PEARSON science

A.B.

10

1.1 Structure of DNA

Science understanding

Visual/Spatial Logical/Mathematical

DNA building blocks

The building blocks of the DNA molecule are nucleotides. Each nucleotide has three parts:

- phosphate group
- sugar
- nitrogen-rich base.

1 **Use** these three terms to label the nucleotide shown right.

DNA structure

The nitrogen-rich bases can be one of four types:

- adenine (A)
- thymine (T)
- cytosine (C)
- guanine (G).

In a double-stranded DNA molecule, A and T always form a pair and C and G always form a pair.

2 The sequence of bases below represents a section of a single strand of DNA. **Propose** the base sequence in the complementary strand of DNA.

3 **(a)** **Identify** which of the following figures represents a possible base sequence in a molecule of DNA. ii

(b) **Justify** your decision for each molecule.

(i) Not a possible sequence. In the sixth base pair, G is paired with G instead of C.

(ii) A possible sequence. All base pairs are complementary.

(iii) Not a possible sequence. In the third base pair, A is paired with A instead of T; in the eighth base pair, G is paired with G instead of C.

(iv) Not a possible sequence. In the seventh base pair, T is paired with C instead of A; in the tenth base pair, T is paired with G instead of A.

1.2 Discovery of DNA

Science as a human endeavour

Verbal/Linguistic

Refer to the Science as a Human Endeavour on pages 5–6 of your student book to answer the following questions.

1 (a) **State** when the chemical now known as DNA was first identified.

1869

(b) **Name** the scientist who first identified it.

Johannes Friedrich Miescher

2 **Describe** the contribution that Phoebus Levene made to what was known about DNA.

Levene identified the components of DNA and the arrangement of the sugar, phosphate and base in a nucleotide.

3 **Explain** why Levene did not think that DNA was the chemical that carried the genetic code.

Levene thought that the DNA molecule was too simple to carry the genetic code.

4 **Identify** the scientists who showed Levene's reasoning to be incorrect.

Oswald Avery demonstrated that DNA was the material that contained genetic information.

5 **Identify** the invention that led to the discovery of the structure of DNA.

X-ray crystallography

6 Erwin Chagraff could not explain why the amount of guanine plus adenine was always equal to the amount of thymine plus cytosine in DNA. In your own words, **explain** why this relationship is always found.

Individual Student Response

7 **Construct** a timeline from 1869 to 1965 showing the significant events leading to the scientific understanding of the structure of DNA.

Answers may vary. Timeline should include the following:

- 1869 – DNA isolated by Miescher
- 1900 – Levene identifies the chemical components of DNA
- 1913–1914 – X-ray crystallography invented by the Braggs
- 1940s – Chargaff's research leads to Chargaff's rule
- 1943 – Avery identifies DNA as the molecule carrying the genetic code
- 1951 – Franklin and Wilkins create X-ray crystallograph of the DNA molecule
- 1953 – Watson and Crick determine the structure of DNA
- 1965 – Watson, Crick and Wilkins are awarded the Nobel Prize in Chemistry.

1.3 Mitosis

Science understanding

Visual/Spatial

The diagram represents five stages of mitosis. However, they are not in the correct order.

The following captions A–E are descriptions of the five stages of mitosis shown. The descriptions are not in the correct order.

A The chromatids separate. The spindle fibres contract, pulling the chromosomes to opposite poles of the cell.

B Separate chromosomes become visible. Each chromosome comprises two chromatids.

C In the period between cell divisions, the DNA replicates.

D The nuclear membrane re-forms, enclosing the chromosomes into a new nucleus at each pole. Division of the nucleus is now complete. The cytoplasm then divides, resulting in two identical daughter cells.

E The membrane surrounding the nucleus breaks down. The spindle appears, extending from the poles of the cell to each chromosome. The chromosomes line up across the equator of the cell.

1 (a) In the table below, redraw each stage of the diagram shown to **demonstrate** their correct order.

(b) **Identify** the letter of the correct caption for each stage.

First stage	Second stage	Third stage	Fourth stage	Fifth stage
d	b	a	e	c
Caption: C	Caption: B	Caption: E	Caption: A	Caption: D

1.4 Meiosis

Science understanding

Visual/Spatial

Draw a line to **identify** the diagram of the stage of meiosis that matches each description.

1		a	The nuclear membrane breaks down and pairs of double-stranded chromosomes line up on the equator of the cell with spindle fibres attached.
2		b	The nuclear membranes form and the cytoplasm divides to produce four new cells. Each cell now contains the haploid number of chromosomes. These cells are the gametes.
3		c	In the period between cell divisions, the DNA replicates.
4		d	The spindle contracts, pulling the chromatids apart towards the poles of the cells.
5		e	At the end of the first part of the division, nuclear membranes may re-form. The chromosomes at each pole are enclosed into new nuclei.
6		f	The spindle contracts, drawing one chromosome from each pair to opposite poles of the cell. At this stage, each chromosome is still two chromatids.
7		g	The DNA becomes visible as separate chromosomes each of which comprises two chromatids.
8		h	After the first part of the division, a new spindle forms at right angles to the first. The new spindle attaches to the chromosomes that have lined up on the equator of the cell.

1.5 Punnett squares

Science understanding

Visual/Spatial **Logical/Mathematical**

You may have noticed that some people have long eyelashes and others have short, straight lashes. Having long or short lashes is the phenotype of the person—the way they look. The length of your eyelashes is an inherited trait, with long lashes being dominant to short lashes. The alleles that you have inherited to determine the length of your eyelashes is your genotype.

1 **Use** a Punnett square to **demonstrate** the inheritance of long and short eyelashes. In this example, Ria, the mother, is homozygous for long lashes. Aidan, the father, is homozygous for short lashes.

Use the letter E as the symbol for the dominant allele.

	Genotype	Gametes	
Ria	EE	E	E
Aidan	ee	e	e

Aidan's gametes \ Ria's gametes	E	E
e	Ee	Ee
e	Ee	Ee

(a) Possible genotypes of children: Ee

(b) Possible phenotypes of children: long lashes

2 **Demonstrate** how the characteristics of the offspring would change if the parents were both heterozygous for eyelash length.

	Genotype	Gametes	
Ria	Ee	E	e
Aidan	Ee	E	e

Aidan's gametes \ Ria's gametes	E	e
E	EE	Ee
e	Ee	ee

(a) Possible genotypes of children: 1 EE : 2 Ee : 1 ee

(b) Possible phenotypes of children: 3 long lashes : 1 short lashes

3 In guinea pigs, black coat colour (B) is dominant to white coat colour (b).

(a) **Deduce** the ratio of phenotypes and genotypes of the offspring from a cross between a heterozygous black guinea pig and a white guinea pig.

F_1 genotype: ½ Bb : ½ bb F_1 phenotype: ½ black : ½ white

(b) **Demonstrate** how you worked out the answer below.

Heterozygous black: Bb. Gametes: ½ B + ½ b

Homozygous white: bb. Gametes: all b

	B	b
b	Bb	bb
b	Bb	bb

Pedigree analysis

Science understanding

Visual/Spatial Logical/Mathematical

The inheritance of a characteristic in a family can be demonstrated using a family tree or pedigree. In a pedigree, such as the one shown, symbols are used to identify males and females, and those with or without the characteristic or trait.

The following diagram shows a pedigree for three generations of a family in which the ability to roll the tongue has been recorded. Tongue rolling is a dominant trait.

1 **Deduce** the genotype of each individual in the pedigree and record it in the box provided. Use the letter R to represent the dominant allele. Use a '?' for an unknown allele (for example 'R?').

2 (a) **Deduce** whether the trait shown in the following pedigree is caused by a dominant or a recessive allele.

recessive

(b) **Justify** your response.

The phenotypes of individuals 5 and 6 do not show the trait, but the daughter of 5 and 6 (individual 14) does show the trait. Therefore, 5 and 6 must both carry the allele for the trait. If they carry the allele and it is not their phenotype, then it must be a recessive characteristic.

3 The following family pedigree is for the recessive disease cystic fibrosis.

(a) **Deduce** the genotype of each of the family members and record it in the space provided. Use the letter D to represent the dominant allele.

(b) **Identify** by name the two individuals for whom you could not work out the genotype.

Troy, Tom

(c) **Explain** why you were not able to work out the genotypes for these individuals.

Troy and Tom could have inherited dominant alleles from both their parents and been homozygous for the dominant normal allele. Alternatively, one or both of them may have inherited the recessive allele from either of their parents, in which case they would be heterozygous carriers of the CF allele. They do not have any children, so we do not know which alleles they carry.

1.7 Sex-linked genes

Science understanding

Visual/Spatial Logical/Mathematical

The gene for coat colour in cats is carried on the X-chromosome. There are two alleles—black (B) and orange (O). These two alleles are codominant.

The genotypes X_BX_B and X_BY result in black cats.

The genotypes X_OX_O and X_OY result in orange cats.

The genotype X_BX_O results in a tortoiseshell cat that has black, orange and white patches of fur.

1 **Use** a Punnett square to **determine** the possible genotypes of the offspring resulting from a cross between a black male and an orange female.

	Genotype
Female	X_OX_O
Male	X_BY

Gametes	
X_O	X_O
X_B	Y

	Female gametes	
	X_O	X_O
Male gametes: X_B	X_OX_B	X_OX_B
Male gametes: Y	X_OY	X_OY

2 One of the tortoiseshell cats from the cross in question 1 had kittens—one black female, three tortoiseshell females, one black male and one orange male.

(a) **Deduce** the genotype of the father of the litter.

(b) **Use** a Punnett square to **justify** your answer.

a The father was black (X_BY). If the father was orange (X_OY) instead of black, there could be no black female offspring (X_BX_B) with a tortoiseshell mother (X_OX_B).

b

	Genotype
Tortoiseshell female	X_BX_O
Black male	X_BY

Gametes	
X_B	X_O
X_B	Y

	Female gametes	
	X_B	X_O
Male gametes: X_B	X_BX_B	X_OX_B
Male gametes: Y	X_BY	X_OY

3 **Construct** a pedigree diagram showing the three generations. Use the following symbols when drawing the pedigree.

1.8 Genetically modified food

Science as a human endeavour

Verbal/Linguistic

The Green Revolution of the 1950s increased food production by using new and improved chemicals to control weeds, insect pests and diseases. New varieties of crops and fertilisers also helped to increase food production.

The Gene Revolution of the 21st century uses genetic modification to grow crops that have the potential to produce more food with a higher nutritional value than traditional crops. The Gene Revolution also uses fewer chemicals. Scientists believe that using gene technology they can improve a variety of crops including corn, wheat, rice, canola, chicory, squash, potato, soybean, alfalfa, cotton, banana and tomato.

Below are some of the arguments for and against the use of genetically modified (GM) food.

Arguments for the use of genetically modified crops

- GM crops are potentially more resistant to disease, can grow in less space, can provide greater yield and need less pesticide.
- Current agricultural methods will not be able to grow enough food to feed the 9 billion people predicted to populate the world by 2050. Genetic modification can improve crops more quickly than conventional selective breeding processes.
- By adding 'toughness genes', scientists can make plants more tolerant of frost, drought and salinity (salt level). These genes can be turned 'off' and 'on' in different parts of the plant. Genetic modification is one tool that farmers can use to maintain or increase crop yields as the climate changes.
- GM foods can improve a poor diet by providing nutritionally improved foods. This should have health benefits in both developing countries and developed nations. GM plants can also deliver medicines. For example, golden rice increases the intake of vitamin A, and bananas can carry a vaccine (cure) for the disease hepatitis D.
- Genetic modification may be able to remove allergens from nuts. Eleven different proteins called allergens in peanuts are known to cause allergic reactions. Scientists are developing genetically modified peanuts in which the two strongest allergens have been removed.
- GM organisms and food products are studied and tested more rigorously than conventional foods. There is no substantial evidence to suggest that approved GM foods are more dangerous than normal foods. Because of the amount of testing they undergo, they may actually be safer!
- In Australia, GM foods are regulated, ensuring that only assessed and approved GM foods enter the food supply.

Arguments against genetically modified crops

- Some people say that GM crops are not safe to eat. They feel that there has not been enough evaluation of potential risks and side effects of the changes in the genetic make-up in an organism. They feel there is a chance that new allergens may be created.
- Herbicides are chemicals that are used to control weeds. Some people think that the genes for herbicide resistance may be transferred from the GM crop to weeds in the environment, making it more difficult to control weed species.

- Some people think that antibiotic resistance may develop in humans and farm animals fed on genetically modified foods. This could make antibiotics less effective in treating disease.
- Some food labelling may not be good enough to alert people to GM ingredients in food.

Social and ethical concerns

- Large companies that own the patent (copyright) for the GM plants may be able to monopolise (dominate) the world food market by controlling the distribution of the genetically modified seeds.
- Using genes from animals in food plants may create ethical or religious problems. For example, eating traces of genetic materials from pork in a vegetable or fruit could be a problem for some religious groups or vegetarians.
- Some people believe that genetically modifying plants and animals is 'playing God' and is unnatural. They say that genes from unrelated species should not be mixed.

Labelling genetically modified food

In Australia, GM foods and ingredients must be identified on labels with the words 'genetically modified'. GM foods with altered characteristics such as increased nutrient levels, or that need to be cooked or prepared in a different way, also have to be labelled.

Below are two examples of labels for food products:

1 Ingredients: meat (60%), reconstituted textured soy protein*, water, wheat flour, soy protein*, dehydrated potato, salt, beetroot powder, onion powder, mineral salts (450), black pepper, soy lecithin*.

*Genetically modified

2 Ingredients: wheat flour, water added, yeast, soy flour (genetically modified), vegetable oil, sugar, emulsifiers (471, 472E), preservative (282), enzyme amylase.

If the food is unpackaged (e.g. loose vegetables), then the information must be displayed with them.

Antibiotic or herbicide resistance

When food crops are genetically modified, scientists introduce a marker gene along with the selected gene. Marker genes are often genes for antibiotic- or herbicide-resistance , which allow selection of plants that have successfully taken up the desired gene.

If the antibiotic resistance genes in the GM food were taken up by bacteria in the human gut, this could reduce the effectiveness of antibiotics given to patients to treat infections. For this to happen the marker gene would have to remain intact after digestion and a long chain of events would have to occur before the antibiotic resistance gene became part of the genetic material of the gut bacteria (see Figure 1.8.1). Each step along the pathway may or may not occur, therefore it is very unlikely that antibiotic resistance becomes part of the bacterial genome.

Figure 1.8.1 Pathway 1 is the most likely series of events after a genetically modified tomato (or any other genetically modified food) has been consumed. All the steps in pathway 2 must occur for antibiotic resistance to become part of the bacterial genome.

Many bacteria have naturally occurring antibiotic resistance and these bacteria are in the foods we eat.

1 **Compare** the Green Revolution and the Gene Revolution.
Answers will vary. Both attempt to increase food production. The Green Revolution used chemicals to control weeds, pests and diseases. New crop varieties and fertilisers also helped to increase food production. The Gene Revolution uses genetic modification to grow more productive crops using fewer chemicals.

2 **Discuss** the idea that genetic modification is just an extension of the strategies, such as selective breeding, that farmers have used to modify food crops for centuries.
Ideas to consider include: Selective breeding gradually changes the genetic make-up of organisms. The genes that are selected may occur naturally or may result from exposure to mutagens. Genetic modification changes the genetic make-up faster. The genes added may not naturally occur in that organism.

3 **Discuss** the concept that a vegetarian is eating fish genes when a gene from a fish is inserted into a tomato plant that is then grown from tissue culture.
Ideas to consider include: The DNA in your cells is manufactured from the DNA consumed in your food. A gene derived from fish DNA inserted into a tomato becomes a tomato gene. Many organisms share a substantial number of genes. Is an identical gene from a horse and a human a human gene or a horse gene?

4 **Identify** what you think is the strongest argument for GM foods.

Individual Student Response

5 **Identify** what you think is the strongest argument against GM foods.

Individual Student Response

6 (a) **Decide** whether you support the continued use of GM foods in Australia.

Individual Student Response

(b) **Justify** your decision.

Individual Student Response

1.9 Stem cells

Science as a human endeavour

Verbal/Linguistic

Refer to the Science as a Human Endeavour on pages 30–31 of your student book to answer the following questions.

1 **Explain** the term *pluripotent*.
Cells that are pluripotent are capable of becoming any one of the 220 different cell types found in the human body.

2 **Describe** the events that led to the discovery of adult stem cells.
Human adult stem cells were discovered by scientists experimenting with bone marrow for use in the treatment of leukaemia.

3 **Compare** adult stem cells and embryonic stem cells.
Adult stem cells are only found within organs that require a large number of new cells. Embryonic stem cells are all the cells of the embryo before differentiation. Adult stem cells are specialised and are only able to make certain types of cells. Embryo stem cells are able to make any type of body cell.

4 **Explain** why scientists are excited about induced pluripotent stem cells (iPSCs).
Stem cells have potential to treat and possibly cure diseases such as cancer, diabetes, heart disease and spinal-cord injuries where cells have been damaged. Adult stem cells are not suitable for these treatments. Experimentation with embryonic stem cells is not accepted by some sectors of the community. iPSCs could be as useful as embryonic stem cells but without the ethical problems.

5 **Construct** a flow diagram of the process used to create iPSCs.
Answers may vary. Example:

Genes are introduced into a mouse skin cell, using a virus.
↓
The genes become part of the mouse DNA.
↓
The genes reprogram the skin cell.
↓
The skin cell becomes a pluripotent cell.

6 **Outline** why there is still a lot of research to do before iPSCs are used to treat humans.
iPSCs have sometimes functioned incorrectly because the genes inserted into the cell interfered with the 'on switches' in some of the mouse DNA, so that necessary proteins were not manufactured. Research is necessary to make sure that iPSCs behave in exactly the same way as embryonic stem cells.

7 **Describe** similarities between the diseases that scientists hope to treat using iPSCs.
They are all diseases where cells have been damaged and are not regenerated normally by the body.

1.10 Literacy review

Science understanding

Verbal/Linguistic

Recall your knowledge of genetics and DNA by inserting words from the list to complete the sentences below. Words may be used more than once.

adult stem cells	alleles	complementary base pairs	cytosine	
deoxyribonucleic acid	differentiate	gene splicing	genetically modified	
genotype	homologous	meiosis	mitosis	phenotype
pluripotent	recombinant DNA	replication	thymine	

(a) Deoxyribonucleic acid (DNA) is the complex molecule that carries the genetic code.

(b) The four nitrogen-rich bases pair up as complementary base pairs. Adenine with thymine and guanine with cytosine.

(c) DNA is able to make copies of itself in a process known as replication.

(d) Replication takes place before both types of cell division: meiosis and mitosis.

(e) Mitosis produces two daughter cells that are identical to the parent cell.

(f) Meiosis produces gametes (eggs and sperm) that have half the number of chromosomes of the original cell.

(g) Homologous chromosomes have the same genes for particular characteristics at the same location on the chromosome.

(h) Variations of genes are known as alleles.

(i) The genotype is the actual genetic information carried by an individual. The phenotype is the observable characteristics of the individual.

(j) During the process of growth and maturation, cells differentiate, meaning they become different from each other in structure and function.

(k) When the genetic information contained within the nucleus is changed by inserting new genes, the cell has been genetically modified.

(l) Scientists use gene splicing to remove unwanted genes and add new genes into the DNA of the bacterium. The product is recombinant DNA, which is DNA that has been recombined with other genes.

(m) Adult stem cells are the cells that allow you to regenerate and repair your tissues.

(n) Embryonic stem cells are pluripotent. They are capable of becoming any one of the 220 different cell types found in the human body.

2.1 Identifying fossils

Science inquiry

Visual/Spatial

Each of these photos shows a different fossilised organism.

(a)

(b)

(c)

(d)

(e)

(f)

(g)

(h)

(i)

(j)

1 **Identify** each type of organism that has been fossilised in the photos by using a general name such as 'cat' or 'snake'.

(a) ray (fish) (b) seastar

(c) plant (d) beetle

(e) frog (f) turtle

(g) bird/dinosaur (it is Archaeopteryx) (h) crustacean/lobster etc.

(i) horse (j) dinosaur

2 **Identify** by letter a fossil that is probably a carbon film.

c

3 **Identify** the six vertebrate fossils by writing their letters.

a, e, f, g, i and j

4 **Name** some types of fossils that are not shown in the photos.

There don't appear to be any external moulds, indirect fossils or casts.

5 Fossil j is a replacement fossil in which the bones have turned to silica, whereas fossil d is an original fossil in which the animal has been preserved by falling in a tar pit.

(a) **Explain** some differences in the way fossils j and d were formed.

In fossil j, the chemicals in the bones were replaced slowly by another chemical called silica. In fossil d, at least some of the original chemicals in the beetle's body are still present in the fossil.

(b) **Explain** what information you could get from fossil d about its original body chemicals that you could not get from fossil j.

You could tell what chemicals were in the beetle's body (fossil d) when it was alive, but you could not tell what chemicals were present in fossil j because they have all disappeared.

6 Fossil g is one of the most famous fossils ever found. It belongs to an animal called *Archaeopteryx*. When it was first discovered, palaeontologists thought it was a dinosaur. But along with the bones, something else was fossilised. **Name** and **describe** this other feature you can see in the fossil.

There seem to be imprints of feathers in the rock around the front limbs. Archaeopteryx is now thought to be a genus of theropod dinosaur that is closely related to modern birds.

7 **Explain** what is meant by the *fossil record*.

A list of all the species that have appeared as fossils (including the order in which they appeared).

2.2 Relative dating

Science inquiry

Logical/Mathematical Visual/Spatial

Some geologists were investigating rock strata in a gently sloping river valley. They drilled down into the rocks in four places labelled A to D, as you can see in Figure 2.2.1. This diagram also shows the ground contours in 5-metre intervals. A contour line shows all places that are the same height above sea level. For example, the 300 line shows all places that are 300 metres above sea level.

The rocks from the four sites were carefully studied for index fossils and the type of rock, such as limestone or shale. The palaeontologists found that five index fossils occurred across the four sites. You can see these five index fossils in Figure 2.2.2.

Figure 2.2.1

Figure 2.2.2

1 The different strata found in the four sites are shown on page 27. Cut these out and place them side by side on the blank space on the next page. Arrange A to D from left to right. Do not glue them yet. Move each column up or down until you have lined up the same layers from each site.

To do this task you need to know that:

- the rock layers at any site are numbered from the top layer down
- the same numbers do *not* mean they are the same layers; for example, A1 is not the same as B1
- a layer in a particular site may not have an index fossil present even though it may be the same age as the layer in another site. There is never a guarantee that a layer at a particular site will have fossils in it.

When you are sure that your strata are correct, glue the four columns onto the space below.

2 **Explain** how the contour lines provide extra information to support your arrangement in question 1.

The contours rank the heights of the sites from highest to lowest as D, A, B and C. (The contours are 305 m, 300 m, 295 m and 290 m.) Matching the strata to each other also ranks the sites in the order D, A, B and C.

3 **Name** the process that you carried out in question 1.

Stratigraphy

4 (a) **Identify** the oldest layer (by site letter and layer number) over the four sites.

C3

(b) **Explain** your reasoning.

It is the lowest stratum of the four sites.

5 (a) **Identify** the youngest layer (by site letter and layer number) over the four sites.

D1

(b) **Explain** your reasoning.

It is the highest stratum of the four sites.

6 **Identify** a layer (by site letter and layer number) that may have been expected to have *Dalmanites* fossils in it, but which did not have any fossils.

B3

7 **Identify** two layers the same age as A2.

B1 and D3

2.3 Absolute dating

Science inquiry

Logical/Mathematical Visual/Spatial

In this activity, you will use a graph called a decay curve to find the age of some fossils. A decay curve shows how the level of radioactivity in a rock decreases over time.

Potassium–argon dating

Radioactive potassium-40 breaks down into a gas called argon, which becomes trapped in the rock. The amount of potassium decaying into argon in a certain time can be measured. Then a graph called a decay curve is drawn, which shows how the proportion of the potassium-40 changes over time. The decay curve for potassium-40 is shown below.

To determine the age of a rock, scientists measure the amount of argon in a sample and the amount of potassium-40. Then they calculate the proportion of the original potassium-40 that is left. Use the graph above to answer the following questions.

1 **State** the age of a rock that has half of its original potassium-40 left.

1251 million years old

2 **State** the age of a rock that has three-quarters of its potassium-40 left.

About 625 million years old

3 **State** the number of half-lives and years that would pass before the rock only had one-quarter of its potassium-40 left.

Half-lives 2 Years 2502 million

4 The Earth is estimated to be 4500 million years old. **State** how many half-lives of potassium-40 have occurred during this time.

3 half-lives of potassium-40 (actually about 3.6 half-lives)

2.4 The move to land

Science as a human endeavour

Verbal/Linguistic **Logical/Mathematical**

Scientists have concluded from the fossil record that life began in the sea, and then moved to the land during the Devonian period. The vertebrate fossil record shows at least 10 species of Devonian lobe-finned fish and early amphibians that provide evidence to support this hypothesis. One source of evidence is the limbs, because tetrapods (four-footed land animals such as amphibians, reptiles and mammals) walk on the land supported by the bones in their legs. So if some fish developed into land animals, you would expect to find fish limbs that had similar bones in them to the tetrapods. This is exactly what many of the fossils, such as those in Figure 2.4.1, show, especially in the front limbs.

Figure 2.4.1 The front limbs of some fossil lobe-finned fish and some living species. Common bones are shaded the same.

The humerus, radius and ulna are common limb bones in amphibians, reptiles, birds and mammals. You have these bones in your arm. Lobe-finned fish had bones at the base of their fins. *Latimeria* and *Neoceratodus* (the Australian lungfish) are living species of lobe-finned fish, while the others shown in the diagram are fossils. *Eusthenopteron* was a lobe-finned fish from just before the time when fossils of land animals appear in the fossil record.

Figure 2.4.2 shows six fossil species. *Tiktaalik* and *Panderichthys* were more like fish than amphibians. *Tiktaalik* had a wrist-like structure in its limbs. Scientists interpreted this feature as being able to support the weight of the animal for brief periods. The other four species were more like amphibians than fish, and clearly had fingers and toes. *Acanthostega* had eight digits and strong limbs more like a land animal's leg than a fish fin. However, *Acanthostega*'s bones could not have supported the weight of the animal's body on land for long periods of time. *Tulerpeton*'s limbs were similar to those of *Acanthostega*. *Proterogyrinus* and *Limnoscelis* had limbs that would support them on land for longer periods than earlier amphibians. They may have lived both in water and on land.

Most living amphibians have lungs as adults, but gills as young. The adults can live on land and in water. The fossil species in these diagrams may have also been like this, but because there are no fossilised lungs scientists cannot be sure. Modern living lungfish have a lung, which they can use for breathing, as well as gills. Scientists wondered why lobe-finned fish and early amphibians developed bony fins and limbs, when they were living in water rather than walking on land. One possibility is that these limbs developed in species living in freshwater swamps where there was much vegetation. Bony supports in limbs would have been much better than fins for moving through the vegetation by gripping it and pushing on it. The lobe-finned fish and early amphibians may also have been able to move brief distances over land from pool to pool, dragging themselves using their front limbs.

Figure 2.4.2 Some early lobe-finned fish and amphibians

To be sure about how this change from water to land occurred, more fossils are needed, especially fossils that clearly show the early beginnings of digits (fingers and toes).

1 **Name** the geological period in which the fossil evidence suggests vertebrates moved from the sea to the land.

The Devonian period

2 **Define** what is meant by a *tetrapod*.

Four-footed land animal (reptiles, mammals, amphibians and birds)

3 **Explain** why palaeontologists are especially interested in the limb structure of lobe-finned fish and early amphibians.

The bones of the limbs provide evidence of life moving from the water to the land.

4 **Name** the limb bone that is common to lobe-finned fish and early amphibians.

Humerus

5 **Name** three bones that were found in all early amphibian fossils.

Humerus, radius and ulna

6 **Describe** the advantages that bony limbs probably gave these lobe-finned fish and amphibians.

Their limbs would have been much better than fins at moving through the environment of water that contained a lot of vegetation. They could move by gripping it and pushing on it.

2.5 Dinobirds

Science understanding, Science as a human endeavour

Verbal/Linguistic

Biologists have concluded that birds are related to dinosaurs. The idea was first proposed in the 19th century just after the bird-like fossil skeleton *Archaeopteryx* was discovered. The skeleton showed *Archaeopteryx* to be almost identical to a dinosaur called *Compsognathus*. *Archaeopteryx* had some features unlike those of birds, such as teeth, a long tail with bones in it and claws on its front legs. However, like a bird, *Archaeopteryx* had a 'wishbone' in the chest (necessary for flight) and feathers. The feathers were present as external moulds in the rock surrounding the fossilised bones.

In the 1990s, at Liaoning in China, many fossils of different dinosaurs were discovered that had strange-looking furry material covering parts of the body. The fossils such as the one shown in Figure 2.5.1 came from an area that had regularly been covered by volcanic ash, which preserved the fossils in beautiful detail. This method of preservation also enabled an accurate dating to be made of the age of the fossils. They were 124 million years old.

Figure 2.5.1 A feathered dinosaur from Liaoning, China. The feathers are the dark lines at the back of the dinosaur's limbs.

The furry covering turned out to be preserved body tissue and some of it was original fossils of the animal's body proteins. As more fossils of different species were discovered, it became obvious that these structures were simple feathers. The feathers were of different forms, and some were like modern bird feathers. Chemical tests on fossilised feathers of one dinosaur showed their chemical structure to be like that of modern bird feathers.

The dinosaurs that had feathers were mainly from one group called theropods. Within the theropods, the main feathered dinosaurs belong to the Coelurosaurs. Most Coelurosaurs were bipedal predators (they walked on two legs). They had long tails and their 'arms' had an ulna bone that was curved outwards, just like modern birds. Some fossils show what look like air sacs in their breathing systems, also similar to many modern birds. Coelurosaurs also laid eggs and nested in a similar way to birds. Fossils have been found of adult Coelurosaurs sitting on a nest of eggs.

Today we know that there are more than 20 genera of dinosaurs that had feathers, nearly all of which are theropods. There are so many similarities in the skeletons of theropod dinosaurs and birds that most palaeontologists are convinced that theropods were ancestors of the birds.

The latest find to support this hypothesis is a dinosaur called *Anchiornis*, discovered in 2009. It has been dated at 161 to 151 million years old, from the Jurassic period. This makes it older than *Archaeopteryx*. It was completely covered in feathers, some like those used in flight in modern birds. It also had long feathers on its legs. Although the arms of Anchiornis were quite long, it probably could not fly very well. On current evidence, biologists have concluded that dinosaur feathers were not an adaptation for flight. They think that feathers were for temperature control, and probably helped to keep some dinosaurs warm. It was only millions of years later that feathers enabled descendants of these dinosaurs to fly.

1 **State** what palaeontologists have concluded about birds and dinosaurs.

Birds are related to dinosaurs.

2 **Name** the first dinosaur discovered that had bird-like features.

Archaeopteryx

3 **List** the features of birds that *Archaeopteryx* showed.

Feathers and a 'wishbone' in the chest

4 **Describe** what the Liaoning fossils showed about the feathers of dinosaurs that *Archaeopteryx* fossils did not.

They had preserved body tissue. Their chemical structure was like that of modern bird feathers.

5 **Describe** some features shared by Coelurosaurs and birds.

They were bipedal, had long tails and their 'arms' had an ulna that was curved outwards. They also laid eggs and nested, which is similar to birds.

6 **Explain** the importance of *Anchiornis* fossils.

Anchiornis is the oldest bird-like dinosaur discovered. It was covered in feathers, some of which are similar to those used in flight in modern birds.

7 **State** how feathers may have been an advantage to the early dinosaurs.

Feathers were good for temperature control, and probably helped to keep some dinosaurs warm.

2.6 Constructing dinosaurs

Science inquiry

Visual/Spatial **Bodily/Kinaesthetic**

The diagram on page 27 shows mixed-up bones from some different dinosaurs. Try to **construct** these dinosaur skeletons. Cut out all the bones and arrange them in the space below to show the skeletons as you think they were in these dinosaurs. Move the bones around until you are sure they are correct, then glue them onto the space below.

Tyrannosaurus:
2, 6, 11, 12, 16, 20, 21, 26, 30, 31, 33

Deinonychus:
1, 3, 4, 5, 7, 8, 13, 14, 15, 17, 22, 23

Triceratops:
9, 10, 18, 19, 24, 25, 27, 28, 29, 32, 34

1 **Name** your dinosaurs if you think you know their names.

Tyrannosaurus, Deinonychus, Triceratops

2 **Discuss** what methods you used to decide how the bones fitted together.

Depends on answer. Size of bones should be similar, bones should be similar on both sides of skeleton, bones may look like a skeleton they already know etc.

2.7 Dinosaur story

Science as a human endeavour

Verbal/Linguistic

Refer to the Science as a Human Endeavour on pages 61–62 of your student book to answer the following questions.

1 **Name** another branch of science that uses some of the same techniques as palaeontologists use when they try to determine how a dinosaur appeared while it was alive.

Forensic science

2 **Describe** how palaeontologists could reconstruct a skeleton if the leg bones were missing on one side.

They could copy bones from the other side because the body should be symmetrical.

3 **Explain** two different ways in which scientists reconstructing a dinosaur decide how large its muscles were.

Marks on the bones show where and how large the muscles were. Comparing with living relatives helps.

4 **Explain** how scientists know what colours and textures to give the skin of dinosaurs.

Scientists study the colour patterns of the nearest living relatives. The skin covering (such as feathers or scales) is known for some dinosaurs because of fossils.

5 **Explain** the methods used by scientists to predict how fast dinosaurs moved.

By measuring the distance between footprints and comparing this with body size, scientists can estimate running speed.

6 **Discuss** the evidence that supports the idea that some dinosaurs lived in groups.

Dinosaur tracks are a good guide that many dinosaurs lived in groups. There are some very good fossil sites that show a herd of dinosaurs walking.

7 **Explain** the different ways in which scientists can predict what food particular dinosaurs ate.

Carnivores had many sharp teeth, whereas herbivores generally had flatter teeth to grind plant material. Fossilised dung showed remains of plants and some fossil sites show dinosaurs preying on others.

2.8 Literacy review

Science understanding

Verbal/Linguistic

1 **Use** the clues to **identify** the jumbled words.

Jumbled word	Clue	Answer
sifsol	The preserved evidence in rocks or soils of organisms that were once alive	fossil
teaistologonpal	Scientist who studies prehistoric life	palaeontologist
nixed	Fossil that can be used to compare the relative age of strata in different locations	index
hypastargrit	Comparing strata in different locations to determine their relative ages	stratigraphy
bole dinfen	Fish with bones in their fins similar to land animals. These organisms were important in the move from sea to land	lobe finned
trodpaste	Land animals with four limbs, including amphibians, reptiles, birds and mammals	tetrapos
irunsosad	Land animals in the reptile group called archosaurs but which also had their limbs placed vertically beneath their bodies	dinosaurs
solfis credor	A list showing the classification of all species that have been found as fossils	fossil record
ateliver	Type of dating that compares one fossil with another	relative

2 **Recall** the statement in column 1 that matches the correct term in column 2 by drawing a line between them.

Column 1		Column 2
Chemicals such as proteins that were made by a living thing		Carbon film fossil
An imprint of the outside of the body in rock		Cast
When an organism in rock decomposes and the space in the rock fills with soil that turns to rock		Mould
A scale showing the history of life and geology		Palaeontology
Layers of sedimentary rock or soil		Absolute dating
When a dead body partially decays and leaves a thin black deposit of carbon		Half-life
Way of determining the actual age of rocks and fossils		Strata
The time it takes for half of a radioactive sample to decay		Organic matter
The study of prehistoric life		Geological time

This diagram of rock strata is to be cut out and used for Worksheet 2.2.

This diagram of dinosaur bones is to be cut out and used for Worksheet 2.6.

3.1 Vertebrate limbs

Science inquiry

Logical/Mathematical **Visual/Spatial**

Vertebrate limbs seem to have a basic underlying pattern, which is called the pentadactyl limb. This pattern is as shown in Figure 3.1.1.

Figure 3.1.1 Generalised pentadactyl limb

Some different vertebrate limbs are shown in Figure 3.1.2. These are not drawn to scale.

Figure 3.1.2 Variations of the vertebrate forelimb (front limb) structure

1 (a) **Identify** four limbs from Figure 3.1.2 that are most like the basic pattern of vertebrate limb that is shown in Figure 3.1.1.

Human, rabbit, bat and mole

(b) **Explain** your choice.

They all have five digits that are similar to each other. The whale has five digits, but these have many more bones in them than the digits on the other limbs.

2 (a) **Identify** the two limbs that are least like the basic pattern.

Horse and whale

(b) **Explain** your choice.

The whale has five digits, but three are tiny and two are very large. The horse seems to only have one digit, and seems to have only one 'forearm' bone.

3 **Explain** how the bat, horse and mole limbs are suited to their particular function.

Bat fingers are long to hold the membrane for the wing. The mole hand is short (so it does not get in the way in a burrow) and broad to give it a big surface to shovel dirt. The horse limb is long, thin, light and strong to allow fast running and support body weight

4 (a) **Propose** which animal's limb bone seems to have changed the most from the generalised pentadactyl limb.

The horse or the whale seems to have changed the most.

(b) **Justify** your choice.

The whale digits have more bones in them, although there are five digits. The horse only has one metacarpal and digit.

5 According to scientific studies, bats are the closest of these animals to humans in terms of ancestry, and rabbits are the second closest. Moles, horses and whales are more distant relatives. **Discuss** whether the animals closest to humans have a more similar limb structure.

It seems to support it, although rabbits probably look more like the human limb than the bat does.

3.2 Artificial selection

Science as a human endeavour

Verbal/Linguistic

Refer to the Science as a Human Endeavour on pages 74–75 of your student book to answer the following questions.

1 **Identify** the two problems with early wild lupin types that made them difficult for farmers to use as feed for animals.

A bitter taste and the seed pods shattered and scattered their seeds, so farmers found them difficult to harvest.

2 **Explain** why John Gladstones's first step in his research was to look through fields of lupins.

He was looking for mutants that may not have shattering pods. An inherited feature could then be used to breed.

3 **Explain** what studies of the two mutant lupins discovered by Gladstones showed.

That pod shattering was controlled by two independently inherited recessive genes.

4 (a) **Describe** what Gladstones did with the two mutant plants.

He cross-bred the two mutant plants.

(b) **Explain** why he did this.

To produce offspring with both of the genes for non-shattering to see if completely non-shattering pods would be the result.

5 **Describe** the problem that was still present in the new cross-bred lupin with non-shattering pods.

The cross-bred lupins still had bitter tasting seeds, which animals did not eat.

6 **Explain** Gladstones's procedure to improve the non-shattering bitter-seeded plant for feeding livestock.

He crossed non-shattering pod plants with sweet-seeded plants to combine the two characteristics.

7 **Explain** why this story on plant breeding is relevant to the idea of evolutionary change in a species.

It shows that the characteristics of a species can be changed by selecting which individuals breed.

3.3 Natural selection of snails

Science inquiry

Logical/Mathematical

In the 1950s, two English scientists, Arthur Sheppard and Philip Cain, investigated natural selection of the brown-lipped snail *Cepaea nemoralis* by the song thrush.

The scientists studied two areas—a forest floor and an open grass-covered field. The forest floor was covered in brown, dead leaves and often partly in shadow. The open grassy areas were well lit and a yellowish-green colour. The grassy areas also had a dark and light striped appearance due to the shadows thrown by the blades of grass.

The song thrush preyed on the snails in both areas. The thrush smashed the snail shells open on special rocks, called anvils, which were in the birds' territories. This is shown in Figure 3.3.1. The snails came in two colours—pinkish-brown and yellow—and some were also banded. Two different types are shown in Figure 3.3.2. The bands were black or dark brown.

Figure 3.3.1
A song thrush eating a brown-lipped snail

Figure 3.3.2
The two colours of brown-lipped snail

At Marley Bog, in a grassy field that has a uniform greenish background, 264 out of 560 living snails collected by Sheppard and Cain in a sample were banded. When the anvils in the area were studied, 486 out of 863 dead snails were banded.

1 **Compare** the percentage of banded snails in the living population with the percentage of banded snails killed by the birds.

% banded in living population is (264/560) × 100 = 47.1%

% banded killed by snails = (486/863) × 100 = 56.3%

2 **Explain** how this selection could change the proportion of the banded genes in the population in this area over a long time.

Banded phenotype is being removed at a greater rate from the population than the unbanded. Thus, banded genes are being removed and there will be fewer in the population.

A different study of a beechwood forest floor looked at the effect of seasons on the selection of the snails by the song thrush. In early spring, the beechwood floor is covered in dead, brown leaves. As spring continues, plants sprout and grow, hiding the dead leaves in new green growth. The results obtained in one study are shown in the following table. The last column gives the percentage of the population in early and late spring that had a brown shell. Note that, throughout spring, the percentage of living snails found that had a brown shell was fairly stable.

Season	Number of snails killed yellow shell	Number of snails killed brown shell	Total snails killed in season	Per cent of snails killed that were brown	Per cent of total population alive that were brown
Early spring (brown leaf litter)	15	21	36	58	76
Late spring (green growth)	9	64	73	87	72

3 For early spring and late spring, use the space below to **calculate** the percentage of those snails killed that were brown, and enter this in the table above.

Early spring
21/36 × 100 = 58%
Late spring
64/73 = 87%

4 (a) **Compare** the percentage of brown snails killed in early and late spring.

The % killed that were a brown background colour increased from early to late spring.

(b) **Describe** the process that could have caused the change.

Bird predators could see the brown snails more easily in late spring as the green background developed. Thus brown were selected out.

5 One possibility to explain the data is that the change in the percentage of brown snails killed was due to a chance increase in the proportion of brown snails. Use the data in the last column of the table to **critically evaluate** this proposition.

The % brown alive in the population was very similar in early and late spring. In fact, there was a slightly greater proportion of brown snails present in early spring than in late spring. So it does not seem true that there was a chance increase in the number of brown snails in late spring.

3.4 Combating bacterial resistance

Science as a human endeavour

Logical/Mathematical Verbal/Linguistic

The development of antibiotic resistance in bacteria is a serious problem for human health that is getting worse. The first factor that is contributing to this resistance is that antibiotics are widespread in the environment. Antibiotics are commonly used to treat infectious diseases in animals and so can sometimes be found in soil and water, and are common in hospitals. Antibiotics are also are being found in human foods because some animals are fed antibiotics to protect them from disease and help them grow faster. The widespread use of antibiotics increases the exposure of bacteria to natural selection by antibiotics.

Additional factors that contribute to the development of bacterial resistance include:

- using antibiotics when they are not needed (such as for a common cold)
- using incorrect dosing amounts of antibiotics
- not finishing an entire course of antibiotic tablets.

How bacteria survive antibiotics

The increasing level of bacterial resistance to antibiotics occurs through natural selection, and mutation is part of this process. Mutations in genes have given bacteria the ability to withstand antibiotics, through means such as:

- being able to destroy or inactivate the antibiotic molecules
- altering the bacterial cell wall so the antibiotic molecules cannot attach
- making it harder for antibiotic molecules to pass through, or permeate, the cell membrane
- being able to pump antibiotic molecules out of their cells so they cannot build up.

Bacteria can develop resistance genes through mutation or by gene transfer between bacteria.

Transfer of genes between bacteria

One bacterial cell can transfer genes to another. This gene transfer can even occur between different species of bacteria. Resistant bacteria can pass genetic information to non-resistant bacteria. The resistant bacterial cell forms a tube that joins the two bacterial cells and the resistant DNA passes through the tube to the other bacteria. This process is shown in Figure 3.4.1. Now both bacteria are resistant to a disease that only one of them has been exposed to.

Figure 3.4.1 Gene transfer in bacteria

Many of the genes that give bacteria antibiotic resistance are found on plasmids. Plasmids are circular strands of DNA that are not part of the chromosome of the bacteria. Plasmids exist separately in the cell. It is not known how plasmids came to be in bacteria. Common bacteria now have combinations of genes that enable resistance to multiple antibiotics. This is largely due to plasmid transfer.

1 **List** places where bacteria are being exposed to antibiotics.

On farms, in hospitals, in human foods, in soil and water

2 **List** five factors that contribute to the development of resistance in bacteria.

Widespread antibiotic use, unnecessary antibiotic use in people, incorrect dosing amounts, and failure by the patient to complete the course of pills, gene transfer between bacteria.

3 **Explain** why antibiotics can be found in human foods.

The antibiotics are being fed to farm animals to improve their growth.

4 **Propose** how antibiotics can enter the soil and water on farms.

In animal droppings, uneaten food, dead animals, water runoff, windblown food

5 **List** four characteristics resulting from mutation that have helped bacteria survive antibiotic molecules.

Destroy/inactivate antibiotic molecule, altering cell wall to stop antibiotic attaching, reducing cell membrane permeability, pumping antibiotic out of cell

6 **List** two ways in which bacteria that have never been exposed to an antibiotic could contain genes that give them resistance to antibiotics.

Mutation, gene transfer (plasmids) between bacteria

7 **Explain** why transfer of genes between bacteria has the potential to be a serious health risk.

Common bacteria can gain combinations of genes that enable resistance to multiple antibiotics that they have never been exposed to.

3.5 Comparing eyes

Science understanding

Visual/Spatial Logical/Mathematical

At night it is difficult for humans to see. We have poor night vision. However, many animals such as cats have very good night vision. Most of the features that make night vision possible are found in the eye structure.

Structure of the retina

The retina in many nocturnal animals (animals that are mainly active at night) has two major differences from the human retina.

The first difference is in the proportions of special light receptors called rods and cones. Cones sense colour but they do not detect enough light at night to send messages to the brain. This is why at night you cannot see the colours of objects. However, the retina also contains another type of receptor called a rod. Rods are long, thin cells that work well in dim light.

Most nocturnal animals have a much larger number of rods in their retina than diurnal animals (animals that are active in daylight). So the eyes of nocturnal animals detect a lot more light at night. Many nocturnal animals, especially bats and lizards, have no cones at all.

Figure 3.5.1 The retinas of diurnal and nocturnal animals

The second difference is that the retina of some nocturnal animals has a layer of tissue called the tapetum. You can see its location in Figure 3.5.1. Light that has passed through the layer of rods and cones can strike the shiny surface of the tapetum and reflect back to the rods. This enables the rods to detect light that was missed the first time. This means that more light is collected, making it easier for the animal to see.

Eye size

Some nocturnal mammals, such as tarsiers, do not have a tapetum. The tarsier is a small primate of the Philippines that jumps through the trees, catching insects. It has the largest eyes of any animal in proportion to its body size. Figure 3.5.2 shows the incredible amount of space the eyes take up in the skull. Each eye is larger than the animal's brain.

Figure 3.5.2 The eye and skull of a tarsier

Because tarsier eyes lack a tapetum, natural selection has favoured large eyes that can collect enough light for the rods in its retina to give clear vision. The tarsier eye is not spherical, but has become slightly tube shaped. The front of the eye has become enlarged to enable tarsiers to collect the maximum amount of light. The pupil and lens are huge, much bigger than in human eyes in proportion to the size of the eyeball. If the eye of a tarsier was spherical like a human eye, it would not fit in the tarsier's skull!

1 **Explain** how a tapetum increases the amount of light collected by the rods.

Light reflects off the tapetum back to the rods, enabling them to detect light that was missed the first time. So more light is collected.

2 **Describe** the shape and size of tarsier eyes.

The tarsier eye is 'tube shaped'. The front of the eye has become enlarged. The pupil and lens are huge in proportion to the size of the eyeball.

3 **Justify** the view that the lack of a tapetum in a tarsier is linked to the shape and size of its eye.

Tarsiers are nocturnal and animals of similar size with a tapetum have much smaller eyes. The tarsier's eyes fill a huge proportion of its skull and the shape is different in a way that maximises light gathering.

4 **Construct** a likely series of events, explaining how natural selection may have changed the eye shape of the earliest ancestors of tarsiers as they became nocturnal animals.

The eye shape of tarsier ancestors that began hunting at night (e.g. due to food shortage) varied. All lacked a tapetum, but their eyeball shape was different due to differences in genes controlling it. The animals with a shape that gathered more light could catch more insects and their survival rate was higher. Natural selection resulted in an increasing proportion of genes for eye shape and mutations were selected for.

3.6 Bipedalism

Science inquiry, Science understanding

Logical/Mathematical **Bodily/Kinaesthetic**

The main feature of the sub-tribe of animals to which modern humans belong is that they walk upright on two legs (this is called bipedalism). A summary of the adaptations that humans have for upright walking are:

- an S-shaped spine with lumbar curve and wedge-shaped vertebrae—this bends the vertebral column into an upright position instead of sloping forward as in chimps and gorillas (see diagrams 1 and 2 below)
- a wide, short pelvis—this allows attachment of muscles between the legs and pelvis, which support the upper body as we walk (see diagrams 1 and 5)
- large hip socket and long legs—this enables large legs that support weight (see diagram 3)
- carrying angle of femur—knees bent inwards for more stable standing and walking (see diagrams 3 and 7)
- a femur with enlarged outer condyle—this bears much of the weight in the knee (see diagram 7)
- arches in the foot—this allows for energy absorption and storage while walking
- an enlarged first metatarsal and big toe—this allows for weight support while walking (see diagram 4)
- a central foramen magnum (the place where the spinal cord exits the skull)—this allows the skull to balance on top of the vertebral column without large muscle support (see diagrams 1 and 6).

To understand how humans are adapted for upright walking, try these activities.

1 Stand with your shoulder to the wall. You must be standing straight up with your hands down by your sides. Now slowly lift the leg furthest from the wall sideways away from you.

Describe what happens to you.

The student should fall towards the side where the leg was lifted, i.e. away from the wall.

2 Stand away from the wall and do the same thing with your leg as in Question 1, but try to stay standing. Feel what your head does as you lift your leg.

Compare these two situations and decide why you fell when against the wall, but not when away from the wall.

Your head moves away from the leg you lift because this 'balances' it.

3 In diagram 3, the dotted line shows the line down which body weight can be considered to act (through the centre of gravity). The knees of a human are positioned close to this line. With a chimpanzee, the knees are much further apart and not as close to the line of weight transmission. When a chimp walks, the only way it can get its body weight to be supported by a leg is to tilt its body sideways towards the leg on the ground. Otherwise, the weight would not pass down through the leg on the ground and it would fall. **Compare** this description with the second activity you tried.

It is the same situation as in the second activity.

4 You do not sway as much as chimps when you walk because your knees bring your foot near the centre of your body. Try walking along a straight line and watch where your feet go and you will see how it works.

Describe what you observed about where your feet landed as you walked.

They should have been towards the centre line of the body.

5 **Explain** why the carrying angle of the femur is an adaptation for upright walking.

A carrying angle bends the leg inwards so that the feet are closer to the centre line of the body.

3.7 Literacy review

Science understanding

Verbal/Linguistic

1 **Use** the clues to **identify** the jumbled words.

Jumbled word	Clue	Answer
iloveunot	Change in the characteristics of a species over many generations	evolution
enoerangit	The time between the birth of an individual and when they produce their own offspring	generation
gloohosumo	The term for structures that are controlled by some of the same inherited genes	homologous
toniravia	Differences in characteristics due to differences in particular genes	variation
costibitain	Chemicals made by fungi to defend themselves against bacteria	antibiotics
cispees	The group of organisms that can interbreed to produce fertile offspring under natural conditions	species
pinosticae	The process by which one species splits into two or more separate species	speciation
domhiniae	The family to which humans and the extinct genus *Australopithecus* belong	hominidae
mipresta	The order of animals with 'grasping' hands, nails rather than claws and forward-facing eyes	primates

2 Use the clues to **identify** the words.

Clue	Word
Inherited ability of a species to withstand chemicals such as pesticides	resistance
Fossils that have features of two or more different groups	transitional
Process where an environmental factor acts on a population and results in some organisms having more offspring than others	natural selection
A map of all the places where a species occurs	distribution
The study of the embryos of different species	embryology
Environmental factor that acts on a population during natural selection	selective agent
DNA contained within the cell mitochondria and passed from mother to sons and daughters	mitochondrial
When interbreeding groups are kept apart by some barrier or mechanism	genetic isolation
The genus to which human beings, and several other extinct species, belong	Homo

4.1 Electron configuration and shells

Science understanding

Visual/Spatial Logical/Mathematical

Electrons are arranged around the nucleus of an atom in shells. Electrons fill the shell closest to the nucleus first, then the second, then the third shell and so on. A maximum of 2 electrons can fill the first shell (n=1), 8 the second shell (n=2), 18 the third shell (n=3) and 32 the fourth shell (n=4). The numbers of electrons that a shell can hold is calculated using the formula $2n^2$, where n is the number of the electron shell.

Use this information to **determine** the electron configuration and fill in the diagrams to show how the electrons are arranged in the first 18 elements of the periodic table. Sodium (Na) has already been done for you.

Periodic nature of the elements

Science inquiry

Visual/Spatial Logical/Mathematical

This table shows the melting points, boiling points and atomic radii of the first 20 elements of the periodic table.

Element	Atomic number	Melting point (°C)	Boiling point (°C)	Atomic radius (Å)
Hydrogen, H	1	–259	–253	2.1
Helium, He	2	–272	–269	1.9
Lithium, Li	3	181	1347	1.6
Beryllium, Be	4	1278	2970	1.1
Boron, B	5	2300	2550	1.0
Carbon, C	6	3500	4827	0.9
Nitrogen, N	7	–210	–196	0.9
Oxygen, O	8	–218	–183	0.7
Fluorine, F	9	–220	–188	0.6
Neon, Ne	10	–249	–246	0.5
Sodium, Na	11	98	883	1.9
Magnesium, Mg	12	650	1107	1.6
Aluminium, Al	13	660	2467	1.4
Silicon, Si	14	1410	2355	1.3
Phosphorus, P	15	44	280	1.3
Sulfur, S	16	113	445	1.3
Chlorine, Cl	17	–101	–35	1.0
Argon, Ar	18	–189	–186	0.9
Potassium, K	19	64	774	2.4
Calcium, Ca	20	839	1487	2.0

1 **Use** the vertical axis on the left on the grid on the next page to help you **construct** a line graph showing how boiling point varies with increasing atomic number.

2 On the same grid and still using the vertical axis on the left, **construct** another line graph showing how melting point varies with atomic number.

3 **Use** the vertical axis on the right of the grid to **construct** another line graph showing how the atomic radius varies with atomic number.

4 **Compare** the overall shape of the melting and boiling point graphs.

The melting and boiling point graphs have roughly similar shapes. When one peaks, so does the other. Likewise, when one dips, so does the other. Some points are nearly identical on both graphs.

5 **Describe** the overall trend in the melting point, boiling point and atomic radius as you move across a period of the periodic table.

The melting points and boiling points increase until mid-period when they suddenly drop. The rough pattern is then repeated in the next period, but at lower values. The atomic radii of the atoms decrease regularly across a period. The radii suddenly increase with a new period and then once again decrease.

6 **Describe** what happens to the trend in the melting point, boiling point and atomic radius when you move from one period to another.

The pattern tends to repeat itself when you move from one period to another.

7 **Use** your graph to **determine** what happens to the size of an atom as you move down a group of the periodic table.

Apart from period 1 elements, the atomic radii increase as you move down a group. For example, in group 2, the atomic radii are: Be 1.1, Mg 1.6, Ca 2.0. Similar trends are found in all groups.

8 **Use** the shell structure to **explain** your observations from question 7.

Another shell is added for every period as you move down a group. This will increase the size of the atom and its atomic radius.

The scientists of the periodic table

Science as a human endeavour

Verbal/Linguistic

Many scientists contributed to our understanding of the elements, their properties and the family relationships between them. Each of these scientists therefore directly or indirectly contributed to the development of the periodic table we use today. Some of these scientists were discussed in the Science as a Human Endeavour on pages 115–116 of your student book. This table provides some more information about them.

Scientist	Lived	Scientific contributions	Other facts
Antoine-Laurent de Lavoisier	1743–93	• Identified and named the existing 33 elements • Proved that mass was not destroyed in a reaction • Proved that rusting involved oxygen bonding to iron (increasing its mass) • Proved that combustion needed oxygen	• Nationality: French • Was incredibly wealthy, working as a tax collector • Had 13 000 beakers in his laboratory • Was executed by guillotine after the French Revolution • His statue in Paris was made with a 'spare' head from another statue • Believed that light was an element
John Dalton	1766–1844	• Revived the Ancient Greek idea of atoms • Gave each element a pictorial symbol, which is not used today • Predicted atomic masses • Developed laws explaining how gases behaved • Showed that compounds were made of elements in definite mass proportions	• Nationality: English • Came from a very poor family • Was put in charge of his small school when he was 12 years old • Still taught mathematics at a primary school when elderly and famous
Jons Jacob Berzelius	1779–1848	• Used atomic mass to arrange elements • Gave elements symbols that we still use today based on their Greek or Latin names • Showed that compounds were made of elements in definite mass proportions • Was the first to classify substances as organic (containing C) or inorganic (no C)	• Nationality: Swedish • Used superscript numbers instead of subscript numbers in chemical formulas—wrote water as H^2O instead of H_2O
Johann Dobereiner	1780–1849	• Placed elements into 'triads', families of three	• Nationality: German
John Newlands	1837–98	• Used atomic mass to arrange elements • Noticed every eighth element 'harmonising' (forming patterns) • Placed elements in periods of 7 elements	• Nationality: English • Called his arrangement 'the law of octaves' after musical octaves
Dmitri Ivanovich Mendeleev	1834–1907	• Used atomic mass to arrange elements • Like Newlands, arranged the elements in periods of 7 • Arranged related elements in columns like Dobereiner's triads • Left gaps for undiscovered elements (e.g. Ge)	• Nationality: Russian • Refused to accept that electrons and radiation and radioactivity existed • Has a radioactive element named after him—mendelevium!
Lothar Meyer	1830–95	• Constructed a table very similar to Mendeleev's • Finished his periodic table before Mendeleev • Published his table after Mendeleev	• Nationality: German
William Ramsay	1852–1916	• Discovered the noble, or inert, gases • Set them as a separate group	• Nationality: Scottish • Received the Nobel Prize in Chemistry
Henry Moseley	1887–1915	• Used atomic number and not mass to arrange elements • Produced the periodic table still in use today	• Nationality: English • Was shot through the head and killed in World War I at Gallipoli

Use the information in the table and information from Unit 4.2 in your student book to **identify** the scientist who:

(a) was Scottish William Ramsay

(b) finished his table before Mendeleev did but received less recognition than him

Lothar Meyer

(c) thought the elements harmonised in octaves like music

John Newlands

(d) received a Nobel Prize William Ramsay

(e) wrote water as H^2O Jons Jacob Berzelius

(f) left gaps in his table Dmitri Ivanovich Mendeleev

(g) developed triads Johann Dobereiner

(h) thought that light was an element Antoine-Laurent de Lavoisier

(i) developed gas laws John Dalton

(j) arranged elements according to their atomic number and not mass
Henry Moseley

(k) was shot in the head Henry Moseley

(l) had his head chopped off Antoine-Laurent de Lavoisier

(m) was Russian Dmitri Ivanovich Mendeleev

(n) revived the idea that atoms existed John Dalton

(o) had 13 000 beakers in his laboratory Antoine-Laurent de Lavoisier

(p) was put in charge of his school when he was 12 John Dalton

(q) grouped chemicals as organic or inorganic Jons Jacob Berzelius

(r) gave the elements the symbols we use today Jons Jacob Berzelius

(s) has a radioactive element named after him, even though he didn't believe in radioactivity
Dmitri Ivanovich Mendeleev

(t) proved that iron got heavier when it rusted Antoine-Laurent de Lavoisier

(u) had a statue that should have had its head chopped off because it was the wrong one!
Antoine-Laurent de Lavoisier

4.4 Families of the periodic table

Science understanding

Visual/Spatial

= Noble/Inert gases
= Alkali metals
= Alkaline earths
= Transition elements
= Halogens
= Actinides
= Lanthanides

1 H hydrogen																	2 He helium
3 Li lithium	4 Be beryllium											5 B boron	6 C carbon	7 N nitrogen	8 O oxygen	9 F fluorine	10 Ne neon
11 Na sodium	12 Mg magnesium											13 Al aluminium	14 Si silicon	15 P phosphorus	16 S sulfur	17 Cl chlorine	18 Ar argon
19 K potassium	20 Ca calcium	21 Sc scandium	22 Ti titanium	23 V vanadium	24 Cr chromium	25 Mn manganese	26 Fe iron	27 Co cobalt	28 Ni nickel	29 Cu copper	30 Zn zinc	31 Ga gallium	32 Ge germanium	33 As arsenic	34 Se selenium	35 Br bromine	36 Kr krypton
37 Rb rubidium	38 Sr strontium	39 Y yttrium	40 Zr zirconium	41 Nb niobium	42 Mo molybdenum	43 Tc technetium	44 Ru ruthenium	45 Rh rhodium	46 Pd palladium	47 Ag silver	48 Cd cadmium	49 In indium	50 Sn tin	51 Sb antimony	52 Te tellurium	53 I iodine	54 Xe xenon
55 Cs caesium	56 Ba barium	57–71 lanthanoids	72 Hf hafnium	73 Ta tantalum	74 W tungsten	75 Re rhenium	76 Os osmium	77 Ir iridium	78 Pt platinum	79 Au gold	80 Hg mercury	81 Tl thallium	182 Pb lead	83 Bi bismuth	84 Po polonium	85 At astatine	86 Rn radon
87 Fr franchium	88 Ra radium	89–103 actinoids	104 Rf rutherfordium	105 Db dubnium	106 Sg seaborgium	107 Bh bohrium	108 Hs hassium	109 Mt meitnerium	110 Ds darmstadium	111 Rg roentgenium	112 Cn copernicium	113 Uut ununtrium	114 Uuq ununquadium	115 Uup ununpentium	116 Uuh ununhexium	117 Uus ununseptium	118 Uuo ununoctium

Lanthanides	57 La lanthanum	58 Ce cerium	59 Pr praseodymium	60 Nd neodymium	61 Pm promethium	62 Sm samarium	63 Eu europium	64 Gd gadolinium	65 Tb trebium	66 Dy dysprosium	67 Ho holmium	68 Er erbium	69 Tm thulium	70 Yb ytterbium	71 Lu lutetium
Actinides	89 Ac actinium	90 Th thorium	91 Pa protactinium	92 U uranium	93 Np neptunium	94 Pu plutonium	95 Am americum	96 Cm curium	97 Bk berkelium	98 Cf californium	99 Es einsteinium	100 Fm fremium	101 Md mendelevium	102 No nobelium	103 Lr lawrencium

1 **Use** different colours or shading to **demonstrate** where the following elements are on the simple version of the periodic table shown. Note that some of your coloured or shaded areas might overlap.

(a) noble or inert gases

(b) alkali metals

(c) actinides

(d) transition elements

(e) halogens

(f) alkaline earths

(g) lanthanides

2 Circle an element symbol to **identify** the:

(a) only non-metal that exists as a liquid at normal room temperatures Br

(b) element found in all living (and dead) things, being the basis for most of their molecules C

(c) lightest of all elements H

(d) heaviest of all elements. Uuo

4.5 Organic chemistry

Science inquiry

Verbal/Linguistic Visual/Spatial

A carbon atom has four outer-shell electrons, placing it in group 14 of the periodic table. When it bonds, these four electrons are shared with other carbon atoms or atoms of other non-metals to form four covalent bonds. This ability to form four bonds gives carbon the capacity to form some amazing molecules. Carbon-based molecules range from small groupings of atoms to long chains and rings that have carbon atoms as their backbone. Some are shown in Figure 4.5.1.

Figure 4.5.1

These carbon backbones give the molecules a new classification too. They are classified as *organic*. Organic chemistry is the study of these molecules, their properties and their reactions.

Organic molecules form the basis of life on Earth. They make up the:

- living tissue of animals, such as their skin and organs
- leaves, stems, trunks and roots of plants
- cell walls of bacteria and other micro-organisms.

Carbon becomes part of plants via photosynthesis, in the following reaction:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$
$$\text{carbon dioxide} + \text{water} \rightarrow \text{glucose} + \text{oxygen gas}$$

During photosynthesis plants take in carbon dioxide, break it up and construct a new organic molecule called glucose ($C_6H_{12}O_6$). Some of this is used immediately in respiration to give the energy the plant needs. The respiration reaction is:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$
$$\text{glucose} + \text{oxygen gas} \rightarrow \text{carbon dioxide} + \text{water}$$

The rest of the glucose is stored within the plants in the form of other organic molecules such as sucrose ($C_{12}H_{22}O_{11}$) and starch. Animals eat plants or eat other animals that eat plants. In this way, the carbon stored in the plant becomes part of the animals' structures too.

Dead organisms also contain organic molecules. For this reason, substances such as wood and paper (from plants) and leather (from animals) are organic. Fossil fuels such as oil, petrol, coal and gas are organic too because they are made from the remains of long-dead organisms. Plastics are made from oil and so they are organic as well.

When burnt, wood, paper, plastics and fossil fuels release much of their carbon into the atmosphere as carbon dioxide (CO_2). For example, petrol contains octane (C_8H_{18}). Its combustion reaction is:

$$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$$
$$\text{octane} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water}$$

Carbon dioxide is a known greenhouse gas. Scientists strongly suspect that its increasing concentration in the atmosphere is causing global warming. Average global temperatures are rising as a result, leading to a change in the climate.

1 For the molecules in Figure 4.5.1, **state** how many bonds each carbon atom has.

Each carbon atom is involved in 4 covalent bonds.

2 Vegetables, meat and other products are often described as organic if they are pesticide- and herbicide-free and only fertilised with natural compost and manure. **Propose** reasons why the term *organic* is used this way when it has such a different scientific meaning.

Living things are carbon-based. Hence, the term 'organic' has become associated with 'natural' products. The most 'natural' produce is free from pesticides and herbicides and only fertilised with natural materials.

3 **Propose** what the following scientists study.

(a) organic chemist

Organic chemists study organic compounds that have carbon backbones.

(b) inorganic chemist

Inorganic chemists study inorganic compounds that do not have carbon backbones.

4 **Compare** the structures of hexane and benzene by listing their similarities and differences.

Similarities: Backbone (or ring) or carbon; hydrogen atoms attached to the backbone; covalently bonded.

Differences: Single/double bonds, backbone is linear/ring-shaped

5 **Explain** where the carbon in the following comes from.

(a) plants Carbon dioxide, which is used in photosynthesis

(b) animals Animals eat plants (or eat animals that eat plants), absorbing the carbon-containing glucose or starch that the plants contain.

(c) fossil fuels From original plants, animals and material like algae. The carbon is still there in their remains but is now part of new compounds.

(d) plastics Oil (a fossil fuel). Since fossil fuels contain carbon, the plastics do too.

6 **Explain** why oil, petrol, gas and coal are known as *fossil fuels*.

Fossil fuels are the remains of long-dead plants and animals compressed and changed into new forms.

7 **Explain** why many scientists link climate change to the combustion of fossil fuels.

The combustion of fossil fuels releases carbon dioxide, a greenhouse gas. Scientists believe that increasing carbon dioxide concentrations in the atmosphere is stopping heat radiating back from Earth into space. Hence, global warming and climate change may result.

Hydrocarbons

Science inquiry

Visual/Spatial Logical/Mathematical

There are many thousands of different organic molecules and so to avoid confusion they must be named in a systematic way. The International Union of Pure and Applied Chemistry (IUPAC) has developed precise rules on how to name organic molecules.

The simplest of all organic molecules are the hydrocarbons. As their name implies, these molecules are made of just carbon and hydrogen atoms. Depending on their bonding, hydrocarbons can be classified as alkanes, alkenes or alkynes. The first ten of each family are shown below.

Hydrocarbon family

	Alkanes	Alkenes	Alkynes
General formula	C_nH_{2n+2}	C_nH_{2n}	C_nH_{2n-2}
$n = 1$	Methane, CH_4	None exists	None exists
$n = 2$	Ethane, C_2H_6	Ethene, C_2H_4	Ethyne, C_2H_2
$n = 3$	Propane, C_3H_8	Propene, C_3H_6	Propyne, C_3H_4
$n = 4$	Butane, C_4H_{10}	Butene, C_4H_8	Butyne, C_4H_6
$n = 5$	Pentane, C_5H_{12}	Pentene, C_5H_{10}	Pentyne, C_5H_8
$n = 6$	Hexane, C_6H_{14}	Hexene, C_6H_{12}	Hexyne, C_6H_{10}
$n = 7$	Heptane, C_7H_{16}	Heptene, C_7H_{14}	Heptyne, C_7H_{12}
$n = 8$	Octane, C_8H_{18}	Octene, C_8H_{16}	Octyne, C_8H_{14}
$n = 9$	Nonane, C_9H_{20}	Nonene, C_9H_{18}	Nonyne, C_9H_{16}
$n = 10$	Decane, $C_{10}H_{22}$	Decene, $C_{10}H_{20}$	Decyne, $C_{10}H_{18}$

1 **Name** the organisation that determines the names of different organic compounds.

The International Union of Pure and Applied Chemistry (IUPAC)

2 Different scientists might speak different languages but they all use the same names for chemicals. **Propose** what science would be like if they didn't.

Scientists would not be able to easily share information they find out about the chemicals. Different scientists may claim that they discovered or invented a certain chemical since they would not recognise that it had already been discovered. This might lead to problems with ownership and therefore patents etc. over the chemical.

3 **Identify** which family of hydrocarbons has:

(a) only single bonds alkanes

(b) a double bond alkenes

(c) a triple bond alkynes

4 **Compare** the alkanes, alkenes and alkynes by listing their similarities and differences.

Similarities: All have a backbone of carbon atoms with atoms of hydrogen attached to it, so all are hydrocarbons. All have covalent bonds holding the atoms together. Each new member of each family differs from the previous one by a CH_2 unit.
Differences: Alkanes only have single covalent bonds between their carbon atoms; alkenes have a double bond between two carbon atoms; alkynes have a triple bond between two carbon atoms. Each has a different proportion of carbon and hydrogen atoms.

5 **Use** the general formulas given in the table on the previous page to **calculate** the chemical formulas of the:

(a) 12th member of the alkanes ($n = 12$) $2n + 2 = 2 \times 12 + 2 = 26$. Formula is $C_{12}H_{26}$.

(b) 20th member of the alkenes ($n = 20$) $2n = 2 \times 20 = 40$. Formula is $C_{20}H_{40}$.

(c) 30th member of the alkynes ($n = 30$) $2n - 2 = 2 \times 30 - 2 = 58$. Formula is $C_{30}H_{58}$.

6 To get the next member of the alkane family, you add a grouping of carbon and hydrogen atoms. **Identify** which of the following groupings needs to be added to get the next alkane: CH, CH_2, CH_4 or CH_6.

CH_2

7 **Use** the list in question 6 to **identify** the grouping that needs to be added to get the next:

(a) alkene CH_2

(b) alkyne CH_2

8 **Propose** reasons why there is no alkene or alkyne with just one carbon atom.

Alkenes have a double bond and alkynes have a triple bond between adjacent carbon atoms in the skeleton. Hence, alkenes and alkynes need at least two carbon atoms.

9 **Propose** possible names of the following hydrocarbons.

(a)

Butene (4 carbons and a double bond), formula C_4H_8.

(b)

Hexyne (6 carbons and a triple bond), formula C_6H_{10}.

(c)

Pentane (5 carbons and single bonds), formula C_5H_{12}.

10 **Construct** diagrams of what you think the following molecules would look like.

(a) butene

or

(b) pentane

Note that any branched structure with 5 carbon atoms and single bonds should also be accepted.

(c) octyne

or any branched structure of 8 carbon atoms and one triple bond

4.7 Literacy review

Science understanding

Verbal/Linguistic

Recall your knowledge of the periodic table to complete this crossword puzzle.

Across

2 One of two special blocks of elements at the bottom of the periodic table

3 Extended 3D structure

5 Formed when electrons transfer from one atom to another

9 Exists as sole atoms

10 Number that tells you how many protons are in the nucleus

12 Small group of atoms bonded together

14 Different forms of the same element

16 Bonding based on an electron 'sea'

18 Bonding that involves complete transfer of electrons

19 Vertical columns in the periodic table

20 Group 18 gases

Down

1 Horizontal rows in the periodic table

4 Shows how electrons are arranged in their shells

6 Bonding between non-metallic atoms

7 The lightest of all the elements

8 Non-metals that are in group 17

11 A special block of elements in groups 3–12

13 118 of these are known to exist

15 Metals that are in group 1

17 Core of an atom

Balancing chemical equations

Science understanding

Logical/Mathematical

Atoms are not created or destroyed in a chemical reaction. Therefore, there must be the same number of atoms in the reactants as in the products of a chemical reaction. This law of science is known as the conservation of mass and is shown by the use of balanced chemical equations.

1 **State** the number of each type of atom in the reactants and products of the following equations. **Identify** if the equations are balanced.

(a) $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

propane, oxygen, carbon dioxide, water

Reactants:

Carbon (C) = 3

Hydrogen (H) = 8

Oxygen (O) = 10

Products:

Carbon (C) = 3

Hydrogen (H) = 8

Oxygen (O) = 10

Balanced/Unbalanced: Balanced

(b) $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + H_2O$

sulfuric acid, sodium hydroxide, sodium sulfate, water

Reactants:

Hydrogen (H) = 4

Sulfur (S) = 1

Oxygen (O) = 6

Sodium (Na) = 2

Products:

Hydrogen (H) = 2

Sulfur (S) = 1

Oxygen (O) = 5

Sodium (Na) = 2

Balanced/Unbalanced: Unbalanced

2 **State** whether the following chemical equations are balanced or unbalanced.

(a) $SO_3 + H_2O \rightarrow H_2SO_4$

sulfur trioxide, water, sulfuric acid

Balanced/Unbalanced: Balanced

(b) $HCl + Na \rightarrow NaCl + H_2$

hydrochloric acid, sodium, sodium chloride, hydrogen

Balanced/Unbalanced: Unbalanced

(c) $C_4H_{10} + 6O_2 \rightarrow 4CO_2 + 5H_2O$

butane, oxygen, carbon dioxide, water

Balanced/Unbalanced: Unbalanced

3 Balance the following chemical equations by filling in the blanks.

(a) $3H_2 + N_2 \rightarrow$ 2 NH_3

hydrogen, nitrogen, ammonia

(b) 6 $Mg + P_4 \rightarrow 2Mg_3P_2$

magnesium, phosphorus, magnesium phosphide

(c) 2 $HCl + CuSO_4 \rightarrow H_2SO_4 + CuCl_2$

hydrochloric acid, copper sulfate, sulfuric acid, copper(II) chloride

(d) $2Al +$ 3 $CuO \rightarrow Al_2O_3 +$ 3 Cu

aluminium, copper(II) oxide, aluminium oxide, copper

(e) $3C +$ 4 $HNO_3 \rightarrow$ 3 $CO_2 + 2H_2O +$ 4 NO

carbon, nitric acid, carbon dioxide, water, nitric oxide

5.2 Moving atoms

Science as a human endeavour

Visual/Spatial Logical/Mathematical

Refer to the Science as a Human Endeavour on page 146 of your student book. Today, scientists can use scanning tunnelling microscopes to not only see atoms but also move atoms around. To demonstrate this technique, scientist have made some of the smallest ever pictures. The stick figure shown in Figure 5.2.1 was made by IBM scientists and is actually made up of carbon monoxide molecules.

Figure 5.2.1 Carbon Monoxide Man was made from 28 carbon monoxide molecules arranged by a scanning tunnelling microscope tip on a platinum surface.

1 **Construct** your own atomic scale picture by shading in the position of your iron atoms on the copper surface represented below.

Copper surface

2 Given that the diameter of an iron atom is 0.074 nm (1 nm is one-billionth of a metre), **calculate** the height and width of your atomic scale picture and indicate these values in nanometres on your figure.

Individual Student Response

3 An average human hair has a diameter of approximately 50 micrometres (50 000 nm). **Calculate** how many times your picture could fit across the width of a human hair.

Individual Student Response

5.3 Combustion of magnesium

Science inquiry

Verbal/Linguistic Visual/Spatial Logical/Mathematical

Before chemists understood the atomic theory of matter, people thought that the process of combustion involved the release of a material they called 'phlogiston'. Today, scientists know that phlogiston does not exist. Instead, combustion occurs when chemicals react vigorously with oxygen.

One of the failings of the phlogiston theory was that it could not explain the combustion of metals. The phlogiston theory predicted that everything that combusts should decrease in mass, due to the release of phlogiston. However, when metals burn they increase in mass. This is because they combine with oxygen to form a metal oxide, which is heavier than the metal.

Zac designed an experiment to measure the mass of 1 g of magnesium (Mg) as it burnt in oxygen (O_2) to produce magnesium oxide (MgO). His results are summarised in the tables below.

Time (s)	0	1	2	3	4	5	6	7	8
Mass (g)	1.00	1.04	1.08	1.12	1.16	1.20	1.24	1.29	1.34

Time (s)	9	10	11	12	13	14	15	16
Mass (g)	1.39	1.44	1.49	1.55	1.61	1.67	1.67	1.67

1 Plot the data points on the axes below to **construct** a graph and draw a line of best fit.

2 **Construct** particle model diagrams showing the atoms in the reactants and products before and after the reaction in Zac's experiment.

Before	After

3 **Construct** a word equation and formula equation for the chemical reaction.

Word equation: magnesium + oxygen → magnesium oxide

Formula equation: $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

4 **Describe** how the mass changed as the magnesium burnt in oxygen.

The mass increased steadily for 14 seconds, then remained constant.

5 **(a)** From the graph, **state** how much time the chemical reaction took to complete.

14 seconds

(b) **Explain** your answer.

The reaction took 14 seconds because after this time there was no increase in mass.

6 **(a)** **State** the law of conservation of mass.

The law of conservation of mass states that during a chemical reaction, atoms cannot be created or destroyed.

(b) **Explain** how it applies to this experiment.

This means that the mass of the products (in this case MgO) is the sum of the mass of the reactants (in this case oxygen and magnesium).

7 **Calculate** the mass of oxygen that was used in the reaction: (Final mass of MgO) − (initial mass of Mg)

= 1.67 − 1.00

= 0.67 g

8 The chemical formula for magnesium oxide, MgO, indicates that there are an equal number of magnesium and oxygen atoms in the compound. **Calculate** how much heavier a magnesium atom is compared to an oxygen atom using the equation:

$$\frac{\text{Mass of Mg in MgO}}{\text{Mass of O in MgO}} = \frac{1.00\ g}{0.67\ g} = 1.5 \text{ times heavier}$$

9 Given that the atomic mass of an oxygen atom is 16, **calculate** the atomic mass of a magnesium atom in the space below.

Atomic mass of Mg

= 1.5 × 16 = 24

Classifying chemical reactions

Science understanding

Logical/Mathematical

Scientists classify chemical reactions into different types. The classification might depend on the type of reactants that are involved, the type of products that are produced or how the reactants interact to form the products. This helps scientists to understand more about chemical reactions because by understanding one chemical reaction, they can also understand other chemical reactions of the same type.

Some common types of chemical reactions are:

- *decomposition*—when one reactant breaks apart to form two or more products
- *combination*—when two or more reactants come together to form one product
- *precipitation*—when two aqueous solutions mix to produce a solid
- *metal displacement*—when a more reactive metal donates its electrons to the ions of a less reactive metal in solution. The less reactive metal ion is reduced to form the metal atom. The reactive metal is oxidised to form ions. This is called a redox reaction.

Use these definitions to **classify** each reaction by placing a cross in the relevant column. Remember, a chemical reaction may fit more than one classification.

		Decomposition	Combination	Precipitation	Metal displacement
(a)	$4HNO_3(g) \rightarrow 2H_2O(l) + 4NO_2(g) + O_2(g)$	✗			
(b)	$2AgNO_3(aq) + Na_2S(aq) \rightarrow Ag_2S(s) + 2NaNO_3(aq)$			✗	
(c)	$S(s) + O_2(g) \rightarrow SO_2(g)$		✗		
(d)	$Zn(s) + Cu^{2+}(aq) \rightarrow Cu(s) + Zn^{2+}(aq)$				✗
(e)	$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$		✗		
(f)	$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(g)$		✗		
(g)	$2KI(aq) + Pb(NO_3)_2(aq) \rightarrow 2KNO_3(aq) + PbI(s)$			✗	
(h)	$H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(l)$		✗		
(i)	$Mg(s) + Sn^{2+}(aq) \rightarrow Mg^{2+}(aq) + Sn(s)$				✗
(j)	$BaCl_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaCl(aq)$			✗	
(k)	$H_2O_2(l) \rightarrow H_2(g) + O_2(g)$	✗			
(l)	$Ca(s) + Ni^{2+}(aq) \rightarrow Ca^{2+}(aq) + Ni(s)$				✗

5.5 Extracting gold

Science understanding

Verbal/Linguistic

Australia is one of the world's largest exporters of gold. Before gold can be used, it first needs to be extracted. Extraction of gold from the ore (rock) occurs in the following stages.

1. Crushing

Rock must first be broken into smaller pieces so that it is easier to transport and treat. Large rocks are smashed into smaller pieces by a large swinging weight. The crushed rocks are now about 10 cm in diameter. The crushed rock is then fed onto a flat rubber belt called a conveyor, which transports it away for the next stage of treatment.

2. Grinding

The small rocks are then broken down to a much finer size, smaller than sand grains. This process is called grinding. Grinding is done in large rotating cylinders called ball mills. The ball mills contain many steel balls inside that roll around and grind the rock into a fine powder. Water is added to flush the fine particles out of the mill. The mixture, which is called a slurry, is pumped to the next stage.

3. Froth flotation

The slurry is added to tanks called froth flotation cells, where the slurry is mixed with special chemicals called surfactants and with air. The air that is blown in at the bottom of the cell rises up through the slurry. The surfactants stick to the fine gold and rock particles and to the rising air bubbles. Therefore, the fine particles of gold and rock float in a froth to the top of the cell. The froth is collected from the top of the cell and is then heated to a high temperature in a process called roasting, which removes sulfur impurities from the concentrated ore.

4. Carbon in leach (CIL)

After roasting, the concentrated ore is added to special tanks where it is mixed with a very poisonous chemical called sodium cyanide. The cyanide dissolves the gold out of the rock particles. The cyanide solution is then passed over tanks containing columns of carbon, which have a very large surface area. The gold solution sticks to the carbon surface.

5. Electrowinning and bullion formation

Caustic soda and sometimes cyanide are used to wash the gold solution off the carbon, a process called elution.

The last stage of extraction is called electrowinning. This process uses electrolysis to remove gold from the gold solution. The gold collects as solid metal on steel plates. Once all the gold has been deposited on the plates, the plates are removed from the electrolytic cells. The solid gold is removed from the plates, washed, and then dried in large ovens to form a material called 'cake'.

The cake is heated in a furnace, which melts the gold. The molten gold is later poured into moulds to make gold bars called bullion, which can be 65–80% gold. This bullion may later be refined to an even higher purity.

1 **List** the five main steps in gold extraction from the mined ore.

Crushing, grinding, froth flotation, carbon leaching, electrowinning

2 **Explain** the need for, and process of, grinding.

Grinding turns the rocks into a fine powder. This frees the small gold particles encased in the rock from the dirt and other minerals, allowing them to be separated by the froth flotation.

3 **Describe** the flotation process.

During froth flotation, the powdered rock containing the gold particles is put into a tank of liquid. The liquid contains a chemical similar to detergent, known as a surfactant. Air is then bubbled through the liquid. The fine rock particles and gold particles stick to the surfactant and the bubbles and float to the top. Larger rock particles sink to the bottom.

4 **Describe** the CIL process.

In CIL, the fine rock particles and gold particles are exposed to a solution of sodium cyanide. The cyanide is able to dissolve the gold, leaving the rock particles behind. The gold cyanide solution is then passed over carbon filters, which suck the gold cyanide particles from the solution.

5 **Identify** the two main steps in the gold recovery stage.

Elution (chemically cleaning the carbon columns) and electrowinning (passing an electrical current through the gold solution to recover the gold)

6 **Explain** how gold is removed from the elution solution.

Positive and negative electrodes are placed into the elution solution, which contains dissolved gold, i.e. gold ions. These ions, being metal ions, are positive and so are attracted to the negative electrode where the gold ions are reduced to form gold atoms that deposit on the electrode.

Reaction rate and surface area of reactants

Science inquiry

Verbal/Linguistic Visual/Spatial Logical/Mathematical

Katrina sets up an experiment to compare how crushing a soluble aspirin tablet affects the rate at which it dissolves. She places a whole aspirin tablet and a crushed aspirin tablet in separate bottles of water and measures the volume of carbon dioxide that is produced over 3 minutes. Her results are summarised in the tables below.

Time (min)	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4
Volume of CO_2 Control (L)	0.00	0.08	0.16	0.26	0.36	0.46	0.58	0.70
Volume of CO_2 Crushed (L)	0.00	0.70	1.90	1.90	1.90	1.90	1.90	1.90

Time (min)	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0
Volume of CO_2 Control (L)	0.84	0.98	1.14	1.31	1.49	1.69	1.90	1.90
Volume of CO_2 Crushed (L)	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90

1 **Use** different symbols to **construct** two graphs from the data in Katrina's experiment on the axes below. Remember to provide a key to show which symbol matches which dataset.

2 **Compare** how the whole and crushed aspirin tablets reacted when placed in water.

The crushed tablet reacted very fast for a short amount of time before it stopped producing carbon dioxide gas. The control tablet reacted more slowly over a longer period of time.

3 **Identify** whether the crushed tablet produced more, less or the same amount of carbon dioxide as the whole tablet. They produced the same amount of carbon dioxide.

4 **State** how much carbon dioxide gas was produced by each tablet.

Both tablets produced a total of 1.9 L.

5 From the graph, **calculate** the time it took for the:

(a) whole tablet to react completely 2.8 min

(b) crushed tablet to react completely 0.4 min

6 **Calculate** how much faster the crushed tablet reacted than the whole tablet did in the space below.

2.8 ÷ 0.4 = 7 times faster

7 A crushed tablet would help to get the aspirin into the bloodstream quickly and relieve pain faster. **Propose** a reason why this soluble aspirin tablet is not taken as a powder or in capsules.

If the crushed tablet was introduced into the stomach via a capsule, it would produce a large amount of gas very rapidly and cause the stomach to expand violently.

8 Katrina learns that carbon dioxide is produced when sodium bicarbonate ($NaHCO_3$) and citric acid ($C_6H_8O_7$) in the aspirin tablet react to form sodium citrate ($NaC_6H_7O_7$), carbon dioxide (CO_2) and water (H_2O). **Determine** the balanced formula equation for this reaction.

$NaHCO_3 + C_6H_8O_7 \rightarrow NaC_6H_7O_7 + CO_2 + H_2O$

5.7 Fast and slow reactions

Science understanding

Visual/Spatial

Some chemical reactions are very fast while others proceed very slowly. The speed at which a chemical reaction takes place is known as the rate of reaction.

Identify whether the rate of the chemical reaction is usually increased or decreased in each situation below and describe what is done to control the rate.

(a) Baking a cake	**(b)** Milk going sour
Increased rate ☑ Decreased rate ☐ By: increasing the temperature.	Increased rate ☐ Decreased rate ☑ By: decreasing the temperature.
(c) Food going stale	**(d)** Capsules to relieve a headache
Increased rate ☐ Decreased rate ☑ By: decreasing the temperature or reducing the concentration of oxygen.	Increased rate ☑ Decreased rate ☐ By: increasing the surface area of reactants.
(e) Fruit ripening on the way to market	**(f)** Respiration during a race
Increased rate ☐ Decreased rate ☑ By: decreasing the temperature.	Increased rate ☑ Decreased rate ☐ By: increasing the concentration of reactants, i.e. breathing more deeply and increased heart rate.
(g) Starting a camp fire	**(h)** Converting carbon monoxide from a car exhaust into carbon dioxide
Increased rate ☑ Decreased rate ☐ By: increasing the surface area of reactants. Also increasing the temperature with an initial spark.	Increased rate ☑ Decreased rate ☐ By: using a platinum catalyst.

5.8 Literacy review

Science understanding

Verbal/Linguistic

Recall your knowledge of chemical reactions by inserting words from the list to complete the paragraphs below.

agitation	area	balanced	catalysts	chemical reactions	
combination	concentration	conservation	created	decomposition	
destroyed	electrons	enzymes	explosion	insoluble	oxygen
precipitation	products	rate	reactants	rearranged	redox
rusting	several	single	solutions	temperature	

(a) Substances can be converted into different substances through chemical reactions. The initial substances are known as the reactants and the substances that are produced are known as the products. During a chemical reaction, the atoms in the reactants can be rearranged to form the products. However, the atoms can never be created or destroyed. This is known as the law of conservation of mass. Scientists communicate this by writing balanced chemical equations.

(b) Scientists classify chemical reactions into different types. Four types of chemical reactions are decomposition, combination, precipitation and redox reactions. During a decomposition reaction, a single reactant breaks into several products. During a combination reaction, several reactants combine to form one product. A precipitation reaction occurs when two clear solutions mix to produce an insoluble solid. In a redox reaction, oxygen atoms or electrons are transferred from one substance to another.

(c) The rate of a chemical reaction is how fast the reaction takes place. An example of a fast chemical reaction is an explosion. An example of a slow chemical reaction is rusting. Nature produces its own chemical helpers, called enzymes, to increase the rate of chemical reactions in your body.

(d) The rate of chemical reactions can be controlled by:

- controlling the temperature
- controlling the concentration of the reactants
- controlling the surface area of the reactants
- stirring or mixing, which is also known as agitation
- adding chemical helpers known as catalysts.

6.1 Rates of cycling

Science understanding

Verbal/Linguistic Logical/Mathematical

Human activity changes the carbon cycle

The carbon cycle is the movement of carbon between the Earth's four major carbon stores (or sinks)—the atmosphere, oceans, terrestrial ecosystems (on land) and the Earth's crust. Humans are a natural part of this cycle.

Understanding the way carbon is cycled and recycled in nature is helpful when looking at ways human activities have affected the carbon cycle. A significant increase in the amount of gases containing carbon compounds in the atmosphere is thought to be caused by a range of human activities including:

- burning of fossil fuels (coal, oil and natural gas) as a source of energy for industry, transport and households—releasing CO_2 and CH_4
- deforestation (removal of trees)—releasing CO_2 and reducing CO_2 uptake through photosynthesis
- changed land use (e.g. for agriculture or urban development)—releasing CO_2
- production of cement and lime—releasing CO_2 from very long-term stores
- waste burning and waste decomposition in landfills—releasing CO_2 and CH_4
- livestock and rice cultivation—releasing CO_2 and CH_4

Of these activities, burning fossil fuels is responsible for about three-quarters of the increased carbon emissions.

About half the additional carbon emissions produced by human activity remains in the atmosphere. The rest is taken up by carbon stores in the oceans and terrestrial ecosystems in about equal proportions.

Carbon stores

The Earth's principal stores of carbon in gigatonnes (Gt) are:

- marine sediments and sedimentary rocks (66 000 000–100 000 000)
- deep oceans (40 000)
- surface oceans (1000)
- vegetation (540–610)
- soils and organic matter (1600)
- coal (3000)
- oil and gas (300)
- the atmosphere (750).

How plants affect the carbon cycle

Plants absorb carbon dioxide from the atmosphere through photosynthesis. Some carbon is returned to the atmosphere almost immediately through respiration. The remainder is used to build leaves, wood and roots, and may be stored for hundreds of years either as the tree itself or in wood products made from it, such as the frames of houses or furniture.

Plant litter (fallen leaves and twigs) and roots become part of the soil organic carbon when decomposer organisms break them down. As the litter is broken down, carbon is released into the atmosphere.

Wildfires, controlled burns or using firewood to heat homes rapidly releases stored carbon into the atmosphere. Most of the carbon will be in the form of carbon dioxide. There may also be carbon monoxide and methane, depending on the conditions of burning. Following burning, carbon may also be added to the soil in the form of charcoal, which remains stable for many years.

How animals affect the carbon cycle

When animals consume plants, they convert some of the plant carbon into the tissues of their bodies. Some carbon is returned to the atmosphere through the animals' respiration and some is added to the soil as manure (wastes), which are used by decomposer organisms as a food source.

Agriculture and the carbon cycle

The concentration of carbon dioxide and methane in the atmosphere is influenced by agricultural activities. For example:

- Cultivating soils can increase the rate of breakdown of soil organic matter, resulting in higher emissions of carbon dioxide to the atmosphere.
- Ruminant or cud-chewing animals such as cattle also return some carbon to the atmosphere as methane.
- Land that is in good condition generally stores more carbon in the soil than degraded land with less vegetation cover.

1 **Name** the Earth's four major stores of carbon.
The Earth's four major carbon stores are the atmosphere, oceans, terrestrial ecosystems and the Earth's crust.

2 (a) **Use** the data about carbon stores to **calculate** the total amount of carbon in Earth's principal stores.
Between 100 050 000 and 66 050 000 gigatonnes

(b) **Calculate** the percentage of carbon in each of the stores and record this below.

Carbon store	Percentage
Marine sediments and sedimentary rocks	99.95
Deep oceans	0.04
Surface oceans	0.001
Vegetation	0.006
Soils and organic matter	0.016
Coal	0.03
Oil, gas	0.0003
Atmosphere	0.008

3 (a) **Propose** the store that is most stable. Reserves in sedimentary rocks and fossil fuels

(b) **Explain** why this is the case.
Carbon is trapped in these reserves and has been unavailable to the carbon cycle for millions of years.

(c) **State** the human activities that are releasing carbon from these stores.
Burning of fossil fuels is releasing carbon from those reserves. Using limestone to manufacture cement is also releasing carbon from long-term stores.

4 (a) **Propose** which of the stores would be changing most rapidly.
Vegetation, soils and organic matter and ocean surface would all be changing rapidly.

(b) **Explain** why this is the case.
Photosynthesis and respiration will be taking place and it is these processes that drive carbon through the carbon cycle.

5 In many areas, forests are burnt to clear land for agriculture. **Explain** how this method of deforestation would alter the carbon cycle.
Burning releases the carbon stored in the trees in the form of carbon dioxide. The carbon dioxide is then available for photosynthesis and the carbon is once again part of the carbon cycle.

6 **Name** the human activity that is responsible for the greatest change to the amount of carbon available for cycling.
Burning of fossil fuels is responsible for about three-quarters of the increased carbon emissions.

7 **Explain** how farming cattle to provide meat and milk may change the amount of carbon in the atmosphere.
Cattle return carbon to the atmosphere as methane. Cultivating soils to produce feed for the cattle can increase the rate of breakdown of soil organic matter, resulting in higher emissions of carbon dioxide. Overgrazing may reduce the quality of the soil, which will store less carbon.

8 **Analyse** the information provided on ways in which human activity changes the carbon cycle. On the diagram of the carbon cycle:

(a) colour in red the arrows that represent movements of carbon that would be increased by human activity

(b) colour in blue the arrows that represent movements of carbon that would be reduced

(c) number each coloured arrow and **explain** the human activity involved and how the activity would bring about change.

1 Mining and burning fossil fuels is returning carbon dioxide to the air. This becomes part of the carbon cycle again.
2 Burning trees returns stored carbon dioxide to the air. This becomes part of the carbon cycle again.
3 Reducing vegetation reduces photosynthesis, which takes carbon dioxide out of the atmosphere.
Other parts of the cycle will be changed because of these changes.

El Niño

Science inquiry

Verbal/Linguistic Visual/Spatial

Refer to the information about El Niño on page 187 of your student book and then answer the following questions.

1 Figure 6.2.1 illustrates the normal conditions over the Pacific Ocean when there is neither a La Niña nor an El Niño event. **Describe** what is happening at each position labelled A–E. (Write your description next to the letter on the diagram)

Figure 6.2.1 Normal climatic conditions in Pacific

2 **Compare** the events illustrated in Figure 6.2.1 with what would be happening in a La Niña event.
In a La Niña event the water in central and eastern Pacific Ocean is cooler than normal and the water currents are stronger. The trade winds blow more strongly than usual and Australia experiences more cloud and wetter conditions than normal, especially in the north.

3 Figure 6.2.2 illustrates the conditions during an El Niño event. **Describe** what is happening at each position labelled M–Q.

Cool ocean near Australia

Surface winds blow away from Australia

Warm air rising over Pacific Ocean

Warm current towards Peru (El Niño)

Warm ocean near Peru

Figure 6.2.2 Climatic conditions in an El Niño year

4 **Compare** the events illustrated in Figure 6.2.2 with a 'normal' weather pattern.

During El Niño years, difference in ocean temperature between the western and eastern Pacific is very small as is the air pressure difference. The trade winds weaken and the moist air they carry fails to reach Australia. Cool air descends over Australia, bringing little rainfall.

6.3 Carbon dioxide emissions

Science understanding

Logical/Mathematical

1 **Construct** line graphs on the grid provided below using the data provided in Table 6.3.1.

Table 6.3.1 CO_2 emissions by country

Year	CO_2 emissions (tonnes per head of population)			
	Australia	USA	China	Japan
1960	8.60	16.20	1.20	2.50
1965	10.60	17.70	0.70	3.90
1970	11.40	20.60	0.90	7.10
1975	11.90	19.70	1.20	7.60
1980	14.80	20.30	1.50	7.90
1985	15.20	18.50	1.90	7.50
1990	17.20	19.20	2.10	8.70
1995	17.10	19.50	2.70	9.00
2000	17.10	20.00	2.60	9.50
2005	18.10	19.50	4.30	9.60
2007	18.10	19.50	4.30	9.60

2 **Explain** why CO_2 *emissions per head of population* is used as a measure of energy consumption.

Comparing the emissions per head of population is a way of being able to compare one country with another. It takes the total energy consumption of the country and divides it by the total population so the comparison can be made regardless of the total population of the country.

3 **Compare** the CO_2 emissions (and therefore the energy consumptions) of Australia and the United States of America.

In 2007, the consumption per head of population in Australia was 18.1 tonnes, which is lower than the consumption in the USA, which is 19.5 tonnes. However, the consumption in Australia from 1960 to 2007 more than doubled. In the same time, in the USA consumption has increased by only 20%.

4 **Describe** the trend in energy use in China.

Energy use in China decreased from 1960 to 1965. There was a 286% increase from 1965 to 1995 and then a slight fall in the next five years. From 2000 to 2005, consumption increased by a further 65% and was steady from 2005 to 2007. In total, the increase from 1965 to 2007 is 514%.

5 **Compare** the data for emissions from the United States of America with the data for the other three countries.

Emissions in the USA increased until 1970, then stabilised to some extent before falling. They have now stabilised at a rate lower than 1970 emissions. The other three countries all increased emissions from late 1960 until 2007.

6 Japan is often portrayed as a country with a large number of people, all using the latest electronic gadgets.

(a) **Compare** this image with the energy consumption illustrated by your graph.

Japan has half the energy consumption per head of population when compared to Australia.

(b) **Propose** reasons for any differences identified in the comparison.

A few people may have a lot of gadgets and use significant amounts of electricity, but a large number of people do not have access to the technology. Therefore, on balance the consumption is lower. Possibly the gadgets do not actually consume much electricity. Electricity used in manufacturing and other industries is accounted for in the per capita data. There could be less industry in Japan, or less energy is consumed by the industry. This could be due to the nature of the industry or that it is more energy efficient.

6.4 Ozone

Science as a human endeavour

Verbal/Linguistic

Refer to the Science as a Human Endeavour on page 199 of your student book to answer the following questions.

1 **Explain** what ozone is.

Ozone is a naturally occurring molecule made up of three atoms of oxygen (O_3).

2 **Describe** the importance of ozone to living things on Earth.

Ozone absorbs ultraviolet (UV) radiation, which is emitted by the Sun. Too much exposure to UV radiation is a cause of skin cancers and eye disease.

3 **Name** the naturally occurring chemicals that can damage the ozone layer.

Naturally occurring molecules that can break down ozone are chlorine (Cl), bromine (Br), nitric oxide (NO) and nitrous oxide (N_2O).

4 **Name** the manufactured chemicals that can destroy the ozone layer.

Chlorofluorocarbons (CFCs) and halons are manufactured chemicals that can destroy ozone.

5 **Explain** what the Montreal Protocol is and why it is considered a very significant agreement. The Montreal Protocol is a treaty that was signed in 1987 by 196 countries. This treaty was an agreement to stop production of CFCs and thereby protect the ozone layer. The treaty demonstrated the contribution science can make to environmental protection agreements.

6 **Describe** the natural annual cycle of change in the ozone layer.

Over Antarctica the values are lowest during September to October when daylight returns after winter. In November prevailing winds carry ozone-rich air from other regions and replenish ozone levels over Antarctica but leave lower ozone levels over Australia and New Zealand.

7 **Explain** what is meant by a *hole* in the ozone layer.

A hole occurs in the ozone when measurements show a value of less than 220 DU.

8 Is *layer* a good explanation of the distribution of ozone in the atmosphere? **Explain** your answer.

Layer is not a good description of ozone distribution. It is not concentrated in a layer where only ozone exists. It is dispersed through out the atmosphere. In some areas the concentration is greater than others.

Science as a human endeavour

Visual/Spatial **Logical/Mathematical**

There is discussion in the media, in parliament and in scientific circles about the effect of human activities on the world climate. Climate is not static. World climate has changed in the past and will continue to change.

Scientists cannot know what the world climate is going to be like in the future, nor can they know for certain what the effect of human activities will be on future change. However, they can use their knowledge to construct models of what they think will happen. These models can help governments plan for the future.

Computer models of climate use quantitative data relating to interactions between the atmosphere, oceans, land surface and ice. Models are used to study ways present climates change as well as to make projections of future climate.

All climate models take into account the balance between the energy entering the Earth's atmosphere and the outgoing energy. If these values are not balanced, there will be a change in average world temperature.

The most discussed models of recent years are those projecting possible changes to average world temperatures caused by changes to the atmosphere. The models predict the effects of increased amounts of greenhouse gases in the atmosphere. All the models project an upward trend in temperature. However, not all models predict the same amount of change.

Models can take into account different levels of greenhouse gas emissions.

1 **Use** the following three maps 1–3 to **demonstrate** different projected futures for Australia based on low emissions, medium emissions and continued high levels of greenhouse gas emissions.

Use the key to decide on colours for each of the temperature increases A–E.

Colour the maps to show the projected change in average temperature from 1990 to 2050.

Map 1 Low emissions

Map 2 Medium emissions

Map 3 High emissions

2 **Propose** reasons for using different levels of greenhouse gas emissions in the models for climate change.

Scientists cannot know exactly what emissions there will be in the future. They are making hypotheses based on current data and ideas of what will happen in the future. Different groups of scientists will interpret the information differently.

There are many different climate models created by individuals or groups. The people who construct the model emphasise different aspects of the data depending on how important they think it is. The result is a range of scenarios for the future. Most of the models have similar projections but there are some that are different.

The following three maps (maps 4–6) use medium levels of emissions of greenhouse gases to predict the percentage change in rainfall from 1990 to 2050. Map 5 represents the mid-point of the model results. Maps 4 and 6 represent the extremes of low and high percentage change in rainfall predicted by different models.

3 **Use** these three maps 4–6 to **demonstrate** how projected changes in average rainfall vary according to different models. Use the key to decide on colours for each of the percentage changes in rainfall A–J.

Colour the maps to show the projected change in average rainfall from 1990 to 2050.

Map 4

Map 5

Map 6

4 **Propose** reasons why the different models produce widely different projected changes to rainfall.

Modern humans have not previously experienced global warming. Data on Australia's climate has been collected for only 200 years. This episode of climate change began thousands of years ago. Scientists do not fully understand the interactions of ocean currents and winds that cause world weather. Therefore, accurate predictions of the effects of global warming on rainfall are difficult.

5 (a) **Compare** the three maps of rainfall projections.

Figure 6.5.2a suggests an overall and significant decrease in rainfall. Figure 6.5.2b suggests a decrease of 5–10% in about half the country with little change in most of the remainder. Figure 6.5.2c suggests that the whole of the country can expect increased rainfall.

(b) **Discuss** problems governments could face when trying to plan future strategies when presented with such different projections.

Using one scenario the plans would deal with severe water shortages necessitating changes in agriculture and in water storage for domestic and industry use. At the other extreme there could be adequate water over the whole country with the potential for flooding in many areas. With significantly increased rainfall there could be a need to change agricultural crops and farming methods.

6 Mark where you live on the maps. **Identify** the projected change in temperature for low, medium and high levels of greenhouse gas emission.

Low _____ Individual Student Response _____ Medium _____ Individual Student Response _____

High _____

7 Using map 5, **identify** the projected percentage change in rainfall for your area.

_____

8 **Construct** a scenario (situation) of how you think the changes in temperature and rainfall would affect life in your area.

_____

_____ Individual Student Response _____

_____

6.6 Sea level changes

Science inquiry

Visual/Spatial Logical/Mathematical

Figure 6.6.1 illustrates changes in sea level for the last 450 000 years.

Figure 6.6.1

1 **Analyse** the data, then mark on the graph times when ice ages occurred in the last 400 000 years.

2 **Explain** why you chose to mark those times.

Those are the times when the sea level was lowest. In ice ages the water is trapped in ice and sea levels fall.

3 **Identify** when the latest rise in sea level started to occur.

About 20 000 years ago

4 (a) **Compare** Figures 6.6.1 and 6.6.2. Both show changes in sea level.

Figure 6.6.2 shows the changes in sea level over a much longer period of time from the present day to 542 million years ago. Figure 6.6.1 shows the changes in only the last 450 000 years.

Figure 6.6.2 Global changes in sea level

(b) **Explain** why the curves on the two graphs are so different.

The scales are very different and Figure 6.6.1 is able to show smaller changes.

5 **Propose** what you would say to someone who suggests that the sea levels we are experiencing are among the highest ever.

Their suggestion is incorrect. Sea levels 450 million years ago were 400 metres higher on average than today's levels.

6 Figure 6.6.2 has two separate curves both representing the same thing but using data from different sources. **Propose** reasons for scientists reaching different conclusions about sea levels in the past.

Sea levels in the past are derived from indirect information such as the placement of sedimentary rocks and the fossils found in them. Scientists interpret the information differently and reach different conclusions.

7 Figure 6.6.3 is also a graph of change in sea level. From the shape of the graph, what would you **conclude** about the changes occurring?

There have been significant fluctuations in sea level since 1984.

Figure 6.6.3 Changes in sea level for the past 12 years

8 **Explain** how the scale on the graph in Figure 6.6.3 has been used in a way that could make people believe that a fast and large rise in sea level is occurring.

The scale on the vertical axis is in millimetres whereas the other graphs have shown sea level rises in metres.

9 **Calculate** the rise in sea level in the 10 years before 2006.

About 30 mm

10 **Calculate** the rise in sea level in the 20 000 years since the last ice age.

About 120 metres

6.7 Impact of rising sea level

Science inquiry

Visual/Spatial

This is a map of a prosperous coastal town. Dairy farming and tourism are the major industries of the town, with large butter and cheese factories in the industrial area. Beef cattle are also important but there is no meat processing in the area. The cattle have to be shipped by road or rail to major centres north of the city.

Propose impacts on this city if the sea level rose by:

(a) 1 metre

Stretches of railway will be under water. The hotel strip and resort would be flooded and parts of the industrial area on the north bank of the river. This would impact on the movement of materials into and out of the city and the tourism industry. Employment would also be affected. Crops and dairy farming would be affected too.

(b) 2 metres

All of the hotel area and the resort would be under water. Residential areas would be threatened or inundated. Therefore more people would lose their jobs and their homes. The railway would be cut in more places. Some coastal roads would be cut and parts of the airport would be inundated, restricting access to the city. About one-third of the industrial area would be under water. So, more jobs would be lost.

(c) 6 metres

The city will be completely under water along with some of the farming land.

6.8 Australian Alps and climate change

Science understanding

Verbal/Linguistic

Australian alpine areas cover less than 0.15% of the continent. Figure 6.8.1 shows their distribution through southern New South Wales, eastern Victoria and central western Tasmania. During the winter alpine areas are the coldest environment in Australia.

In the highest parts of the Australian Alps around Mt Kosciuszko (2228 metres), the average temperature of the warmest month is less than 10°C and snow lies there for about 120 days each year. It is too cold there for trees to grow. At these low temperatures and with snow covering their leaves, plants cannot photosynthesise enough carbon to produce woody growth.

Alpine vegetation consists of herbfields, grasslands and heath. The structure of these communities is similar throughout Australia, but the key species differ slightly in Victoria, New South Wales and Tasmania.

Figure 6.8.1 The alpine areas of Australia

Alpine plants

Most of the plants of the Alps belong to genera growing in other areas of Australia. However, the alpine species have evolved special characteristics in response to the harsh environment. The Kosciuszko alpine area is home to 21 species of plants that live nowhere else in the world.

The uniqueness of the alpine and subalpine vegetation of Kosciuszko National Park is recognised by the United Nations Educational Scientific and Cultural Organisation (UNESCO) as a World Biosphere Reserve. It is one of only 300 Biosphere Reserves listed worldwide.

Unique animals

The unique vegetation creates unique animal habitats and some animals can only live in the Australian Alps.

The mountain pygmy possum (*Burramys parvus*) (Figure 6.8.2) is the only marsupial that hibernates properly over the winter. Other marsupials may sleep and be inactive but they don't lower their body temperature to nearly zero and stop their metabolism, the signs of full hibernation. Fossil records show that in the past when Australia's climate was cooler, the mountain pygmy possum had a much greater range. It is now restricted to living in the mountains above 1400 metres. The possum shares these high altitudes with four other mammals including the broad-toothed rat.

The broad-toothed rat (*Mastacomys fuscus*) remains active under the snow during winter. It feeds on grass, eating 50–70% of its body weight in grass each day. It also sleeps in nests of shredded grass.

An amphibian found only in the New South Wales and ACT Alps is the black-and-yellow-striped corroboree frog (*Pseudophryne corroboree*) (Figure 6.8.3). It is only 3 cm long and hibernates under the snow in winter. It lays its eggs in a burrow in sphagnum moss.

Figure 6.8.2 The mountain pygmy possum feeds on stored seeds when it comes out of hibernation and before migrating Bogong moths arrive. The possum then feeds on the moths, building up a fat store that lasts it through hibernation.

Figure 6.8.3 The corroboree frog has black and yellow strips. It is well camouflaged in the sphagnum moss where it lays its eggs.

Climate change

Recent modelling of climate change predicts that the average temperature of the warmest month in the Australian Alps will be greater than 10°C. This means that trees will be able to expand up into the area now occupied by alpine vegetation. Whether trees expand their range into an area depends on dispersal of the seeds to these new areas, and suitable growing conditions that allow the seedlings to grow and eventually produce seeds themselves.

Even where trees do not expand their range, woody shrubs will move in. The leaves of these shrubs will shade the herbs and grasses of the alpine communities and prevent their growth. The result will be a loss in biodiversity.

Changes in the Australian Alps have already been recorded. Over the last 30 years, as temperatures have warmed slightly, kangaroos, hares and wild horses are being found in larger numbers at high altitudes. These animals graze on the fragile alpine vegetation, putting pressure on it. Seven out of 11 species of migratory birds that fly to the Alps annually are arriving earlier. Foxes are moving uphill into the Alps. Bogong moths are arriving later, forcing the mountain pygmy possums to travel more widely to find food. This increases the opportunities for foxes to prey on the already endangered possums. Foxes also eat Bogong moths. Now that the foxes and possums live in the same area, they are in direct competition for the moths as a food source.

1 There are areas at the top of high mountains where no trees grow. **Explain** why trees are not found at these high altitudes.

The low temperatures and snow cover in winter do not allow plants to photosynthesise enough carbon to produce woody growth.

2 **Propose** what changes could occur to these areas as the world temperature increases.

The average temperature could increase above 10°C for the warmer months. So snow would not lie as thickly or for as long. Woody plants could flourish at higher altitudes and woody shrubs or trees could replace the alpine vegetation on the tops of the mountains. A change in the vegetation would mean a change in the animals that live there.

3 **Deduce** the effect on the broad-toothed rat if there was a reduction in the amount of grassland in the Alps.

The broad-toothed rat eats 50–70% of its body weight in grass each day. They sleep in nests of shredded grass. If grassland was reduced, then the rat would have reduced resources to use for food and shelter. The number of rats the grass could support would be reduced and the population would decrease.

4 There are many unique plant species in the Mt Kosciusko National Park. **Propose** what would happen to them as the climate changes.

The unique species would be greatly reduced in number as their habitat decreased. Since there is nowhere for them to go to, they would eventually become extinct and the biodiversity of the area would decrease.

5 (a) **Identify** the effect on the mountain pygmy possum of climate change in the past.

Increasing temperatures in the past reduced its range. It is now restricted to living in the mountains above 1400 metres.

(b) **Propose** the effect on this animal of current and future climate change.

The range will be further reduced and the species could become extinct. The possum will also face higher levels of predation as carnivores such as the fox come into the area. There may be less seed available for food as grazing animals move in. There will be increased competition from foxes for the possum's other food source—Bogong moths.

6 **Explain** how increasing temperatures could cause a reduction in biodiversity worldwide.

Reduction of habitat and increased predation could cause many of the species unique to alpine areas to become extinct. This loss of species reduces the biodiversity of the area and of the Earth as a whole.

6.9 Literacy review

Science understanding

Verbal/Linguistic

Recall your knowledge of sustainability by writing the term described by each of the following definitions in the correct place in the grid. If all the terms are correct, then the highlighted letters should spell a word relevant to this chapter.

(a) The gas that is fixed in the root nodules of leguminous plants

(b) Units used to measure the thickness of the ozone layer

(c) The land masses on Earth

(d) _____ gases trap heat close to the Earth's surface

(e) The word representing the 'S' in SOI—an indication of the difference in air pressure between Tahiti and Darwin

(f) Circular patterns shown by the ocean currents in the major ocean basins

(g) Fuels containing the carbon of plants and animals that died and were preserved millions of years ago

(h) Areas on Earth where the temperature in layers of soil or rock beneath the surface never rises above freezing point

(i) The process by which carbon is recycled through the soil, through living things and the atmosphere

(j) All living things on Earth

(k) An extreme of the southern oscillation that causes significant rainfall in parts of Australia.

(l) The long-term averages of weather conditions

(m) Term used to describe ecosystems that are diverse and provide for the needs of the organisms that live there

					(a)	N	I	T	R	O	G	E	N	
	(b)	D	O	B	S	O	N	U	N	I	T	S		
				(c)	L	I	T	H	O	S	P	H	E	R	E
			(d)	G	R	E	E	N	H	O	U	S	E	
(e)	S	O	U	T	H	E	R	N						
					(f)	G	Y	R	E	S				
	(g)	F	O	S	S	I	L	F	U	E	L	S		
		(h)	P	E	R	M	A	F	R	O	S	T		
(i)	C	A	R	B	O	N	C	Y	C	L	E			
					(j)	B	I	O	S	P	H	E	R	E
					(k)	L	A	N	I	N	A			
					(l)	C	L	I	M	A	T	E		
				(m)	S	U	S	T	A	I	N	A	B	L	E

Write the word that you have created, along with its definition.

Interglacials—periods between glaciations

Naming stars

Science understanding

Verbal/Linguistic Logical/Mathematical

Only a few stars are well known enough to have their own names. Most stars are named according to the constellation in which they appear.

Figure 7.1.1 shows the stars of the Southern Cross. In astronomy, the Southern Cross is known as Crux (Latin for cross). The brightest star is the one at the bottom of the cross; it is called α-Crucis. The dimmest is called ε-Crucis because it is fifth brightest. The stars of the Southern Cross are marked in Figure 7.1.1.

Figure 7.1.1

The Pointers (α-Centauri and β-Centauri) and the Southern Cross (Crux)

Within a constellation, each star is generally named according to its apparent magnitude (how bright it appears from Earth). The brightest star in a constellation is always designated alpha (α), the first letter of the Greek alphabet (shown in Table 7.1.1). The other stars in the constellation are then named beta (β), gamma (γ), delta (δ) and so on in order of decreasing apparent brightness. For example, α-Centauri (or Alpha Centauri) is well known to Australians as one of the Pointers to the Southern Cross. The astronomical name of Alpha Centauri comes from the fact that it is the brightest star in the constellation Centaurus. The other Pointer is called β-Centauri because it is the next brightest star in that constellation. Notice that the name of the constellation is often slightly modified when used to name a star. Instead of Centaurus, the stars are known as Centauri. Similarly, Crux (for Southern Cross) is modified to Crucis.

This system of naming stars according to their constellation and brightness was invented by the German scientist Johann Bayer in the 17th century and is known as the Bayer designation (system).

There are some exceptions to the rule that the brightest star is given the first letter of the Greek alphabet (see Table 7.1.1). Where two stars are similar in brightness, the one that rises in the east first is named first. For example, Castor and Pollux are the two brightest stars in the constellation Gemini. They are of almost equal brightness, but Pollux is the brighter of the two. For this reason, Pollux would normally be designated as Alpha Geminorum. However, Pollux is instead designated as Beta Geminorum because it rises after Castor. This slightly confusing system was developed because in the 17th century astronomers did not have instruments that could allow them to determine the exact brightness of stars.

1 The two brightest stars in the constellation Lyra are commonly known as Vega and Sheliak. Vega is also known as α-Lyrae and Sheliak is known as β-Lyrae.

(a) **Predict** which star will be brighter when viewed from Earth.

Vega

(b) **Explain** your answer.

It is designated α.

2 The brightest two stars in the constellation Cygnus (the Swan) are called Deneb (brightest) and Albireo (second brightest). **Use** the Bayer system for naming stars in a constellation to **identify** which one would be called Alpha Cygni and which would be Beta Cygni.

Deneb would be Alpha Cygni and Albireo would be Beta Cygni.

3 **Use** the Bayer system to reorder the following list of stars in order of decreasing brightness from 1 to 7, where 1 is the brightest and 7 is the least bright.

Common name	Bayer designation	Order of decreasing brightness
Alnilam	ε-Orionis	5
Alnitak	ζ-Orionis	6
Bellatrix	γ-Orionis	3
Betelgeuse	α-Orionis	1
Mintaka	δ-Orionis	4
Rigel	β-Orionis	2
Saiph	κ-Orionis	7

Table 7.1.1 Letters of the Greek alphabet

Letter (lower case)	Name
α	Alpha
β	Beta
γ	Gamma
δ	Delta
ε	Epsilon
ζ	Zeta
η	Eta
θ	Theta
ι	Iota
κ	Kappa
λ	Lambda
μ	Mu
ν	Nu
ξ	Xi
ο	Omicron
π	Pi
ρ	Rho
σ	Sigma
τ	Tau
υ	Upsilon
φ	Phi
χ	Chi
ψ	Psi
ω	Omega

4 In the TV show *Futurama*, a group of aliens come from a planet called Omicron Persei 8. This is the eighth planet orbiting a star in the constellation Perseus.

(a) **Use** the Bayer system to **calculate** how many stars in this constellation must appear brighter than Omicron Persei when observed from Earth.

14, since omicron is the 15th letter of the Greek alphabet.

(b) **Explain** why it is unlikely that the aliens from this planet would call their planet's sun Omicron Persei.

The constellation Perseus could not be seen from this planet.

It would be the brightest star in their sky.

The Hertzsprung–Russell diagram

Science inquiry

Visual/spatial **Logical/mathematical**

The Hertzprung–Russell (or H-R) diagram plots the temperature of a star on the horizontal axis of the chart and absolute magnitude (brightness) on the vertical axis. The table gives values for over 50 stars. Our Sun's values are shown in *italics*.

Star	Temperature (K)	Absolute magnitude	Star	Temperature (K)	Absolute magnitude
40 Eridani A	4900	6.0	Dubhe	4900	0.2
40 Eridani B	10 000	11.1	Elnath	12 400	–1.6
61 Cygni A	4130	7.6	Epsilon Eridani	4590	6.1
61 Cygni B	3870	8.4	Epsilon Indi	4130	7.0
70 Ophiuchi A	4950	5.8	Fomalhaut	9060	2.0
70 Ophiuchi B	3870	7.5	Gacrux	3750	–0.5
Achemar	20 500	–2.4	Hadar	25 500	–5.3
Acrux	28 000	–4.0	Kaus Australis	11 000	–0.3
Adhara	23 000	–5.2	Menkalinan	9340	0.6
Al Na'ir	15 550	–1.1	Miaplacidus	9300	–0.6
Aldebaran	4130	–0.8	Mirfak	7700	–4.6
Alhena	9900	0.0	Mirzam	25 500	–4.8
Alioth	9900	0.4	Peacock	20 500	–2.3
Alkaid	20 500	–1.7	Polaris	6100	–4.6
Alnilam	26 950	–6.2	Pollux	4900	1.0
Alnitak	33 600	–5.9	Procyon A	6580	2.6
Altair	8060	2.2	Procyon B	9700	13.0
Arcturus	4590	–0.4	Regulus	13 260	–0.8
Atria	4590	–0.1	Rigel	12 140	–7.2
Avior	4900	–2.1	Shaula	25 500	–3.4
Bellatrix	23 000	–4.3	Sirius A	9620	1.4
Canopus	7400	–3.1	Sirius B	14 800	11.2
Capella	5150	–0.6	Spica	25 500	–3.4
Castor	9620	1.2	*Sun*	*5840*	*4.8*
Delta Canis Majoris	6100	–8.0	Tau Ceti	5150	5.7
Alpha Centauri	5840	4.3	Theta Scorpii	7400	–5.6
Beta Centauri	25 500	–5.1	van Maanen's Star	13 000	14.2
Alpha Crucis	20 500	–3.3	Vega	9900	0.5
Beta Crucis	28 000	–4.7			

Construct your own H-R diagram by plotting the stars from the table onto the grid below.

Note that the horizontal temperature axis is drawn to a logarithmic scale. This means that the values of grid lines are not evenly spaced as in a normal linear scale. (In fact, each grid line is a factor of $10^{0.1}$ or 1.26 times higher than the previous one.)

History of cosmology

Science as a human endeavour

Visual/Spatial **Logical/Mathematical**

Cosmology is the study of everything in the universe. The table lists some of the major events in the history of humanity's changing understanding of the structure of the universe.

Date	Event
Around 350 BCE	Aristotle describes the geocentric (Earth-centred) model of universe.
Around 200 BCE	Aristarchus proposes a heliocentric (Sun-centred) model of the universe that is widely ignored.
Around 150 BCE	Ptolemy refines the geocentric model of the universe to try to explain the retrograde (east to west) motion of the planets.
1520	Ferdinand Magellan is the first European to observe the Magellanic Clouds, which are later recognised as galaxies outside the Milky Way.
1543	Nicholas Copernicus publishes a paper that presents the heliocentric model with a number of improvements on Aristarchus' version.
1600	Giordano Bruno is burnt at the stake. One of his 'crimes' was promoting the heliocentric model of the universe.
1609	Kepler publishes *Astronomia Nova*, explaining the motion of the planets by using a heliocentric model of the universe and elliptical (oval-shaped) orbits.
1610	Galileo Galilei observes the moons of Jupiter.
1632	Galileo publishes his *Dialogue on Two World Systems*, which argues in favour of the heliocentric model of the universe.
1687	Isaac Newton publishes *Principia Mathematica* in which, among other things, he explains the law of universal gravitation (gravity).
1750	Thomas Wright suggests that the Milky Way galaxy is a flattened disk of stars and that nebulae might be other galaxies.
1781	William Herschel discovers Uranus.
1785	William Herschel constructs the first map of the Milky Way galaxy.
1838	Friedrich Bassel observes stellar parallax—the apparent movement of stars due to the Earth's movement around the Sun.
1846	John Couch Adams discovers Neptune.
1922	Ernst Opik demonstrates that the Andromeda nebula lies outside the Milky Way galaxy.
1927	Georges Lemaitre proposes the Big Bang theory, which suggests that the universe began as a giant explosion of energy.
1929	Edwin Hubble discovers evidence of an expanding universe, which supports the Big Bang model.
1930	Clyde Tombaugh discovers Pluto.
1964	Arno Penzias and Robert Wilson discover cosmic microwave background radiation, further evidence supporting the Big Bang model.
1969	Neil Armstrong and Buzz Aldrin are the first human beings to walk on the surface of the Moon.
1983	*Pioneer 10* becomes the first spacecraft to leave the solar system.
1998	The spacecraft *Galileo* returns data suggesting that Europa has liquid oceans under its icy surface.
2005	Planet-sized objects Eris, Haumea and Makemake are discovered in the Kuiper Belt.
2006	The International Astronomical Union rules that Pluto is not a planet.

1 Using the information presented in the table, choose the ten events that you consider most significant to developing our understanding of the cosmos and **construct** a timeline depicting these on the blank timeline below.

Individual Student Response

2 **Justify** two of your choices.

Individual Student Response

The Hubble constant

Science inquiry

Visual/Spatial Logical/Mathematical

In 1929, Edwin Hubble published his research into the motion of galaxies. This research fundamentally changed our understanding of the cosmos as it provided the first evidence that the universe was expanding. For each of the galaxies he studied, Hubble measured two properties—its distance from the Milky Way galaxy in megaparsecs (Mpc) and its recession velocity, i.e. the speed with which it is moving away from our galaxy. The data he collected is shown in the following table.

Distance (Mpc)	Recession velocity (km/s)
0.032	170
0.034	290
0.214	–130
0.263	–70
0.275	–185
0.275	–220
0.45	200
0.5	290
0.5	270
0.68	200
0.8	300
0.9	–30
0.9	650
0.9	150
0.9	500
1	920
1.1	450
1.1	500
1.4	500
1.7	960
2	500
2	850
2	800
2	1090

1 **Construct** a graph of recession velocity against distance for these data on the grid on the following page.

2 **Construct** a line of best fit through the points. (Note: Hubble's techniques have been refined in recent years to provide a much smaller spread of data.)

3 **Calculate** the gradient of the line of best fit. This is known as the Hubble constant, H_0. The units of the Hubble constant are km s^{-1} Mpc^{-1}. Hubble measured this value as being about 500 km s^{-1} Mpc^{-1}.

Use gradient $= \frac{\text{rise}}{\text{run}} = \frac{850-450}{2-1.1} = \frac{400}{0.9} = 444$ km s^{-1} Mpc^{-1}

4 Notice that at the bottom left-hand corner of the graph, there are a number of galaxies that have negative recession velocities. This means that they are moving towards our galaxy rather than away from it. This contradicts the idea of an expanding universe. **Identify** a reason why galaxies that are close to the Milky Way might be moving towards it rather than away from it.

Galaxies close to the Milky Way are moving towards us due to the Milky Way's gravitational pull.

7.5 Large Hadron Collider

Science as a human endeavour

Verbal/Linguistic

Refer to the Science as a Human Endeavour on page 234 of your student book to answer the following questions.

1 **Define** the term *hadron*.

Hadrons are the group of particles that include protons and neutrons.

2 **List** three different types of subatomic particle observed in the Large Hadron Collider (LHC).

Pions, mesons and quarks

3 **Identify** where the LHC is located.

Beneath the border between France and Switzerland

4 **Describe** the purpose of the LHC.

To find evidence for a Grand Unified Theory and to study the particles and particle interactions that may have existed just after the Big Bang.

5 **Classify** the LHC as a type of scientific instrument.

Particle accelerator

6 **Identify** how many countries are collaborating in the LHC project.

35 countries

7 **Explain** why some people were nervous about the development of the LHC.

There were concerns that it would create a microscopic black hole that would destroy the Earth. This did not occur.

7.6 The Titius–Bode law

Science inquiry

Logical/Mathematical

Throughout history, cosmologists have been fascinated by the power of mathematics to predict and explain aspects of the universe. The Titius–Bode law is a mathematical rule that can be used to estimate the average distance between the Sun and many of the planets and dwarf planets of the solar system. It was discovered by Johann Titius in 1766 and published by Johann Bode in 1772. (Unfairly, Bode did not give any credit to Titius for his discovery.)

The rule is usually written as:

$$a = 0.4 + 0.3 \times k$$

where a is the distance between a planet and the Sun in astronomical units (AU) and k = 0, 1, 2, 4, 8, 16 and so on up through successive factors of two. An astronomical unit is a unit of length based on the average distance between the Earth and the Sun.

Mercury, the closest planet to the Sun, corresponds to $k = 0$:

$$a = 0.4 + 0.3 \times 0 = 0.4 \text{ AU}$$

This is the average distance between Mercury and the Sun.

The next planet from the Sun, Venus, corresponds to $k = 1$,

$$a = 0.4 + 0.3 \times 1 = 0.7 \text{ AU}$$

This is the average distance between the Sun and Venus.

Earth corresponds to $k = 2$ and Mars to $k = 4$. Using a value of $k = 8$ predicts the distance to Ceres, the dwarf planet that is part of the asteroid belt.

At the time when Titius discovered the law and Bode published it, only the inner planets to Saturn had been discovered. Bode was particularly excited by William Herschel's discovery of Uranus in 1781 as its position fitted the Titius–Bode law very well. (In fact, it was Bode who suggested the name 'Uranus' for the planet; Herschel preferred to call it 'Georgium Sidus' in honour of King George III.)

While the match between the law's predictions and the real distances is not perfect, the results are very close as shown in Table 7.2.1 on page 94.

Strangely, there is no known theoretical reason why the Titius–Bode law should work. Some scientists believe though that the match is too good to simply be coincidence. Some suggest that the law is evidence of some as yet undiscovered process in the formation of the solar system.

1 **Use** the Titius–Bode law to complete Table 7.2.1 on page 94. Show your calculations in the space below

Table 7.2.1 Results of the Titius–Bode law and distance between the Sun and the planets

Planet	*k*	Titius–Bode law distance (AU)	Real distance (AU)
Mercury	0	0.4	0.39
Venus	1	0.7	0.72
Earth	2	1.0	1.00
Mars	4	1.6	1.52
Ceres	8	2.8	2.77
Jupiter	16	5.2	5.20
Saturn	32	10.0	9.54
Uranus	64	19.6	19.2
Neptune	128	38.8	30.06
Pluto (dwarf planet)	256	77.2	39.44

2 Note that the law does not work well for Neptune. **Propose** which body's orbit is predicted more accurately by $k = 128$.

Pluto

3 **(a)** **Identify** which planet (other than Neptune and Pluto) has the biggest difference between the predicted and real value.

Saturn

(b) **State** this difference.

0.46

4 **Discuss** whether or not you think the accuracy of the Titius–Bode law is just a coincidence or the result of an as yet unknown cosmic law.

Individual Student Response

7.7 Literacy review

Science understanding

Verbal/linguistic

1 **Use** the clues to **identify** the words.

Clue	Word
When particles come together due to gravity to form a larger object	accretion
Theory that the universe began with an enormous explosion of energy	Big Bang
Study of the history and structure of the entire universe	cosmology
Microscopic organisms that can store energy using photosynthesis	cyanobacteria
The distance light travels in a year	light year
Measure of the brightness of a star	magnitude
Galaxy in which our solar system is located	Milky Way
Remains of a supernova, consisting entirely of neutrons	neutron star
Theory that life came to Earth on a comet or meteorite	panspermia
Technique used to measure the distance to other stars	parallax
Astronomical unit of length equivalent to 3.26 light-years	parsec
Collapsing cloud of gas that will eventually become a star	protostar
Star produced when the core of a Sun-sized star runs out of hydrogen	red giant
Stretching of light waves due to the motion of stars away from the Earth	red shift
Another name for a black hole	singularity
Giant explosion that occurs when a star runs out of nuclear fuel	supernova
Hot, dense star that is the remains of a red giant	white dwarf

2 Once you have identified the words, find them and highlight them in the wordfind.

R	E	D	Y	E	A	R	G	A	F	E	C	L	W	D	S
E	C	Y	A	N	O	B	A	C	T	E	R	I	A	I	I
D	W	X	Q	P	W	I	E	C	M	Z	E	G	D	P	N
G	H	D	P	A	E	G	G	E	Q	Z	D	H	S	A	G
I	I	A	R	N	E	U	T	R	O	N	S	T	A	R	U
A	T	C	O	S	M	O	L	O	G	Y	H	Y	C	S	L
N	E	K	T	P	P	B	E	J	I	P	I	E	C	E	A
T	D	N	O	E	A	S	W	S	H	I	F	A	R	C	R
M	W	R	S	R	R	J	H	F	T	A	T	R	E	O	I
I	A	L	T	M	A	G	N	I	T	U	D	E	T	G	T
L	R	N	A	I	L	E	G	V	L	C	C	Z	I	D	Y
K	F	B	R	A	L	B	S	U	P	E	R	N	O	V	A
Q	B	I	G	B	A	N	G	J	F	B	U	B	N	C	F
C	F	M	J	P	X	M	I	M	I	L	K	Y	W	A	Y

Mobiles distract more than passengers do

Science as a human endeavour

Verbal/Linguistic

Read the following article about the effect of mobile phone use in cars and then answer the questions that follow.

Mobiles distract more than passengers

'Using a hands-free device on a mobile phone is more distracting than sitting next to a talkative passenger, say US researchers.

Their finding, published in the *Journal of Experimental Psychology: Applied*, adds to a growing body of evidence that mobile phones can make driving dangerous.

Professor Lee Strayer of the University of Utah and colleagues found in a series of experiments using driving simulators that hands-free mobile phones are just as distracting as handheld models.

Figure 8.1.1 Drivers using a hands-free device drift out of their lanes and miss exits more frequently, say researchers.

They have previously demonstrated that chatting on a mobile phone can slow the reaction times of young adult drivers to levels seen among senior citizens, and shown that drivers using mobile telephones are as impaired as drivers who are legally drunk.

For their latest study the researchers used a simulator to test 96 adults aged 18 to 49 years.

Strayer's team showed that drivers using a hands-free device drifted out of their lanes and missed exits more frequently than drivers talking to a passenger.

Second set of eyes

The researchers believe it may be due to passengers acting as a second set of eyes or sometimes helping when they see the driver needs to make a manoeuvre.

'When you take a look at the data, it turns out that a driver conversing with a passenger is not as impaired as a driver talking on a mobile phone,' says Strayer.

'The passenger adds a second set of eyes, and helps the driver navigate and reminds them where to go.'

Passengers also simplify conversation when driving conditions change, the researchers write.

'The difference between a mobile phone conversation and passenger conversation is due to the fact that the passenger is in the vehicle and knows what the traffic conditions are like, and they help the driver by reminding them of where to take an exit and pointing out hazards,' says Strayer.

In 2005, an Australian study published in the *British Medical Journal* found drivers who used a mobile phone, with or without a hands-free device, were four times more likely to have an accident within 10 minutes of using it, than if they had not.

Source: ABC/Reuters, December 2008

1 Researchers have found that using a hands-free mobile device is more distracting than having a conversation with a passenger in the car.

(a) **Describe** how using a mobile phone affects a driver's reaction time.

Using a hands-free mobile device lengthens a driver's reaction time.

(b) **Recall** the two comparisons made by the researchers to describe the effect of this altered reaction time.

Reaction times of young adult drivers can be slowed to levels seen among senior citizens, and drivers using mobile telephones are as impaired as drivers who are legally drunk.

2 **Recall** two driving behaviours that the researchers found were more likely to occur when a driver was speaking on a mobile phone.

Drivers talking on a mobile phone were more likely to drift out of their lanes and to miss exits than drivers talking to a passenger.

3 **Propose** why speaking to a person in a car is not as distracting as having a conversation on a mobile while driving.

When speaking to a person in the car, this person can act as a second set of eyes for the driver. Because they are aware of the driving situation, the passenger can assist the driver by navigating, can alert the driver of hazards or can pause their conversation when the driver needs to concentrate more fully.

4 According to the 2005 Australian study mentioned in the article, **state** how many times more likely a driver is to be in an accident within 10 minutes of using a mobile phone.

A driver is 4 times more likely to be involved an accident within 10 minutes of using a mobile phone.

5 **List** arguments for and against using a hands-free mobile device while driving.

Advantages of using a hands-free mobile device while driving	Disadvantages of using a hands-free mobile device while driving
For example, making use of travel time by conversing with people	For example, not able to fully concentrate on the road
For example, assists in organising work schedules and appointments	For example, more likely to miss exits or hazards
For example, can check where you are meeting other people	

6 (a) **Recommend** if and when you think drivers should be allowed to use a hands-free mobile device while in a car.

Individual Student Response

(b) **Justify** your choice.

Individual Student Response

Distance– and displacement–time graphs

Science understanding

Visual/Spatial Logical/Mathematical

1 Jake, Charlie and Nasir compete in a 100-metre race. The distance–time graph of their motion is shown. **Analyse** this graph to answer the following questions.

(a) **State** who won the race.

Charlie

(b) **Calculate** the average speed of the three runners in metres per second (m/s). Express your answer to one decimal place.

(i) Charlie's average speed = $\frac{\text{distance travelled}}{\text{time taken}}$ = $\frac{100}{10}$ = 10 m/s

(ii) Jake's average speed = $\frac{100}{18}$ = 5.6 m/s

(iii) Nasir's average speed = $\frac{100}{13}$ = 7.7 m/s

(c) **Compare** Nasir's motion to that of Charlie and Jake.

Charlie and Jake both accelerated as they ran the race, with their speed increasing until they finished the race. Nasir ran at a fairly constant speed for the first 6 seconds of the race. He then stopped for 2 seconds, before increasing his speed to finish the race.

2 The following distance–time graph applies to Lucy as she rides her bike along a bike path along a beach. **Analyse** Lucy's motion to answer the following questions.

(a) **Calculate** Lucy's average speed as she travels from A to B.

The gradient of this section of the graph = $\frac{100}{20}$ = 5 m/s

(b) **Calculate** Lucy's average speed as she travels from C to D.

$\frac{100}{30}$ = 3.3 m/s

(c) **Identify** the interval(s) in which Lucy:

(i) stops During intervals B–C (20–30 seconds) and D–E (60–80 seconds)

(ii) travels with constant speed During intervals A–B (0–20 seconds) and C–D (30–60 seconds)

(iii) travels with increasing speed. From E to F (80–110 seconds)

(d) **Calculate** Lucy's average speed for the entire journey.

$\frac{\text{distance travelled}}{\text{time taken}}$ = $\frac{350}{110}$ = 3.2 m/s

(e) **Explain** how this average speed does not fully describe Lucy's motion over the entire journey.

For some intervals, such as A–B, Lucy was travelling faster than this average speed, but because she stopped twice on her journey, this average result is lower than much of her actual motion.

(f) Assuming the bike path followed a northerly direction, **state** Lucy's displacement for the journey.

350 m north

3 **Calculate** the gradient ($\frac{\text{rise}}{\text{run}}$) for each stage of the two displacement–time graphs shown below. **Use** your results to plot the corresponding velocity–time graph of each using the axes provided.

(a)

(b)

Speed–time graphs

Science inquiry

Visual/Spatial Logical/Mathematical

1 The table shows the instantaneous speed recorded from the speedometer in a car at every minute of a 15-minute journey.

Time (min)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Speed (km/h)	0	22	47	50	50	50	35	11	29	60	32	3	0	0	25	60

(a) **Use** this data to **construct** a speed–time graph of the car's motion on the axes below.

(b) **(i)** Using a red pen, **identify** on your graph when the car was speeding up.

(ii) Using a blue pen, **identify** on your graph when the car was slowing down.

(c) **(i)** At one stage of the journey, the driver slowed down and turned a corner. **Propose** how many minutes into the trip this occurred.

7 minutes into the journey

(ii) At another stage of the journey, the driver stopped at a set of traffic lights. **Propose** how many minutes into the trip this occurred.

12 minutes into the trip

2 A family set out on a long car journey to reach a holiday destination. A speed–time graph of their motion is shown below. They drive for a certain time on freeways before having a break for a meal, then drive a further distance through a major city before reaching their accommodation.

(a) **Describe** the family's motion:

(i) 1–4 hours into the trip They accelerate over the first hour to reach 100 km/h. They then travel at a constant speed of 100 km/h for the next 3 hours.

(ii) 4–4.5 hours into the trip They slow down and stop.

(iii) 4.5–6 hours into the trip They have stopped for a meal.

(iv) 6–6.5 hours into the trip They start moving again and increase their speed to 50 km/h.

(v) 6.5–7.5 hours into the trip They travel for an hour at a constant 50 km/h, and then slow down to a stop.

(b) Recalling that the distance travelled is equivalent to the area below the speed–time graph for the journey, **calculate** the distance the family travelled to reach their holiday destination.

Area below speed–time graph = (½ × 1 × 100) + (3 × 100) + (½ × 0.5 × 100) + (½ × 0.5 × 50) + (1 × 50) + (½ × 0.5 × 50)
= 50 + 300 + 25 + 12.5 + 50 + 12.5
= 450 km

8.4 Road statistics

Science as a human endeavour

Visual/Spatial Logical/Mathematical Verbal/Linguistic

The data presented in the following questions is taken from the 'Road Deaths Australia 2008 Statistical Summary' compiled by the Australian Government Department of Infrastructure, Transport, Regional Development and Local Government.

1 Figure 8.4.1 shows the total number of people who died on Australian roads each year from 1981 to 2008.

Figure 8.4.1 Australian annual road deaths

(a) **Describe** the trend in the numbers of people killed on Australian roads over this period.

The numbers of people killed on Australian roads has decreased from the period of 1982 until 2008.

(b) **Propose** reasons to explain the trend.

Individual student response. For example, more speed cameras, mobile breathalyser testing units in force, many advertising campaigns discouraging speeding and drink driving and encouraging people to take a break from driving if fatigued.

2 Figure 8.4.2 illustrates the breakdown of deaths per road-user group according to gender.

Figure 8.4.2 Deaths by road-user group and gender

(a) **State** the type of road user (driver, passenger, pedestrian, motorcyclist or cyclist) that was most often killed in an accident.

Drivers

(b) **Propose** a reason to explain this finding.

Every car has a driver, but not always a passenger, so there are more drivers on the road. Also, there are more cars on the road than bikes or motorbikes so this result is not surprising.

(c) In 2008, 516 of drivers killed in car accidents were male and 178 were female. In 2007, 615 of those killed were male and 168 were female. **Propose** reasons to explain this difference between men and women.

Individual student response. For example, males generally take greater risks than females; influence of their peer group and showing off.

(d) **Explain** why many more motorcyclist deaths may have occurred amongst males.

More males ride motorbikes than females in total.

3 Figure 8.4.3 provides data about the speed limit at crash sites.

Figure 8.4.3 Speed limit at crash site

(a) **State** the speed limit zone in which the highest number of road deaths occurred.

100 km/h or above

(b) **Explain** why you think this result occurred.

The greater the speed of a vehicle in an accident, the greater the damage is caused.

4 Study the three graphs shown in Figure 8.4.4. They show the time of accidents that occurred, whether anyone killed was a pedestrian or driver, and their age.

Figure 8.4.4
Crashes involving death of selected road users by time of day and day of week

(a) **State** the time of day and days of the week when drivers under the age of 26 were at a much greater risk of having an accident.

Saturday or Sunday between midnight and 6 am

(b) **State** the time of day that generally involved the most accidents for drivers over the age of 26.

Afternoon, from midday until 6 pm

(c) **Propose** reasons why your responses to the last two questions were different.

For example, young people are more likely to take risks, such as driving under the influence of alcohol or drugs in the early hours of the morning after a party on a weekend. This is their time of greatest risk. Older drivers were involved in accidents at all times of day, but slightly more during the afternoon, probably due to the heavier traffic on the road during peak hour.

(d) **State** the time of day that pedestrians were at greatest risk of being hit by a car.

Evening, between 6 pm until midnight.

(e) **Justify** why the greatest number of accidents involving pedestrians happened in this time interval.

Reduced visibility of pedestrians crossing the road at night is likely to cause this result.

8.5 Newton's second law

Science understanding

Logical/Mathematical

Newton's second law of motion can be stated as:

$$F_{net} = m \times a$$

where F_{net} is the sum of all forces acting on an object (N), m is the mass of the object (kg) and a is the acceleration of the object (m/s^2).

This equation can also be stated in terms of acceleration: $a = \frac{F}{m}$

and in terms of mass: $m = \frac{F}{a}$

1 **Use** the appropriate equation to **calculate** the missing quantities in the table below.

	Force (N)	Mass (kg)	Acceleration (m/s^2)
(a)	12.2	6.1	2
(b)	145.6	45.5	3.2
(c)	750	250	3
(d)	5645.1	910.5	6.2
(e)	5.2	0.8	6.5
(f)	6750	1250	5.4

2 **Use** the correct equation to complete each of the following tasks.

(a) If a 1200 kg car accelerates at 3.0 m/s^2, **calculate** the force supplied by its engine.

$F_{net} = m \times a = 1200 \times 3$

$= 3600$ N

A force of 3600 N is supplied by the car's engine.

(b) Sarah accelerates at 8.0 m/s^2 as she starts running in a race. Given that her legs supply a force of 472 N, **calculate** Sarah's mass.

$m = \frac{F}{a} = \frac{472}{8} = 59$ kg

Sarah has a mass of 59 kg.

(c) The engine of a train of mass 250 000 kg, supplies a force of 1 525 000 N as it leaves a station. Ignoring the effects of friction, **calculate** the acceleration of the train.

$a = \frac{F}{m} = \frac{1\,525\,000}{250\,000} = 6.1$ m/s^2

The train accelerates at 6.1 m/s^2

Work and energy

Science understanding

Logical/Mathematical

1 **Calculate** the work done in the following situations. Show your working.

(a) A weightlifter applies a force of 784 N in order to lift a heavy barbell 2.1 m above the ground.

$W = F \times s = 784 \times 2.1 = 1646.4$ J

The work done by the weightlifter in lifting the barbell is 1646.4 J.

(b) Tayla lifts a sports bag with a force of 280 N to raise it 1.3 m from the ground into the boot of her car.

$W = F \times s = 280 \times 1.3 = 364$ J

Tayla does 364 J of work in lifting the sports bag.

2 **Calculate** the kinetic energy of the following moving objects.

(a) Diego is moving in a dodgem car at a speed of 8 m/s; the combined mass of Diego and the dodgem car is 325 kg.

$E_k = ½mv^2$

$= ½ \times 325 \times (8^2) = 10{,}400$ J (or 10.4 kJ)

Diego has a kinetic energy of 10 400 J

(b) A seagull of mass 0.5 kg is flying at a speed of 12 m/s.

$E_k = ½mv^2$

$= ½ \times 0.5 \times (12^2) = 36$ J

3 **Calculate** the gravitational potential energy in each of the following situations.

(a) Sophie of mass 18 kg is sitting at the top of a 20 m climbing structure made from steel cables.

$E_p = mgh = 18 \times 9.8 \times 20 = 3528$ J

Sophie has 3528 J of gravitational potential energy.

(b) A paint tin of mass 200 g is resting on a 1.5 m high shelf in a garage.

$E_p = mgh = 0.2 \times 9.8 \times 1.5 = 2.94$ J

The paint tin has 2.94 J of gravitational potential energy.

4 A car of mass 12 100 kg is travelling at 15 m/s. The driver sees that the traffic light ahead has changed to red and applies the brakes, bringing the car to a stop.

(a) **Calculate** the initial and final kinetic energy of the car.

$E_k = ½mv^2 = ½ \times 12\,100 \times (15^2) = 1\,361\,250$ J

When the car comes to a stop, its kinetic energy is zero.

(b) **State** the change in kinetic energy as the car comes to a stop: 1 361 250 J

(c) The change in kinetic energy is equal to the work done by the brakes in stopping the car. **State** the work done by the brakes in stopping the car: 1 361 250 J

(d) Given that a force of 18 150 N was supplied by the brakes of the car, **calculate** the distance over which the car slowed to a stop.

Work done $= F \times s$ $\quad 1\,361\,250 = 18\,150 \times s$

$s = \frac{1\,361\,250}{18\,150} = 75$ m. This means that the car came to a stop in 75 m.

5 Mia and Amir need to lift 5 kg packing boxes by 1 m into a truck. Amir lifts his box vertically, while Mia pushes her box up a ramp.

(a) **Calculate** the increase in gravitational potential energy of each box, assuming the acceleration due to gravity is 9.8 m/s^2.

$E_p = mgh = 5 \times 9.8 \times 1 = 49$ J

The increase in gravitational potential energy of each block is 49 J

(b) **State** whether Mia or Amir did more work in shifting or lifting the packing box.

Because both blocks are raised the same vertical distance (1 m), both Mia and Amir do the same amount of work in shifting the blocks.

(c) **Justify** your answer to part (b). Amir applies a greater force over a smaller distance, while Mia supplies a smaller force over a greater distance.

6 This diagram shows the rollercoaster that Tina and Rebecca rode on at a fun park.

(a) **Calculate** their gravitational potential energy at point A at the top of the first hill.

$E_p = mgh = 220 \times 9.8 \times 60$
$= 129\,360$ J

(b) **Describe** how the gravitational and potential energy of the cart has changed as the girls ride through point B on the track.

As the girls ride through B on the track, half of their gravitational potential energy has been converted into kinetic energy.

(c) **Calculate** the gravitational potential energy at point C.

$E_p = mgh = 220 \times 9.8 \times 15 = 32\,340$ J

(d) Ignoring energy losses due to friction, **calculate** the girls' speed at point C, rounding off your answer to one decimal place.

Gravitational potential energy at C is 32 340 J.

So kinetic energy = 129 360 − 32 340 = 97 020 J

$E_k = ½mv^2 = 97\,020$ J

$v^2 = 882$; so speed is approximately 29.7 m/s

8.7 Literacy review

Science understanding

Verbal/Linguistic

1 **Use** the clues to **identify** the words.

Clue	Word
The straight line distance between the finishing and the starting point, written with a direction	displacement
A quantity that has size but not a direction	scalar
A quantity that has size and direction	vector
The rate of change of distance	speed
The rate of change of displacement	velocity
The rate of change of velocity	acceleration
Another name for Newton's first law	inertia
The acceleration of an object depends upon the size of the force acting and the object's _____	mass
For every action force there is an equal and opposite _____ force.	reaction
When a force moves an object, this has been done.	work
The rate at which work is done	power
The unit used to measure work and energy	joule
The type of energy a moving object has	kinetic
The energy of an object due to its position is potential energy.	gravitational
The energy of a stretched or compressed spring is _____ potential energy.	elastic
A measure of the amount of useful energy produced	efficiency

2 **Summarise** the key equations used in forces and energy.

	Symbol	Formula
Average speed	v	$v = \frac{s}{t}$
Average acceleration	a	$a = \frac{v - u}{t}$
Newton's second law	F_{net}	$F_{net} = ma$
Work done	W	$W = Fs$
Power	P	$P = \frac{W}{t}$
Kinetic energy	E_k	$E_k = \frac{1}{2}mv^2$
Gravitational potential energy	E_p	$E_p = mgh$
Efficiency	Efficiency	$\frac{\text{useful energy}}{\text{total energy}} \times 100\%$

9.1 Foundations

Science inquiry

Verbal/Linguistic **Visual/Spatial**

Sometimes the ground will not be strong enough to support the entire weight of a heavy building structure. The building will then sink into the ground instead of sitting on top of it. This is when foundations are needed. Foundations ensure that the ground provides the upwards ground reaction force that can balance the weight of the building.

Foundations fall into two broad categories:

- *Piles:* Most soil types cannot support heavy buildings such as skyscrapers and bridges. Only solid rock can do that. For this reason, deep foundations (called piles) are dug, hammered or drilled into the soil until they meet a layer of solid rock. Many homes in Australia also use piles but these only go a metre or so into the ground since the soil at that depth is compacted enough to provide the required support.

- *Slabs:* Concrete slabs spread the weight of a building over a far wider area and so reduce the force on the soil at any one spot. Slabs are particularly useful when building on sandy, clay or swampy soils that shift when too much force is applied to them.

9.1

1 **State** the two main types of foundations.

Piles and slabs

2 The forces on a building must be balanced, adding up to zero. **Describe** what would happen to the building if they didn't.

If the forces on a structure weren't balanced, then the weight force was greater than the ground reaction force. That part of the structure would break, stretch or twist and the structure would fall or sink into the ground.

3 **Name** the force that causes you to fall off your chair and causes buildings to collapse.

Weight

4 **Name** the force that balances this force and ensures that a building doesn't sink into the ground.

Ground reaction force

5 **Explain** why slabs are used as foundations in sandy or muddy areas instead of piles.

Pile foundations concentrate all the weight of a building into only a few spots underneath it. Stress is high. This would cause the sand or mud to shift. Slabs spread the weight force across a much wider area and so there is less force on any part of the ground underneath it. Stress is much lower.

6 The pile foundations of a skyscraper need to be hammered or drilled into the ground until they hit solid rock. In contrast, many houses have piles that only go a metre or so into the soil. **Propose** reasons why these two building types need such different types of piles.

Skyscrapers are much heavier than normal houses and so need a more solid base. Also skyscrapers will sway more. Deep piles will stop them toppling over.

7 The solid rock of Manhattan Island allowed incredibly high skyscrapers to be built in New York City (USA). In contrast, London (UK) is built on mud and has only a few tall buildings. **Explain** why it is much more difficult to build tall buildings in London than New York.

Tall buildings are heavier and need stronger foundations underneath them than shorter buildings. The solid rock of Manhattan Island provides this support, whereas the mud of London (UK) does not. Hence tall buildings are more difficult to build in London.

9.2 Expansion and contraction in structures

Science inquiry

Verbal/Linguistic Logical/Mathematical

Most solids expand (get larger) when heated and contract (get smaller) when cooled. Also, different substances expand and contract differently, even when heated or cooled by exactly the same amount. Most of the time, this expansion or contraction only causes a building to creak noisily as it heats up or cools down.

However, sometimes the forces in a structure will be enough to crack or twist its structure so badly that it collapses. For example, if a plate that's been in the fridge is put in the oven or under a hot tap then it is likely to crack. This is because the outside of the plate is heating and expanding faster than the inside of the plate. The plate can't withstand the forces inside it and so it shatters.

1 **Define** the terms:

(a) expand Expand means to get larger or longer.

(b) contract Contract means to get smaller or shorter.

2 **Describe** what most substances do when they are:

(a) heated Most solids expand when heated.

(b) cooled Most solids contract when cooled.

3 A plate taken straight from the fridge to the oven will often crack. **Explain** why.

A plate taken straight from the fridge to the oven will often crack because its outside is heating and expanding faster than its insides. The plate can't withstand the forces inside it and so it shatters.

Expansion joints

Bridges are usually built with expansion joints (flexible gaps) at either end to allow the bridge to expand and contract with changes in the weather. These are shown in Figure 9.2.1.

Figure 9.2.1

4 **Describe** what expansion joints are and what they do.

Expansion joints are small gaps used at the end of bridges. They allow the bridge to expand when heated and contract when cooled without buckling or cracking.

5 Imagine that the bridge shown in Figure 9.2.1 on the previous page heats up slightly. From the options below, **identify** what is most likely to happen to its expansion joints by circling a letter.

Reinforced concrete

Concrete is a strong material under compression but breaks easily under tension. In contrast, steel is strong under tension. Reinforced concrete is concrete with steel rods or steel mesh embedded in it. Reinforced concrete benefits from the properties of both substances. As the table below shows, concrete and steel expand and contract exactly the same when heated or cooled. In reinforced concrete, this allows the concrete to expand and contract without cracking away from the steel inside it.

Aluminium expands more than twice as much as steel and concrete. So, if aluminium was used instead of steel then the concrete would quickly crack away from it.

Material	If the temperature increases by 100°C, then a 1 m bar of the material will expand by:
Concrete	1.2 mm
Steel	1.2 mm
Aluminium	2.6 mm

6 **Explain** how a steel mesh in the concrete would make a driveway much stronger.
Concrete is good under compression but fails under tension. Steel mesh allows it to be strong under tension too, making the concrete far stronger.

7 Four different reinforced concrete beams are shown in Figure 9.2.2. **Identify** which would be strongest.
C (the lower edge is under tension and therefore that is where the steel rod should be).

Figure 9.2.2

8 **Explain** why steel is used to reinforce concrete and not aluminium.
Steel expands the same as concrete when heated and contracts the same when cooled. It therefore moves with the concrete. Aluminium expands more than twice the amount of concrete and would cause it to crack.

9 **Use** the table above to **calculate** how much the following substances would expand:

(a) 1 m of steel if its temperature increases by 100°C 1.2 mm

(b) 1 m of aluminium if its temperature increases by 200° C 2 × 2.6 = 5.2 mm

(c) 3 m of concrete if its temperature increases by 100°C 3 × 1.2 = 3.6 mm

(d) 2 m of aluminium if its temperature increases by 50° C 2 × 2.6 × 0.5 = 2.6 mm

9.3 Elevators

Science inquiry

Verbal/Linguistic Visual/Spatial

The elevator (lift) that American inventor Elisha Otis demonstrated in 1853 was not the first elevator to be invented. However, it was the first elevator with a brake that stopped it from falling if its cable broke. Before this elevator, the height of buildings was limited by how many stairs people wanted to climb.

Building taller towers meant that more people would be in them. This required more and more elevators to carry them up and down. If every elevator serviced every floor, then:

- trips up and down would be extremely slow, potentially with stops at every floor
- the lower floors of the skyscraper would be filled with elevator shafts, leaving little room for offices and apartments.

Figure 9.3.1

For this reason, modern skyscrapers rarely have elevators going from bottom to top. Instead, the elevators only go as far as particular floors. One elevator, for example, might run express all the way to the top while others only service floors 1 to 20, 20 to 40 and so on. In this way, fewer elevators are needed to service the building.

The World Trade Center towers in New York (USA) were the tallest buildings in the world until they were destroyed on 11 September 2001. They were constructed as three small stacked skyscrapers of 44, 34 and 32 floors each. Between each was a 'sky lobby', which allowed people to change from one set of lifts to another. This is shown in Figure 9.3.1.

1 (a) **Name** the person who invented the braked elevator. Elisha Otis

(b) **State** when this was. 1853

2 The heights of buildings were limited to around 10 storeys before the invention of the elevator. **Explain** why.

People were unwilling to climb more than 10 storeys to their homes or offices. Buildings were therefore unlikely to go higher than 10 storeys.

3 Not all the elevators in a very tall skyscraper stop at every floor. **Explain** why.

If all the elevators in a very tall skyscraper stopped at every floor, then a trip to the bottom or top might involve 100 or so stops! This would make trips extremely slow.

4 The World Trade Center buildings in New York had sky lobbies.

(a) **Explain** what these were.

Sky lobbies were where people changed from one set of elevators to another.

(b) **Outline** how you would get to the 90th floor using these sky lobbies.

You could travel to the 44th level sky lobby, change to another lift then travel to the 78th level sky lobby, then change to another lift and travel to the 90th floor. You could also travel direct to the 78th level sky lobby, change lifts and then travel to the 90th floor.

5 Not all tall skyscrapers have sky lobbies. Imagine you are designing the elevators for a new 100-floor skyscraper. **Modify** the diagram on the right by ruling in lines to show how you would install 10 elevator shafts to service the 100 floors.

Individual Student Response

9.4 Resonance and Galloping Gertie

Science inquiry

Verbal/Linguistic Visual/Spatial

If you want to get a playground swing to go higher, then you give it another push every time the swing returns to you. The increasingly high swing you produce is known as resonance. Pushing a swing doesn't always cause resonance. If you push the swing at the wrong time, then the swing can slow or stop.

1 Imagine you are pushing a small child on a playground swing. **Describe** how you would get the swing to go higher and higher.

Push the swing at just the right time, on its return to you.

Resonance is also what causes the sound when you blow across the top of an open bottle. Blow right across the bottle's lip and the bottle will vibrate and make a wonderful, resonant sound. However, blow at the wrong speed and it does nothing.

2 **Describe** how you know when resonance is happening in an open bottle that you are blowing across.

Resonance is happening in a bottle whenever it produces its characteristic sound when blown across.

3 **Propose** a reason why different bottles resonate differently.

Different bottles produce different sounds, indicating that they resonate differently.

The Tacoma Narrows Bridge

Bridges swing and vibrate too. Heavy trucks and trains passing over them cause them to vibrate, as does the wind. The swinging is not usually a problem. However, if the wind gusts are at just the right times, then the bridge will resonate like a playground swing. It will swing more and more violently until the materials making up the bridge can no longer cope. The bridge will then collapse.

Figure 9.4.1

The Tacoma Narrows Bridge in the USA (Figure 9.4.1) opened in 1940 and soon began wobbling and swaying (resonating) whenever the wind blew across it. Locals nicknamed the bridge Galloping Gertie and many drove huge distances to avoid crossing it. Four months after opening, strong wind gusts caused the bridge to resonate greater than ever before. Its swings grew more violent until the steel and concrete making up the bridge broke up. The bridge then fell into the water below.

However, some parts of the bridge didn't move at all. The white line down the middle of the bridge didn't shift. Neither did the exact centre of the bridge or the supports at either end. These 'dead spots' are known as nodes. The bridge supervisor drove onto the bridge on its final day to see what was happening but soon had to abandon his car there. He then staggered along the white line back to land. Unfortunately, his daughter's dog Buffy was still in the car as it and the bridge fell.

4 Bridges swing and vibrate all the time. Think of a bridge near your home and **list** what would cause it to vibrate.

Individual Student Response

5 Tacoma Narrows Bridge wasn't open for long before it collapsed. **State** how long this was.

4 months

6 **Outline** what caused the Tacoma Narrows Bridge to collapse.

Resonance caused by wind made the Tacoma Narrows Bridge buckle so far that the materials making it up cracked, and it collapsed.

7 **Define** the term *node*.

A node is a point that doesn't move.

8 **Modify** Figure 9.4.2 to show the location of the nodes of the Tacoma Narrows Bridge.

There is also a node running all the way along the centre of the bridge.

Figure 9.4.2

9 The bridge supervisor was on the bridge just before it collapsed. **Explain** how he made it back to land.

He walked along the centre line of the bridge, which was acting as a node.

10 **Name** the only victim of the collapse of the Tacoma Narrows Bridge.

Buffy the dog

9.5 The Sydney Harbour Bridge

Science as a human endeavour

Verbal/Linguistic

Some structures are so remarkable that they become symbols or icons of the cities they are in, becoming part of its identity and culture.

The Sydney Harbour Bridge became an icon of Sydney well before it was opened in 1932, its construction is shown in images by famous photographers such as Henri Mallard and artists such as Grace Cossington-Smith.

Although the bridge is now dwarfed by skyscrapers, it towered over all of Sydney when it was built between 1923 and 1932. It is still the largest steel arch bridge in the world (but not the longest—that's in the USA). Built at a time when very few families had cars and much of the traffic was still horsedrawn, the bridge seemed far too large and wide for the needs of the Sydney of 1932. This is because it was designed to cope with the expected traffic demands of a much bigger city, the Sydney of the future.

The chief engineer J.J.C. Bradfield designed the bridge as a series of steel trusses that would make up two halves or sides of an arch. Until the two halves met in the middle, they were supported by cables locked into the rock on both shores. The cables were not needed for support once the two halves met because each half pushed against each other, keeping each other from collapsing into the water below. The process of construction is shown in Figure 9.5.1.

Figure 9.5.1

The platform of the bridge was then hung from the arch by thick cables. This provided the deck for the road and rail tracks.

The bridge was opened in 1932 when a ribbon across its road was cut not by the New South Wales Premier Jack Lang, who was standing next to it with his scissors, but by a member of an opposing political party, Captain Francis De Groot. He rode up on his horse and slashed the ribbon in two with a sword!

The bridge provides a vital link between the north and south shores of Sydney Harbour, although some of the traffic now travels underneath the harbour through a tunnel (completed in 1992).

1 **List** three cities you know of that can be identified by a structure.

Individual student responses. For example, Paris (Eiffel Tower), New York City (Empire State Building), Sydney (Sydney Opera House)

2 To the people of Sydney in 1932, the Sydney Harbour Bridge seemed even bigger than it does now. **Propose** reasons why.

In 1932, buildings were much, much smaller and shorter than today. There were no skyscrapers and the bridge towered over the city. Although the bridge is still impressive today, it is dwarfed by other structures in the city, making it look a little smaller.

3 The road of the bridge was made very wide, even though few cars existed in 1932. **Explain** why.

To cope with the traffic of a busier city of the future.

4 Some bridges use scaffolding and frames underneath to support them while being built. **Propose** reasons why this method could not be used for the Sydney Harbour Bridge.

Being built over water, scaffolding and frames would have needed to be floated on pontoons. This would be almost impossible. Also, any framework would stop shipping from passing underneath.

5 **Describe** what stopped the two halves of the bridge from collapsing before they met and were connected in 1930.

Cables fixed into the rock on each shore kept the two halves in place before they met and were connected in 1930.

6 **Describe** what holds the bridge up now.

The two halves push against each other, stopping each from falling.

7 **Name**:

(a) a photographer who recorded the bridge's construction Henri Mallard

(b) an artist who painted the bridge during construction Grace Cossington-Smith

(c) the chief engineer of the bridge J.J.C. Bradfield

(d) the premier of New South Wales when it was opened Jack Lang

(e) the person who cut the ribbon with his sword Captain Francis De Groot

8 **Propose** reasons why photographers and artists were so interested in the bridge during its construction.

The bridge was such an impressive structure and so large that it captivated the minds of everyone in the city, including photographers and artists.

9 Since 1992, only some of the traffic between the north and south shores travel across the bridge. **Explain** why.

The cross-harbour tunnel was opened in 1992, taking some of the traffic away from the bridge.

10 Some people argue that the bridge has lost some of its importance as a symbol of Sydney. **Propose** reasons why.

Sydney now has other icons such as the Opera House and Centrepoint Tower. Hence, the bridge has lost some of its importance as a symbol.

9.6 Literacy review

Science understanding

Verbal/Linguistic

1 **Use** the clues to **identify** the words.

Speeds up	accelerates
Slows down	decelerates
Forces that squash	compression
Forces that stretch	tension
Beam that supports the wall above a door or window	lintel
Series of triangles to make a light, strong beam	truss
Three laws of motion were developed by this scientist	Newton
Three-dimensional arch	dome
A type of bridge	cantilever
Buildings are examples of these	structures
Vertical uprights under compression	columns
Frame of a skyscraper	superstructure
A pointed arch	Gothic
A rounded arch	Roman
A flying structure	buttress
Cracks, breaks or snaps	failure
Push, pull or twist	force
When forces add up to zero	balanced
A simple structure that can be used as a bridge (three words)	post and beam
Wires in tension	cables

2 Once you have identified the words, find them and highlight them in the wordfind.

C	N	S	C	N	A	Q	E	S	B	Q	G	F	S	N
E	A	V	E	Z	O	R	N	U	S	O	L	U	N	O
S	M	N	T	T	U	I	T	E	T	U	P	O	M	I
T	O	W	T	L	A	T	S	H	W	E	R	E	U	S
R	R	Y	I	I	R	R	I	N	R	T	C	T	L	S
U	C	A	E	E	L	C	E	S	E	R	O	L	O	E
C	F	F	S	P	A	E	T	L	O	T	A	N	C	R
T	I	S	S	I	F	R	V	F	E	D	O	M	E	P
U	S	F	M	F	U	S	P	E	K	C	M	Y	Z	M
R	I	T	K	C	C	R	Y	F	R	M	E	H	W	O
E	S	E	T	A	R	E	L	E	C	C	A	D	H	C
S	C	U	P	O	S	T	A	N	D	B	E	A	M	A
L	R	L	I	N	T	E	L	S	E	L	B	A	C	P
E	D	E	C	N	A	L	A	B	Z	C	C	I	K	L
J	M	Z	S	U	W	H	S	E	Y	R	D	R	I	A

Time of death

Science understanding

Verbal/Linguistic Logical/Mathematical

The human body starts cooling immediately after death. This is accompanied by other changes that can also help tell scientists how long a person has been dead.

Blood starts to settle or 'pool' in the lowest parts of the body (corpse) because the heart is no longer pumping. Blood pooling usually takes around 6 hours. The location of pooling can also indicate whether the body was moved after death.

Rigor mortis is the stiffening of muscles because of a build-up of lactic acid after death. Rigor mortis moves through three phases, each lasting 6–12 hours. Stiffening starts in the eyelids and jaw and spreads until the whole body is stiff. The muscles then release and once again become flexible.

Skin colour changes, first turning pale and then blue then green. The green colouring happens within 2 days and is caused by bacteria decomposing (digesting) the internal tissues. Four to seven days after death, veins become more obvious, giving the skin a marble-like appearance.

Decomposition of the body proceeds in clear steps. Bloating occurs 4–7 days after death as decomposition gases inflate the corpse. The soft tissue of the body decays extensively in the second week, leaving little except sticky goo by the end of a month. After that, only the skeleton, nails, hair and perhaps some dried, leathery skin will be left.

Different species of insects are attracted to different stages of decomposition of a body and will consume its flesh or lay eggs in or on the body. The eggs hatch, releasing larvae such as maggots or caterpillars. These moult and grow, each new growth stage being known as an instar. Later on, a pupa or cocoon is spun in which the larvae undergo metamorphosis, changing into their adult form. A typical life cycle is shown in Figure 10.1.1.

Figure 10.1.1 Life cycle of the common blowfly

1 **Define** the following terms.

(a) rigor mortis Stiffening of the muscles due to lactic acid build-up after death.

(b) bloating Swelling due to the release of gases from within the body from internal decomposition.

(c) larvae Immature insects (e.g. maggots are the larvae of flies, caterpillars are the larvae of butterflies and moths)

2 **Specify** the length of time a body has been dead if:

(a) the whole body is stiff 6–24 hours

(b) blood is pooled 6 hours

(c) skin is green 2 days

(d) the body is bloated 4–7 days

(e) large maggots are on the body 2–7 days

(f) skin is 'marbled' 4– 7 days

(g) nothing is left other than a skeleton and hair More than a month

(h) only goo, bones and skin are left Around a month

(i) blowfly eggs are on the body Within a day, possibly only a few hours

(j) eyelids are stiff but muscles are flexible 6–12 hours

3 **Explain** why blood doesn't normally pool in a living human being.

Blood is pumped to all parts of the body, often against gravity.

4 **Explain** how blood pooling could indicate that a body has been moved after death.

If the body was shifted, then pooling might appear on its upper surface.

5 **Propose** a reason why skin turns pale and then blue soon after death.

Blood quickly becomes deoxygenated and changes in colour. As it does so, the skin pales and then becomes blue.

6 **Name** the chemical that produces rigor mortis.

Lactic acid

7 **State** what causes a body to bloat.

Gases from the decomposition of the insides of the body

8 The green colouring of bacterial decay starts near the waist. Think about the organs found around there and **propose** reasons why the green colouring starts there and not elsewhere.

The main organs of the digestive system are located near your waist. Undigested food and semiprocessed food and faeces will provide the ideal environment for bacterial growth. Hence discolouring tends to start there.

9 When animals die in the bush, their bodies decompose in similar stages to those of humans. **Propose** reasons why this is a good thing for the environment.

Otherwise their remains would always be in the environment. By decomposing, the bodies return their elements to the earth, enriching it.

Blood typing

Science inquiry

Verbal/Linguistic Logical/Mathematical

One of the roles of blood is to rid the body of foreign bodies such as bacteria and viruses. It does this using two different chemicals:

- antigens—these chemicals are attached to the outside of cells and cause your immune system to attack cells that do not belong to you
- antibodies—these chemicals are in the plasma or serum of your blood and attack any foreign particles that have entered your body.

Blood group

Blood is classified or grouped according to the antigens in it. Table 10.2.1 shows how.

Table 10.2.1

Blood group	Red blood cell antigens	Plasma/serum antibodies
A	A	Anti-B
B	B	Anti-A
AB	A and B	No antibodies
O	No antigens	Anti-A and anti-B

Rhesus

The rhesus factor is a protein that is either present or not present on the surface of the cells in your body. If you have the rhesus factor, then you are positive (e.g. A+). If you don't have it, then you are negative (e.g. AB–).

Forensic use of blood groups

Different racial groupings tend to have different blood groups and so the blood groups found at a crime scene might narrow the range of suspects (Table 10.2.2).

Table 10.2.2

Blood group	Proportion of Australians with that blood group	Racial grouping the blood most likely came from
A	39% (A+ = 32%, A– = 7%)	Caucasian (European, North African, Middle Eastern)
B	11% (B+ = 9%, B– = 2%)	Asian, African
AB	4% (AB+ = 3%, AB– = 1%)	All racial groups
O	46% (O+ = 38%, O– = 8%)	All racial groups

Determining blood groups

If blood is mixed with any foreign antibodies, then the blood will coagulate (clump). Table 10.2.3 shows how each blood type reacts with different antibodies. The blood group of an unknown blood sample can therefore be determined by mixing it with different antibodies.

Table 10.2.3

Blood group	Mixed with anti-A antibody	Mixed with anti-B antibody
A	Coagulates	Nothing happens
B	Nothing happens	Coagulates
AB	Coagulates	Coagulates
O	Nothing happens	Nothing happens

1 **Use** the circle shown right to **construct** a pie chart showing the occurrence of different blood groupings in Australia.

2 **List** the specific blood groups A+, A–, B+, B–, AB+, AB–, O+ and O– in order from most common to least common.

O+ (38%), A+ (32%), B+ (9%), O– (8%), A– (7%), AB+ (3%), B– (2%), AB– (1%)

3 **Define** the following terms.

(a) rhesus factor
A protein that is either present or not on the surface of the cells in your body.

(b) coagulate
To clump, used to describe how blood cells clump together when foreign antibodies are introduced into the blood.

4 Half of Australians are either group O or group AB. These blood groups are also common in all racial groups. Hence, a sample of blood group O or AB tells investigators very little. Despite this, all blood drops found at a crime scene will be tested for their blood group. **Propose** reasons why.

A negative test (i.e. one showing that the suspect does not have O or AB blood group) narrows the search to the more rare blood groupings.

5 The proportion of people of blood group A+ is about the same as O+. Despite this, blood splatters of group A+ are far more useful to investigators than O+. **Explain** why.

The proportion of people of blood group O+ is spread across all racial groups. A+ mainly comes from Caucasian people. A test showing A+ therefore narrows the search away from people of Asian or African descent.

6 A blood drop is found at a crime scene. Its blood group is the relatively rare AB–.

(a) **State** the percentage of the Australian population that has this grouping.

1%

(b) **Discuss** whether this blood group would make it any easier to find the suspect.

If other evidence points to a particular suspect, then the rarity of the blood group is likely to pinpoint the person who committed the crime. However, the rarity of the blood group will make it difficult to determine the pool of potential suspects.

7 Four samples of blood from a crime scene were mixed with two different antibodies. The results are shown below. **Identify** the blood group of each sample.

Key: ○ Clear drop of blood ● Coagulated drop of blood

10.3 Mapping your teeth

Science inquiry

Bodily/Kinaesthetic Visual/Spatial

Dentists keep accurate dental charts that record any natural irregularities (differences) in their patients' teeth and the location and size of fillings, pins and crowns that have been put in at any time. Teeth are very tough and tend to outlast the rest of the body and provide a way of identifying the body of someone who has been missing for a long time. This is done by matching the teeth with dental charts. Below are the dental charts of an 'average' healthy child and an 'average' healthy adult.

1 **Compare** the teeth of a child with those of an adult by completing the table on the right.

	Numbers of teeth	
	Child	Adult
Total number	20	32
Incisors	8	8
Canines	4	4
Premolars	2	8
Molars	8	12
Wisdom teeth	0	4

(including 4 wisdom teeth)

2 **Propose** why children have fewer teeth than adults. The skulls and jaws of children are much smaller than adults. This means that fewer teeth can fit into the jawline. Hence there are fewer and smaller teeth.

3 Run your finger over your teeth to find how many teeth you have. **State** this total.

Numbers will vary between 20 and 32.

4 Based on the number of teeth in question 3, **assess** which of the above diagrams (child or adult) best describes your teeth. _____

Individual Student Response

5 **Modify** the diagram you chose in question 4 so that it more accurately records your teeth. Do this by:

- crossing out any teeth you don't yet have
- marking any teeth that are still in the process of coming down
- crossing out any teeth that are missing for some reason
- marking any teeth that have fillings, caps or other dental work
- marking any teeth that have chips in them
- marking any large gaps you have between your teeth.

Individual Student Response

6 Dental records won't always be an accurate way of identifying a body. **Propose** why.

It depends on how recently the person visited the dentist. If it has been a long time, then their teeth have probably changed (with new decay, cracks, chips etc.).

10.4 DNA media analysis

Science as a human endeavour

Verbal/Linguistic

Read the following article about how DNA evidence helped prove a man innocent and then answer the questions on page 126.

Thirty years on, DNA tests free US man convicted of rape

A US man has tasted freedom for the first time in nearly 30 years after a judge overturned his conviction because DNA evidence showed he did not rape an 11-year-old girl.

'It finally happened, I've been waiting,' Raymond Towler, 52, said today as he hugged sobbing family members in the courtroom.

He walked from the courthouse, arms around relatives, amid the smell of freshly cut grass, blooming trees and a brisk wind off Lake Erie. He was headed to an 'everything on it' pizza party.

Towler had been serving a life sentence for the rape of a girl in a Cleveland park in 1981. Prosecutors received the test results Monday and immediately asked the court to free him.

In a brief, emotionally charged session, Cuyahoga County Common Pleas Court Judge Eileen Gallagher recapped the case, discussed the recently processed DNA evidence and threw out his conviction. She also told him that he can sue over his ordeal.

'You're free,' the judge said, leaving the bench to shake Towler's hand at the defence table. The judge choked back tears as she offered Towler a traditional Irish blessing.

The Ohio Innocence Project, an organisation that uses DNA evidence to clear people wrongfully convicted of crimes, said Towler was among the longest incarcerated people to be exonerated by DNA in US history.

The longest was a man freed in Florida in December after serving 35 years, according to the project.

Towler was arrested three weeks after the crime when a park ranger who had stopped him on a traffic violation noticed a resemblance with a suspect sketch. The victim and witnesses identified him from a photo, police said.

Carrie Wood, a staff attorney with the project, said the identifications were questionable.

The latest technology allowed separate DNA testing of a semen sample and other genetic material, possibly skin cells, she said.

'That was the test result that we got this week and it excluded Mr Towler,' she said. 'Because Mr Towler's conviction was in '81, the technology did not exist to do the kind of DNA testing that we can do now.'

Attorneys with the project at the University of Cincinnati have been working on the Towler case since 2004, and Towler said that and his faith had given him hope.

Prosecutor Bill Mason said his staff would test crime-scene evidence to try to identify the attacker.

Source: www.theage.com.au, 6 May 2010

1 **Name** the man mentioned in the article who was released on the basis of DNA evidence.

Raymond Towler

2 **State** how long he served in prison before release.

Nearly 30 years

3 **Outline** the crime for which the man was convicted (sent to prison).

The rape of an 11-year-old girl

4 **Outline** the evidence used originally to convict the man.

A park ranger stopped Towler on a traffic violation and noticed a resemblance to a sketch of the suspect. The victim and witnesses identified Towler from a photo.

5 **Calculate** the approximate age of the man when convicted.

Around 22 years

6 **List** the samples that were collected from this crime scene from which DNA could be extracted.

Skin cells and semen

7 **State** which one of those samples was used to release the man from prison.

Semen

8 **Explain** why the samples were not originally tested for DNA.

The DNA testing technology was not available in 1981.

9 **Name** the US-based organisation that uses DNA to clear people wrongfully convicted of crime.

The Ohio Innocence Project

10 **State** how long the project had been working on this case.

6 years, from 2004 to 2010

11 **State** the longest time spent by a person in prison in the USA before being released on DNA evidence.

35 years

12 Some people have suggested that all crimes should be re-assessed using new DNA technology. **List** the advantages and disadvantages of this proposal.

Advantages: it would find people wrongly convicted and still in prison, allowing them to be released.
Disadvantages: it would be very expensive and time consuming; some innocent people would remain in jail because appropriate samples might not have been collected at the time or may have been destroyed.

10.5 Poisons

Science as a human endeavour

Verbal/Linguistic

Throughout history, poisons were used as a murder weapon. This is because they were:

- relatively easy to get, many coming from common plants such as belladonna
- relatively easy to administer, most commonly slipped into food or drink
- difficult to detect since their symptoms resembled those of natural health problems such as dizziness, vomiting and diarrhoea. The murderer was therefore unlikely to be caught. If the poison was detected, by then the murderer was far away from the crime scene.

Some of the common poisons used in the past are shown in Table 10.5.1.

Table 10.5.1

	Arsenic	Cyanide	Deadly nightshade	Death cap mushroom	Strychnine
Found in	Rocks	Laurel plant	Belladonna plant	A deadly form of mushrooms	Seeds of a tree
Symptoms	Weak pulse, vomiting, intense saliva production, eventual multi-organ failure	Dizziness, convulsions, asphyxiation (inability to get enough oxygen), unconsciousness	Pupil dilation, dry mouth, fever, hallucinations (seeing things), enlarged pupils, coma	Stomach cramps, diarrhoea, vomiting, coma. Symptoms disappear after a day but then keep returning	Restlessness, muscular spasms that rip muscles from their ligaments
Affects	Circulatory and digestive systems	Red blood cells so that they stop carrying oxygen	Heart and lungs, causing paralysis	Digestive system, causing liver failure	Muscles, triggering spasms, paralyses lungs

The use of poisons as a murder weapon is now very rare. This is because forensic pathologists can detect the presence of even small doses of poison in a body. Poisonings nowadays are usually accidental, from the environment or deliberate mass terrorism.

Environmental poisoning

Before the 1970s, the people of Bangladesh had poor health because they gathered their water from stagnant and bacteria-filled ponds or polluted rivers. Since then, an estimated 10 million wells (called tube wells) have been constructed across the country. The groundwater drawn from them is usually bacteria-free but also has an unusually high amount of dissolved arsenic in it. This arsenic has leached into the water from underground rocks and is slowly poisoning between 35 million and 77 million people who drink it each day. An estimated 20 000 people in Bangladesh die from arsenic poisoning each year.

Accidental poisoning

In 1984, a cloud of poisonous methyl isocyanate gas was accidently released from the Union Carbide pesticide factory in Bhopal, India. Over half a million people breathed in the gas and at least 4000 people died that night. Since then, another 8000–25 000 people have died from their exposure to the poison.

Deliberate poisoning

Chemical and biological weapons are poisonous gases that are deliberately spread in the air to kill, usually in a war or terrorist attack. Some well-known examples have been the use of:

- mustard gas, phosgene and chlorine gases in World War I (1914–18). About 100 000 soldiers were poisoned this way
- zyclon B (or cyclon B) in the concentration camps of Nazi Germany during World War II (1939–45). This cyanide-based gas was used to kill an estimated 1.2 million Jews and political prisoners
- mustard gas and sarin gas by Sadaam Hussein's army in 1988 to kill an estimated 10 000 Kurdish people in the north of Iraq
- sarin nerve gas by the Japanese terrorist group Aum Shinrikyo. Sarin was released into the Tokyo subway in 1995, killing 12 people waiting for trains
- anthrax spores (reproductive plant matter, so tiny that it is like pollen) sent through the mail in 2001 to US government officials, killing five of those people who opened the letters.

1 In the past, poisons offered a potential murderer many 'advantages'. **List** them.
Poisons were relatively easy to obtain; were relatively easy to administer; often mimicked the symptoms of natural illnesses, allowing the murderer to get away before the crime became obvious.

2 Poisons are rarely used nowadays to kill. **Explain** why.
Medical testing quickly detects the presence of foreign chemicals in the body, allowing little time for the murderer to escape.

3 Strychnine poisoning is very painful. **Propose** a reason why.
Strychnine causes powerful muscle spasms that eventually rip muscles from bones.

4 (a) **Explain** why the UN paid for millions of water wells to be installed in Bangladesh.
To give the people fresh water, instead of their normal supplies of bacteria-filled ponds and streams

(b) **State** where the arsenic from these wells has come from.
Leaching from rocks into the underground water

5 **Use** the information on this worksheet to complete the following table.

	Date (s)	Poison	Estimated deaths
Bangladesh	Now	Arsenic	20 000 per year
Bhopal	1984	Methyl isocyanate (MIC) gas	4000 then another 8000 to 25 000 later on
Trenches of WWI	1914–1918	Mustard gas, phosgene and chlorine gases	100 000
Nazi Germany	1939–1945	Zyclon B/Cyclon B	1.2 million
Iraq	1988	Mustard and sarin gas	10 000
Tokyo	1995	Sarin gas	12
USA	2001	Anthrax	5

10.6 Art forgery

Science as a human endeavour

Verbal/Linguistic

Paintings by important artists sell for millions of dollars. So it is not surprising that they are sometimes forged. Sometimes simple checks can reveal that an artwork is fake.

Each painting should have a provenance, which is a detailed history of its owners since it was painted and where and how it was purchased each time it changed hands. If there is no provenance or there are parts of the history missing, then the artwork is probably fake. Otherwise, it could be real but stolen.

Each artist has their own characteristic style, colours, pattern of brushstrokes and signature. Sometimes, a check of these features is all that is needed to prove an artwork as fake. However, if more evidence is needed, the next step for the forensic investigator is to use simple non-destructive techniques that do not damage an artwork.

Non-destructive techniques

A stereomicroscope shows detailed brushstrokes and can indicate whether the varnish over the paint has been artificially cracked to make the painting look older than it is.

X-rays show whether cracks are just on the surface paint layers (suggesting fake ageing) or pass through all the paint layers to the canvas below (suggesting real ageing).

Infrared (IR) radiation reveals painting and sketches under the surface image, which would indicate that the painting has been changed, painted over or had bits glued on.

Ultraviolet (UV) radiation causes materials within the varnish and pigments that make up the paint to fluoresce (shine). The fluorescing colour can indicate the era in which the painting was made. For example, materials from the 1800s usually fluoresce blue-green.

Destructive techniques

Destructive techniques of analysis are only used when all other techniques have failed to determine whether an artwork is fake or not. A small scraping of paint is taken from an edge or from a flake of paint that has come off. The destructive techniques commonly used are X-ray analysis and mass spectrometry.

X-rays scatter (reflect) off different pigment crystals in the paint in different ways. Although the colours of the pigments may have faded and be unrecognisable, X-ray scattering will identify the exact pigment used. The invention of each new pigment is well documented and so a painting can be aged from the pigments found in it. For example, the presence of Prussian blue indicates that the artwork must have been painted after 1704.

Mass spectrometry can determine the amount of impurities in the pigments. The purer the pigment is, the more recent it is. This technique can also determine whether the pigments were mixed with egg albumen, oil or water. For example, oil paints were only invented in the 15th century (1400s) and water-based paints (acrylics) in the 20th century (1900s).

1 It is easier to forge paintings of artists who are dead than the paintings of those still alive. **Propose** a reason why.
Living artists can check the painting and are likely to have a photographs of it. If the artists are recently dead, then family or friends may be able to check a painting. If the artist is long dead, then no-one will be present who knew the artist personally or their work.

2 **Define** the following terms.

(a) provenance The recorded history of ownership of a work of art

(b) UV ultraviolet light

(c) IR infrared light

(d) fluoresce shine

3 A 30-year gap appears in the provenance of a painting by Picasso. **Propose** what this could mean.
The painting may have been stolen and kept by the thief or person who bought it from the thief for 30 years.

4 **List** two ways in which X-rays can assist forensic investigators to determine whether a painting is real or a fake.
To show whether cracks are just on the surface paint layers (suggesting fake ageing) or pass through all the paint layers to the canvas below.
To identify pigments and so the age of painting.

5 An 'old' painting by Titian has cracks all across its varnish but X-rays show there are none in the paint itself. **Predict** whether the painting is real or a fake.
Probably fake since an old painting would have cracks in its varnish and in its paint.

6 A Claude Monet painting of a street scene is tested with IR radiation. It shows that there is a sketch of a person's face on the canvas but no street scene. **Explain** why the painting is unlikely to really be by Monet.
Most artists make a sketch of their subject first. Hence a street scene should have a similar sketch of a street scene under it. Hence the painting is most likely a fake.

7 **Use** the following information to **classify** the paintings as real or fake. **Justify** each of your classifications.

Painter	Lived	Painting tested by	Evidence found	Real or fake?	Justification
Von Guerard	1811–1901	Mass spectrometry	Used acrylics	Fake	Acrylic paint was invented in the 20th century.
Rembrandt	1606–69	X-ray scattering	Includes Prussian blue	Fake	Prussian blue was only used after 1704.
Jackson Pollock	1912–56	UV fluorescing	Pigments fluoresce blue-green	Fake	Blue-green indicates the materials used came from the 1800s.
Ghirlandaio	1449–94	Mass spectrometry	Uses oils	May be real	Oils were used from the 1400s.
Tom Roberts	1856–1931	IR analysis	Major features of a portrait were changed by painting over them	May be real but unlikely	Minor features might change but it is unlikely that major features would. Hence probably a portrait changed by a forger.

10.7 Literacy review

Science understanding

Verbal/Linguistic

1 **Use** the clues to **identify** the words.

Clue	Word
The scientific study of evidence	forensics
Deliberate fire	arson
The killing of another person	homicide
The study of guns and bullets	ballistics
Person who sees a crime	eyewitness
The systematic dissection of a dead body	autopsy
Dead body	corpse
A chemical 'fingerprint' found in every cell in your body	DNA
Absorbs water and oil	porous
Microscopic organisms found in water	diatoms
The large bone in your upper leg	femur
Loops, whorls, arches and composites are different types	fingerprints
The use of a liquid to separate colours in dyes	chromatography
Raised printing on a banknote	intaglio
The coloured muscular ring at the front of the eye	iris
The back of the eye	retina
Liquid that dissolves solids and other liquids	solvent
A technique that matches parts of the face to reconstruct the face of a criminal	Identikit
Plastic film used to make Australian banknotes	polymer
A type of fingerprint	whorl

2 Once you have identified the words, find them and highlight them in the wordfind.

S	R	H	I	L	P	I	S	X	L	T	O	C	I	S
T	A	N	I	T	E	R	D	F	N	F	D	N	F	M
N	E	Y	E	W	I	T	N	E	S	S	T	O	O	O
I	T	H	I	B	S	R	V	T	N	A	L	S	R	T
R	K	P	I	A	K	L	Y	P	G	T	C	R	E	A
P	R	H	C	C	O	K	R	L	J	I	I	A	N	I
R	C	O	T	S	M	M	I	O	T	I	I	K	S	D
E	D	I	C	I	M	O	H	S	H	C	R	S	I	E
G	N	G	N	Y	D	B	I	P	T	W	Y	I	C	T
N	A	J	C	K	S	L	F	E	M	U	R	F	S	P
I	B	R	Y	O	L	P	O	L	Y	M	E	R	O	S
F	Y	H	P	A	R	G	O	T	A	M	O	R	H	C
O	T	M	B	X	O	P	C	T	J	L	O	O	N	F
B	Q	T	K	C	D	T	S	Y	U	U	C	R	Y	J
W	B	U	F	S	W	P	F	E	S	A	S	B	Q	I