it can be studied and understood

mutualistic A relationship between different species in which all the species benefit

natural material A material found in its raw form in nature

non-linear scale A scale that increases by multiple or exponential amounts

nuclear fusion Process by which the nuclei of two lighter elements come together to form a bigger nucleus, releasing energy and radiation

nutrients Substances that living things use to construct important molecules necessary for survival

observation Something seen; in science, something seen (observed) under controlled conditions

offspring The child or product of reproduction

orbit A circular or elliptical path of one object around another

organism A living thing

oxidation Chemical change in which oxygen reacts and bonds with another substance

ozone layer Region of the Earth's atmosphere in which ultra-violet radiation from the Sun is filtered by the molecule ozone, O_3

palaeontology The study of the prehistoric, particularly of fossils

parasitic A relationship between different species in which one of the species benefits and the other species is harmed

pascal (Pa) Unit of pressure in the SI system of units

photosynthesis The process of converting solar energy into chemical energy

physical change A change in the arrangement of particles without forming a new substance

physical property The measured physical characteristics of a material

plane A flat surface

population The number of individuals in a species living in the same area at the same time

potential energy Stored energy

predation The process of a consumer hunting, killing and eating another animal

predator An animal that hunts, kills and eats other animals (prey)

prediction Statement about the effect expected to be observed in an experiment

pressure The amount of force per unit area exerted on an object

prey An animal that is hunted, killed and eaten by another animal (predator)

primary consumer An animal that eats plants

producers Plants

propagate Transmission of energy through a medium (substance); spreading of something

prototype The first working model of a machine or other design, used to test it

P-wave A vibration in the Earth causing a compression or side-to-side motion

radioactive dating Use of the decline in radioactivity of natural substances to find their age

radioactivity Natural process where materials give out ionising radiation or particles

rational To be logical, basing deductions and conclusions on what is known with some certainty

resilient Able to recover from stress or damage

retrograde rotation Rotation of a planet or satellite in the opposite direction to its orbit around the Sun

saline A salt solution

sandstone Sedimentary rock formed by compressed sand

satellite Any object caught in orbit in the gravitational field of a more massive object

saturated A solution that has absorbed the maximum possible amount of solute

secondary consumer An animal that eats primary consumers

seismometer Device for measuring vibrations in the Earth

sexual reproduction Reproduction that occurs as a result of the combination of male and female genetic information; two 'parent' organisms are involved

Solar System The system of objects whose motion is strongly determined by the gravitational pull of the Sun

solid A physical state of matter where particles are arranged and strongly bonded so that the material is rigid

solubility The extent to which a solute will dissolve in a solvent

solute A substance which can be dissolved in a solvent

solution A solute dissolved in a solvent

solvent A substance (usually a liquid) which can dissolve another substance

space probe An artificial device or robot sent by humans to make measurements and observations in space

species A group of living things that have very similar genetic characteristics and can reproduce to have offspring that are also capable of reproducing

spreadsheet A computer program designed to facilitate calculations

state of matter The physical arrangement of matter as solid, liquid, gas or plasma

stimulus (plural **stimuli)** Something that causes a response in a living thing

stratosphere Region of the Earth's atmosphere above the troposphere, extending to about 50 km of altitude

suspension A mixture of a solid in a liquid that with time separates out on its own

sustainable A process or system that can be maintained and in balance over a long period of time

S-wave A vibration in the Earth causing a sideways or shearing motion

tectonic plate A region of the Earth's crust that is moving, delineated by constructive and destructive boundaries

thermal A rising column of warm air caused by convection

thermal conductor A material that transfers heat efficiently through conduction

thermosphere Region of the Earth's atmosphere with very low density but very high particle energies, extending from the stratosphere out to 500 km or more from the Earth's surface

troposphere Region of the Earth's atmosphere closest to the surface, between 9 km and 17 km in altitude

ultra-violet radiation Energy transferred as a wave with wavelength somewhat shorter than visible violet light

uniform The same throughout

unit of measurement A quantity of measurement, standardized in the metric Système international d'unités or SI units

valid Relevant to the inquiry; reasonable

variable Any quantity that can change or be changed in an experiment

viable Whether or not a process or action is economically worthwhile, i.e. can produce a profit

vibrate To move from back and forth around a fixed point

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p.14 Figure 1.9: Fig 4 from 'IB Middle Years Programme Sciences Guide' (For use from September 2014/January 2015), © International Baccalaureate Organization 2014, reproduced by permission of the publisher; **p.65** Table 3.15: Adapted from www.exploratorium.edu/cooking/bread/activity-yeast.html; **p.144** Table 6.5: One estimate of global water distribution, from Igor Shiklomanov's chapter 'World fresh water resources' in Peter H. Gleick's from *Water in Crisis: A Guide to the World's Fresh Water Resources* (OUP USA, 1993); **p.146** Fig 6.35: Evidence of receding polar caps; data for North Pole ice surface area to 2015 (National Snow and Ice Data Centre, accessed 28/12/15)

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