DNA and genetics

1

HAVE YOU EVER WONDERED…

- why people in families often look alike?
- where the differences between people come from?
- what is meant by a genetic disease?
- how scientists are able to change the genetic information in an organism?
- why discussion of genetic modification can lead to debate?

After completing this chapter students should be able to:

- describe the role of DNA in controlling the characteristics of organisms
- use models and diagrams to represent relationships between DNA, genes and chromosomes
- explain the role of meiosis and fertilisation in the passing on of genetic information to offspring from both parents
- describe patterns of inheritance of a simple dominant/recessive characteristic through generations of a family
- predict simple ratios of offspring genotypes and phenotypes in crosses involving dominant/recessive and sex-linked inheritance
- describe mutations as changes in DNA or chromosome numbers and outline the factors that contribute to mutations
- describe the development of the double helix model for the structure of DNA
- investigate the history and impacts of developments of genetic knowledge
- describe how the development of fast computers made DNA sequencing possible
- discuss applications of gene technologies and genetic engineering
- describe the role of genetic testing in decision-making relating to embryo selection, identification of carriers of genetic mutations and the use of this information by companies and medical authorities.

1.1 DNA the molecule

Organisms on Earth have many differences. Not many people would confuse an elephant with an earthworm, a tree with a tarantula or a penguin with a python. However, at one level the differences between organisms are not as great as you might think. All the living things mentioned here, along with humans, have slightly different versions of the same chemical in the nucleus of their cells. This chemical is DNA and it controls the way you look and how your body functions.

INQUIRY science 4 fun

What do you know?

What do your friends and family know about DNA and what it does?

Collect this…

- notebook
- pen

Do this…

1. Make a list of the friends and family you are going to talk to.
2. Ask these people what they know about DNA.

Record this…

Describe what your family and friends know about DNA.

Explain why there may be differences in their understanding.

Deoxyribonucleic acid

Life on Earth is very diverse. However, for most living things **deoxyribonucleic acid (DNA)** is the molecule that determines their characteristics. It also contributes to the diversity of living things.

DNA is a complex chemical compound that has a similar structure in all organisms. DNA is made up of molecules called **nucleotides**. The basic structure of a nucleotide is shown in Figure 1.1.1. Nucleotide molecules have three main parts:

- **phosphate group**
- **deoxyribose sugar**
- one of four **nitrogen-rich bases**.

The nucleotides are organised in a way that makes DNA a double helix. The shape of a double helix is like a twisted rope ladder. The uprights of the ladder are made of alternating phosphate and sugar groups.

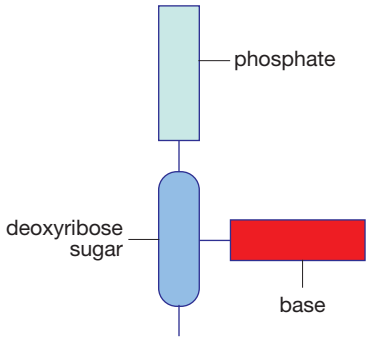


Figure 1.1.1 All the nucleotides of DNA have the same basic structure. It is the type of base that is different.

The nitrogen-rich bases (commonly called bases) pair up to form the rungs. The four bases **adenine (A)**, **thymine (T)**, **guanine (G)** and **cytosine (C)** all have different chemical structures. This means that they can only pair up in one way, a characteristic known as **complementary base pairing.** For example, adenine can only form a complementary base pair with thymine (A–T) and guanine can only pair with cytosine (G–C).

Therefore there are two types of 'rungs' on the 'ladder': A–T rungs and C–G rungs. This can be seen in Figure 1.1.2.

1 p8

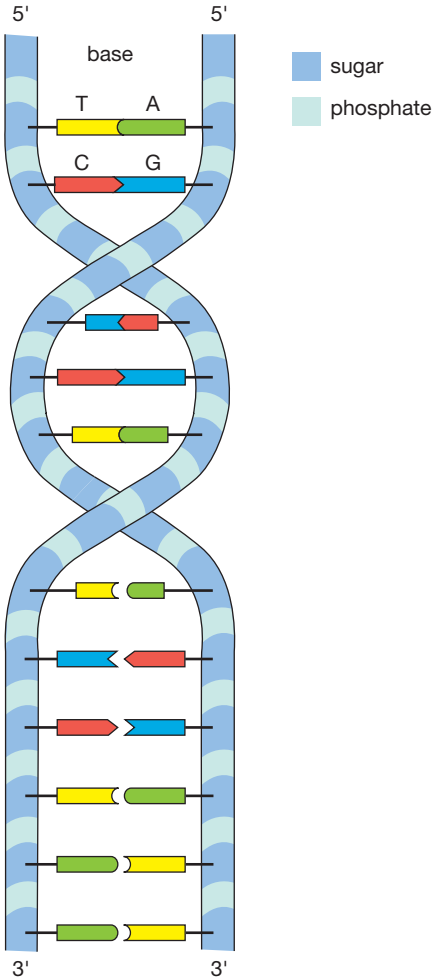


Figure 1.1.2 DNA structure—the lower section is shown uncoiled to illustrate the pairing of the bases.

Complementary base pairing

The chemical structure of the nitrogen-rich bases means that they can only form chemical bonds with one of the other bases.

- Adenine (A) only pairs with thymine (T)
- Cytosine (C) only pairs with guanine (G).

One side of the DNA ladder could be like Figure 1.1.3 with the sugar–phosphate backbone and the attached bases.

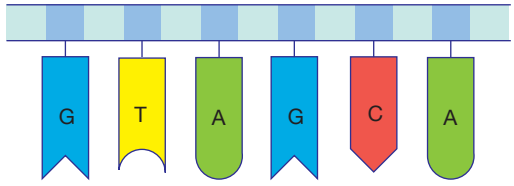


Figure 1.1.3 One side of the DNA ladder

Using complementary base pairing, the other side of the molecule would look like Figure 1.1.4.

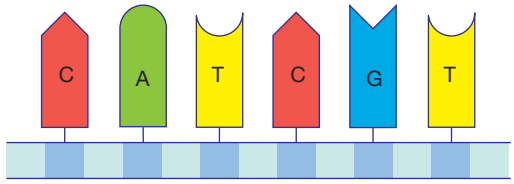


Figure 1.1.4 The other side of the DNA ladder

When the two sides are put together, the DNA molecule in Figure 1.1.5 would be the result.

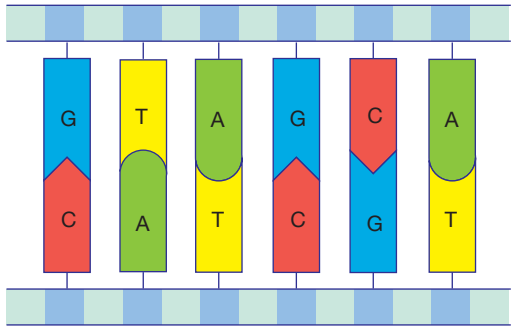


Figure 1.1.5 The resulting DNA molecule

1 1 2 p9 3 p9

Genes and chromosomes

Chromosomes are long, thin, threadlike structures found in the nucleus of cells. Chromosomes are made of DNA and protein. The cells in the human body each contain 46 chromosomes (in 23 pairs). The only exceptions are the sperm and egg cells, which only contain 23 chromosomes (one of each pair) and red blood cells, which have no nucleus. Other organisms have different numbers of chromosome pairs in their cells.

Genes are sections of DNA. A single gene is marked in Figure 1.1.6. Each chromosome can have over 1000 genes. The difference between one gene and the next is the:

- order of bases along the DNA strand
- length of the DNA strand.

The order of the bases along the DNA strand is the genetic code. Each gene codes (contains instructions) for a specific protein. Proteins control many characteristics or functions in the body. Proteins include the structural materials that build up your cells and tissues, most hormones and all enzymes.

SciFile

That much!

The nuclei of your cells are about 6 µm or six-thousandths of a millimetre in diameter. Each nucleus contains about 2 metres of tightly coiled DNA with about 6 million base pairs.

SciFile

No nucleus

Mature red blood cells are different from all the other cells in your body. They do not have a nucleus, so they do not have any chromosomes.

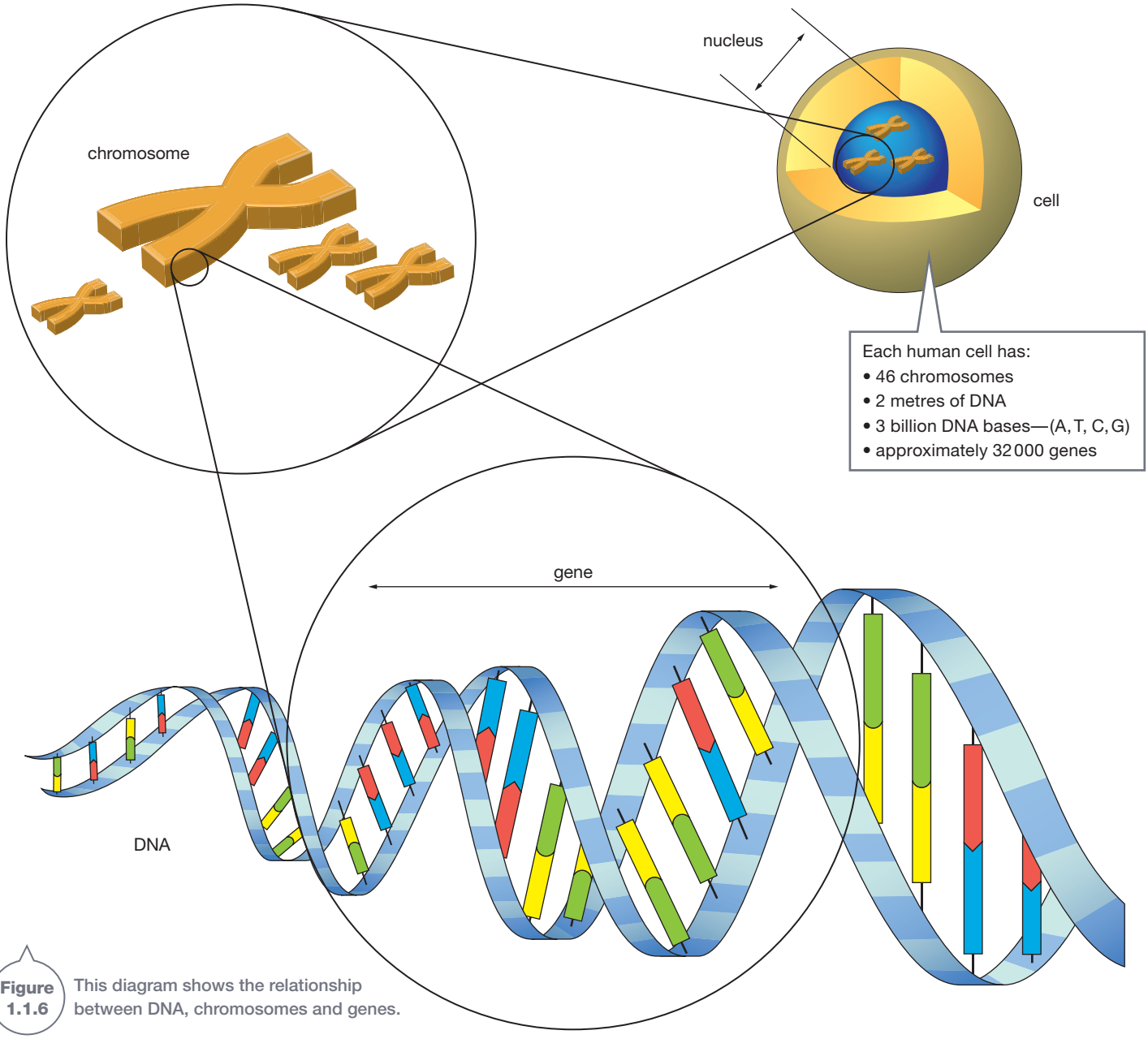


Figure 1.1.6 This diagram shows the relationship between DNA, chromosomes and genes.

SCIENCE AS A HUMAN ENDEAVOUR

Nature and development of science

Discovery of DNA

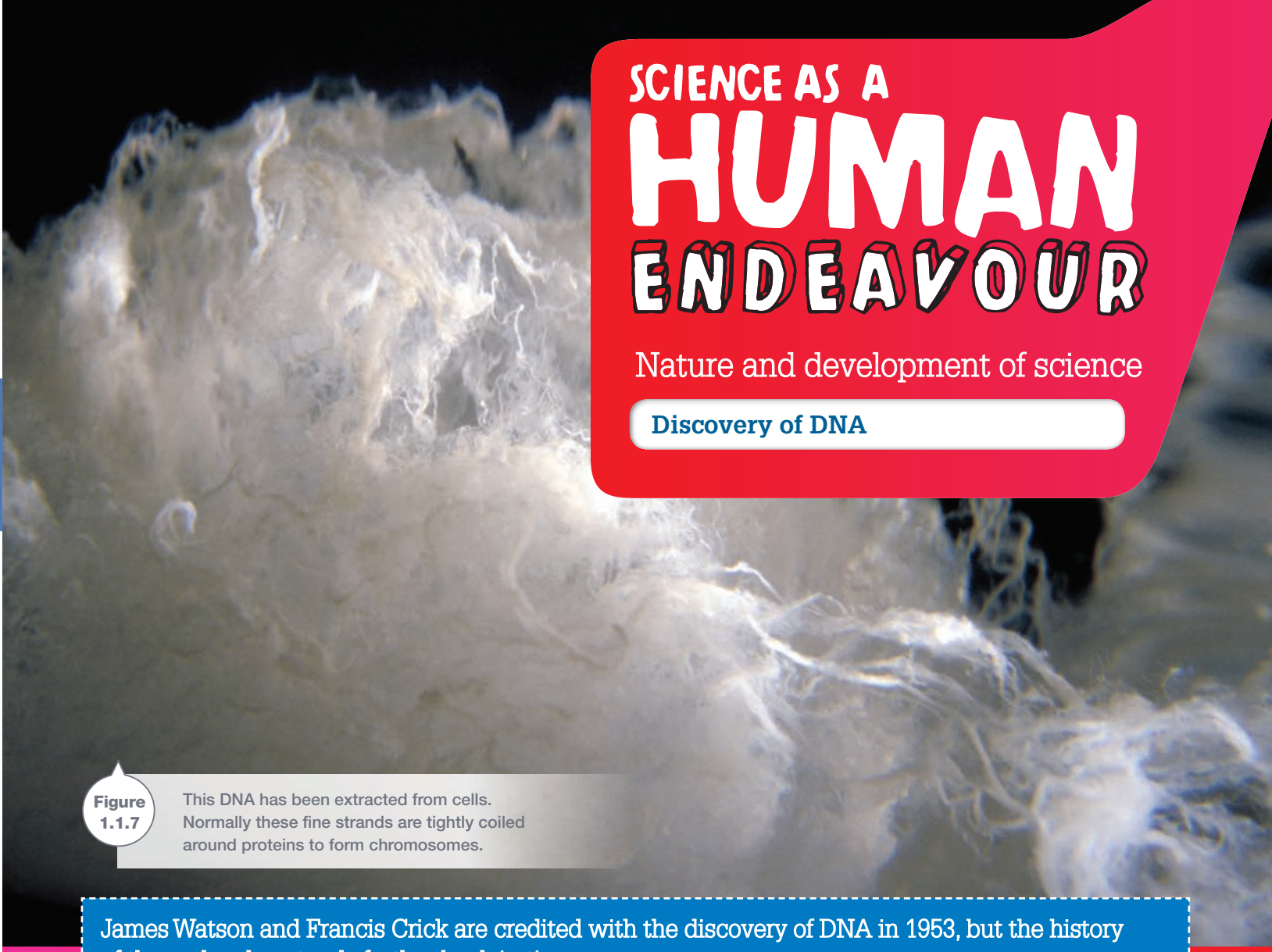


Figure 1.1.7 This DNA has been extracted from cells. Normally these fine strands are tightly coiled around proteins to form chromosomes.

James Watson and Francis Crick are credited with the discovery of DNA in 1953, but the history of the molecule extends further back in time.

In 1869, Johannes Friedrich Miescher (1844–95), a Swiss physician and biologist, isolated a previously unknown chemical from the nuclei of dead white blood cells. Miescher was looking for proteins when he identified a substance that was chemically very different. He called this new chemical *nuclein* because it was found in the cell nucleus. The name was changed to nucleic acid and eventually to deoxyribonucleic acid (DNA). DNA is shown in Figure 1.1.7. Miescher did not know that he had discovered the substance that is the genetic code.

Phoebus Levene (1869–1940) was a Russian–American biochemist who studied nucleic acids. He identified the components of DNA and the arrangement of the sugar, phosphate and base in a nucleotide. Levene thought the DNA molecule was too simple to store the genetic code.

In 1943, work by Oswald Avery (1877–1955), an American physician and medical researcher, proved Levene to be wrong—DNA does hold the genetic code.

In the 1940s, Erwin Chargaff (1905–2002), an Austrian biochemist, expanded on Levene's work. He made three significant discoveries.

- Nucleotides are not arranged in the same order in all species.
- In all species, the amounts of adenine and thymine in the DNA are always similar, as are the amounts of guanine and cytosine. This became known as Chargaff's rule.
- The amount of adenine plus guanine is always equal to the amount of thymine plus cytosine.

Much earlier (1913–14) and in a completely different field, British physicists Sir William Henry Bragg (1862–1942) and his son Sir William Lawrence Bragg (1890–1971) developed the new science of X-ray crystallography.

In the early 1950s, Rosalind Franklin (1920–58), a British scientist, used her skills as an X-ray crystallographer to investigate DNA. She and fellow worker Maurice Wilkins (1916–2004), a New Zealander working in England, created an X-ray crystallograph of DNA. From the pattern seen in Figure 1.1.8 on page 6, they deduced that DNA contained rungs like a ladder and had an X-shape—a pattern consistent with it being a helix.

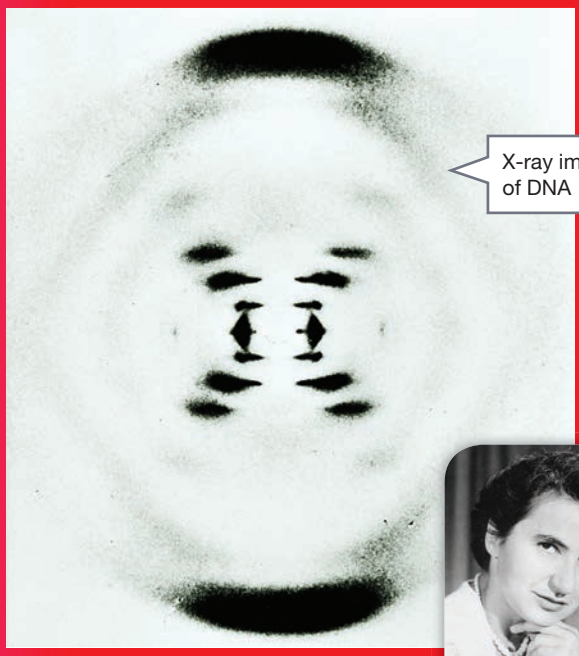


Figure 1.1.8 Rosalind Franklin obtained this image of DNA in 1953. James Watson and Francis Crick used it to work out the structure of the molecule.

In 1951, American molecular biologist James Watson (1928–) attended a lecture in which Franklin presented her research. Using this new information about DNA, Watson and his associate, Francis Crick (1916–2004), a British molecular biologist, refined the 3D models they had been building in attempts at discovering DNA structure. They used Franklin's image to fit all the parts together. Later that year they published their research with diagrams of the double helix structure of DNA (Figure 1.1.9).

In 1965, Watson, Crick and Wilkins jointly received a Nobel Prize for their work. Nobel prizes cannot be awarded posthumously so Rosalind Franklin, who died in 1958, was not included in the award. The significant contribution that her work made was not acknowledged until Watson wrote his book *The Double Helix* in 1968.

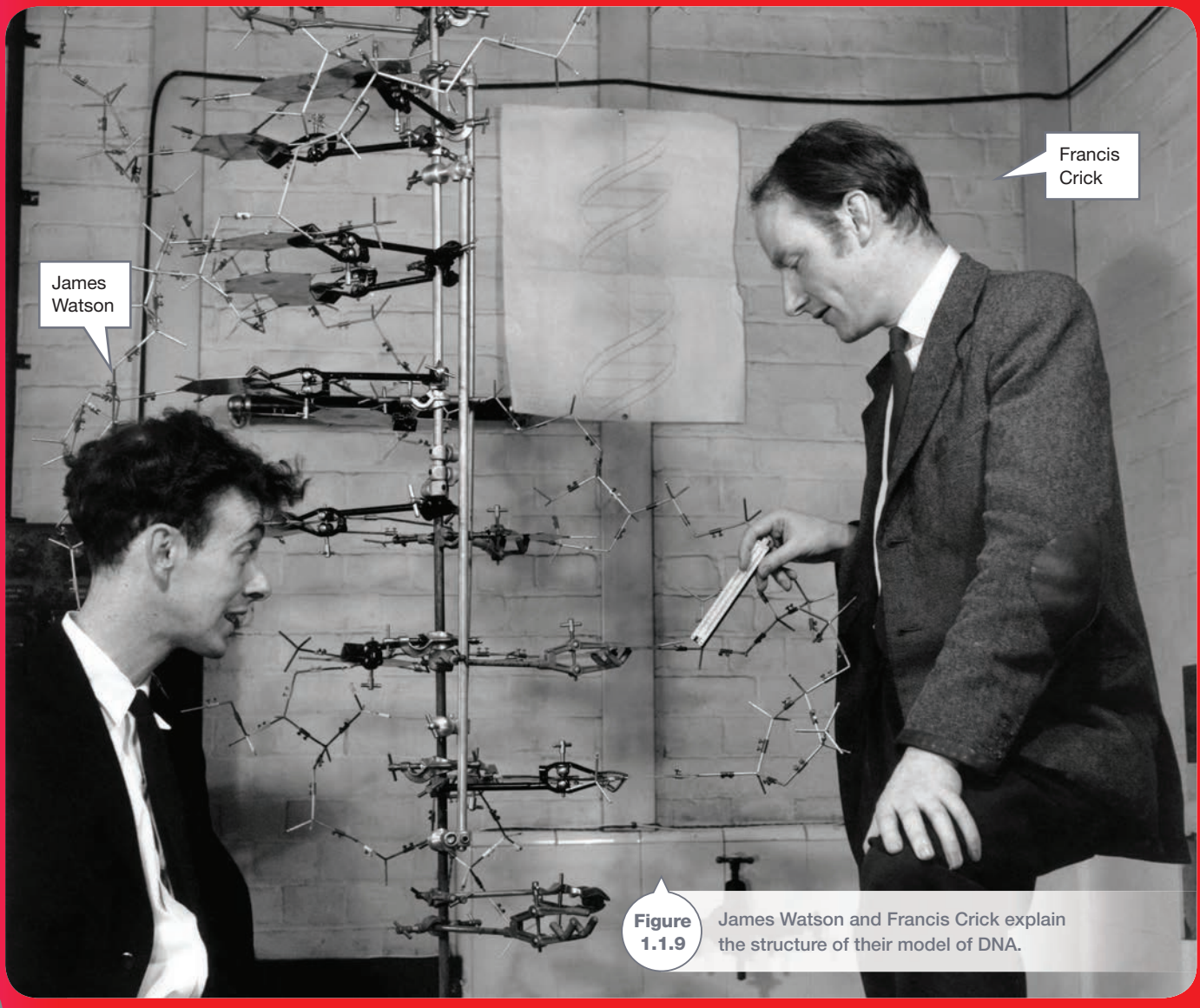


Figure 1.1.9 James Watson and Francis Crick explain the structure of their model of DNA.

1.1 Unit review

Remembering

1 **State** what the initials DNA represent.

2 **Name** the parts that are the building blocks of a DNA molecule.

3 **State** how long scientists have known of the existence of DNA.

4 **Recall** what the letters A, T, C and G represent in the context of DNA.

5 In the DNA molecule:
- a **recall** what makes the 'rungs' of the ladder
- b **name** the molecules that make the 'uprights' of the ladder
- c **recall** the molecule of the 'upright' to which the 'rungs' are joined.

Understanding

6 **Explain** why the DNA molecule is compared with a twisted ladder.

7 **Describe** where DNA is found in an organism.

8 **Describe** the relationship between DNA, chromosomes and genes in words or in pictures.

9 **Explain** in your own words what is meant by *complementary base pairing*.

10 **Explain** in your own words what characteristic of DNA creates the genetic code.

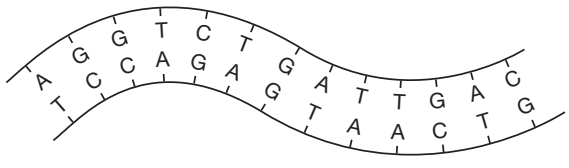
11 a **Name** four scientists who contributed to our understanding of DNA.
- b **Outline** what each scientist did.

Applying

12 **Use** coloured pencils to draw and label a simple diagram representing a:
- a DNA molecule
- b nucleotide.

13 **Identify** the mistakes in the following sections of DNA.

a



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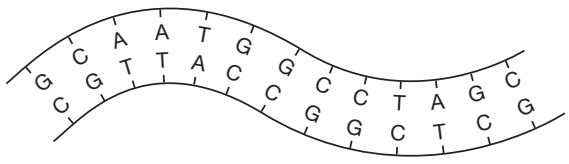

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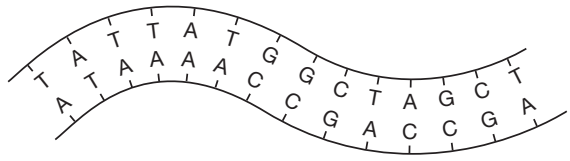


Analysing

14 **Compare** the amount of information that would be held in two chromosomes if one was shorter than the other.

15 **Compare** a gene and a chromosome.

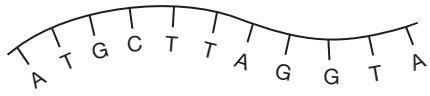
Evaluating

16 **Deduce** what similarities would be found in the DNA structure of genes from a cat, human and eucalyptus tree.

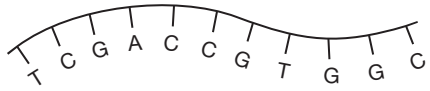
Creating

17 **Construct** a diagram of the complementary DNA strand for these two examples.

a



b



Inquiring

1 Find out what the Human Genome Project is and what scientists hope to learn from it.

2 Find out what mutations are and how certain agents can cause mutations. Agents you could research include UV radiation, nuclear radiation and certain chemicals.

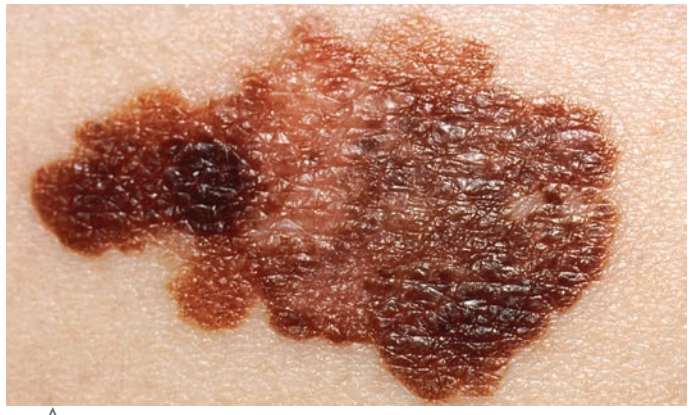


Figure 1.1.10 Melanoma is a skin cancer caused by a mutation, which in turn was caused by UV radiation from sunlight.

1.1 Practical activities

1 Investigating DNA

Purpose

To extract and examine DNA.

Materials

- $\frac{1}{2}$ cup dried split peas (soaked overnight)
- 200 mL water
- dishwashing detergent
- dropping pipette
- fine-mesh kitchen strainer
- glass rod or skewer
- large beaker
- large test-tube
- light microscope
- meat tenderiser
- methylene blue
- microscope slide and coverslip
- paper towelling
- small beaker of alcohol
- spatula
- test-tube rack
- vitamiser or blender

Procedure

Part A: Extracting the DNA

1. Process the peas and water in the blender for about 20 seconds. The mixture should be a thin, soupy consistency.
2. Pour the mixture through the strainer into the large beaker.
3. Add about 80 mL of dishwashing detergent to the strained mixture. This will help break down the cell membranes. Stir thoroughly with the glass rod.
4. Add a spatula-full of meat tenderiser (to destroy any proteins). Continue stirring for about 5 minutes.
5. Quarter-fill the large test-tube with the pea mixture.
6. Holding the test-tube at an angle, gently pour about the same quantity of alcohol (about a quarter of a test-tube) down the side of the test-tube. The test-tube should now be about half full. The alcohol should form a layer on top of the pea mixture. Alcohol causes the DNA to come out of solution.
7. Observe the mixture for a few minutes. A white, threadlike substance should rise from the pea mixture to lie above the alcohol layer (see Figure 1.1.11). This is the DNA that you have extracted from the cells of the peas.
8. Position the tip of the glass rod or skewer where you can see the threads of DNA. Slowly and steadily twist the rod or skewer as if you were making candy floss. You should be able to pull the strands of DNA out of the mixture.


Figure 1.1.11

Part B: A closer look

9. Use a pipette to carefully remove some of the DNA from the top of your preparation.
10. Place one or two drops onto a microscope slide.
11. Add 2 drops of methylene blue. Wait 3–4 minutes to allow the methylene blue to be absorbed by the DNA.
12. Place a coverslip on the slide. Soak up any excess liquid with a piece of paper towel.
13. Observe the DNA under low power, and then high power.

Results

Describe the appearance of the DNA under high power of the microscope. Use words and diagrams.

Discussion

1. **Describe** the material floating at the top of the test-tube after the alcohol was added.
2. **Explain** why each of the following chemicals was used in the extraction process:
   - detergent
   - meat tenderiser
   - alcohol.
3. **Explain** why methylene blue was used when observing the DNA under the microscope.
4. **Deduce** what factors affected your success in extracting and examining the DNA.

2 Modelling DNA

Purpose

To construct a model of DNA.

Materials

- 36 coloured paperclips (9 yellow, 9 green, 9 blue, 9 red)
- 2 strips of paper 1.5 cm × 30 cm
- coloured pencils

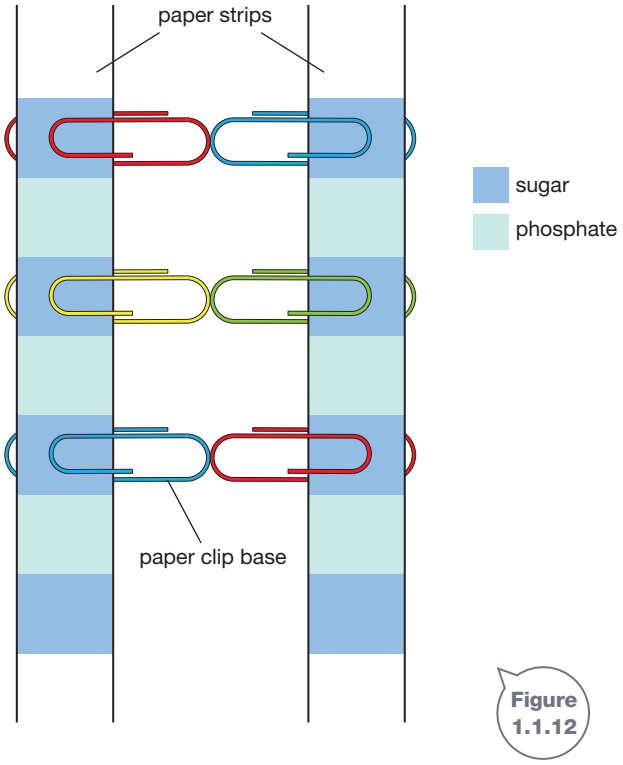


Figure 1.1.12

Procedure

1. Use paperclips to represent the bases in your DNA molecule. Choose a different colour for each of the bases adenine, guanine, cytosine and thymine. Make a note of bases and their colours. (Note: If all groups use the same colours, it will be easier to compare results at the end of the experiment.)
2. Mark the two strips of paper into 2 cm sections.
3. Shade the two strips of paper in alternating blocks of colour to represent the sugar and phosphate molecules, as shown in Figure 1.1.12.
4. Attach ten of your coloured clips randomly (in any sequence you like) to the 'sugar molecules' along one of the strips.
5. Use the base-pairing rules described on page 3 to build and attach the complementary strand.

Results

Draw a diagram of the DNA molecule you have made.

Discussion

1. **Compare** your model to the others made in your class.
2. **Account** for any similarities and differences.
3. **Calculate** the number of different variations of single DNA strands that can be made using only the ten bases you started with.
4. **Discuss** what would happen to the number of different models that could be made if the strand of DNA was thousands of bases in length.

3 Make your own DNA

Purpose

To design and build a model of DNA from scratch.

Materials

Materials of your own choice

Procedure

Construct an accurate model of a strand of DNA using different coloured objects such as lollies, beads and pipe cleaners.

Discussion

Compare your model with what DNA is really like.

1.2 Making new cells

Your life began as a single cell produced when an egg cell and sperm fused to form a zygote. As you grew, the number of cells in your body increased as the original cell divided over and over again. Now you are made up of billions of cells. Body cells continue to divide throughout life, even once you have stopped growing. Millions of skin cells, cells lining your intestines and bone cells divide, forming new cells. If this did not happen, then your skin would wear away, cuts would not heal and you would run out of blood. Without cell division, reproduction would be impossible.

INQUIRY science 4 fun

Variation

How does increasing the number of variables affect the amount of variation?

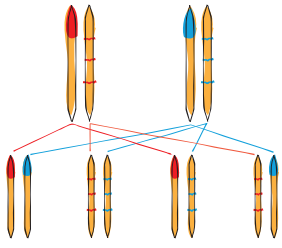
Yes

Collect this…

- 8 toothpicks
- 4 colours of marker pen (e.g. red, blue, green and purple)

Do this…

1. Create a red pair of toothpicks by colouring the tip of one red and placing two or three red stripes on the other. Create blue, green and purple pairs in the same way.
2. Sort the toothpicks into their colour pairs.
3. Sort the red and blue toothpicks into two groups with one red and one blue toothpick in each. Now try a different combination of red and blue. Make as many different groups as possible. Use the diagram on the right as a guide.
4. Record the number of pairs you created.
5. Add in the pair of green toothpicks. Again sort the toothpicks into two groups each with three toothpicks—one toothpick of each colour. Create as many different groups as you can.
6. Record the number of different groups you created.
7. Add in the purple toothpicks and sort all the toothpicks into two groups of four, following the same rules about colour.
8. Record the number of different groups you created.



Record this…

Describe how you were able to change the number of groups you created.

Explain why this happened.

Replicating the DNA

Apart from red blood cells, all the cells in your body have nuclei that contain chromosomes made of DNA. Each cell contains exact copies of the chromosomes that were in the original zygote that became you. This means that it must be possible to copy DNA molecules. The process of copying DNA is known as **replication**.

Replication

In the first step of replication (shown in Figure 1.2.1), the strands of the double helix separate from each other in much the same way as a zip opens. The bases are then exposed. Within the nucleus there are individual nucleotides that are not part of a DNA chain. In step 2, these nucleotides pair up with the exposed bases following the rules of complementary base pairing. In step 3, the sugar and phosphate molecules bond with neighbouring nucleotides and new strands of DNA are formed

Replication occurs on both of the exposed strands of DNA, and the result is two identical double helices of DNA. Figure 1.2.2 shows chromosomes after replication. Each chromosome is a double structure made up of two **chromatids** joined together. Each chromatid is a double helix of DNA.

Having made copies of all the chromosomes, the cell is ready to divide.

Figure 1.2.2 Scanning electromicrograph (SEM) of a human chromosome that has replicated and which consists of two identical chromatids

SciFile

Slow copy

It takes about 8 hours for one of your cells to completely copy its DNA.

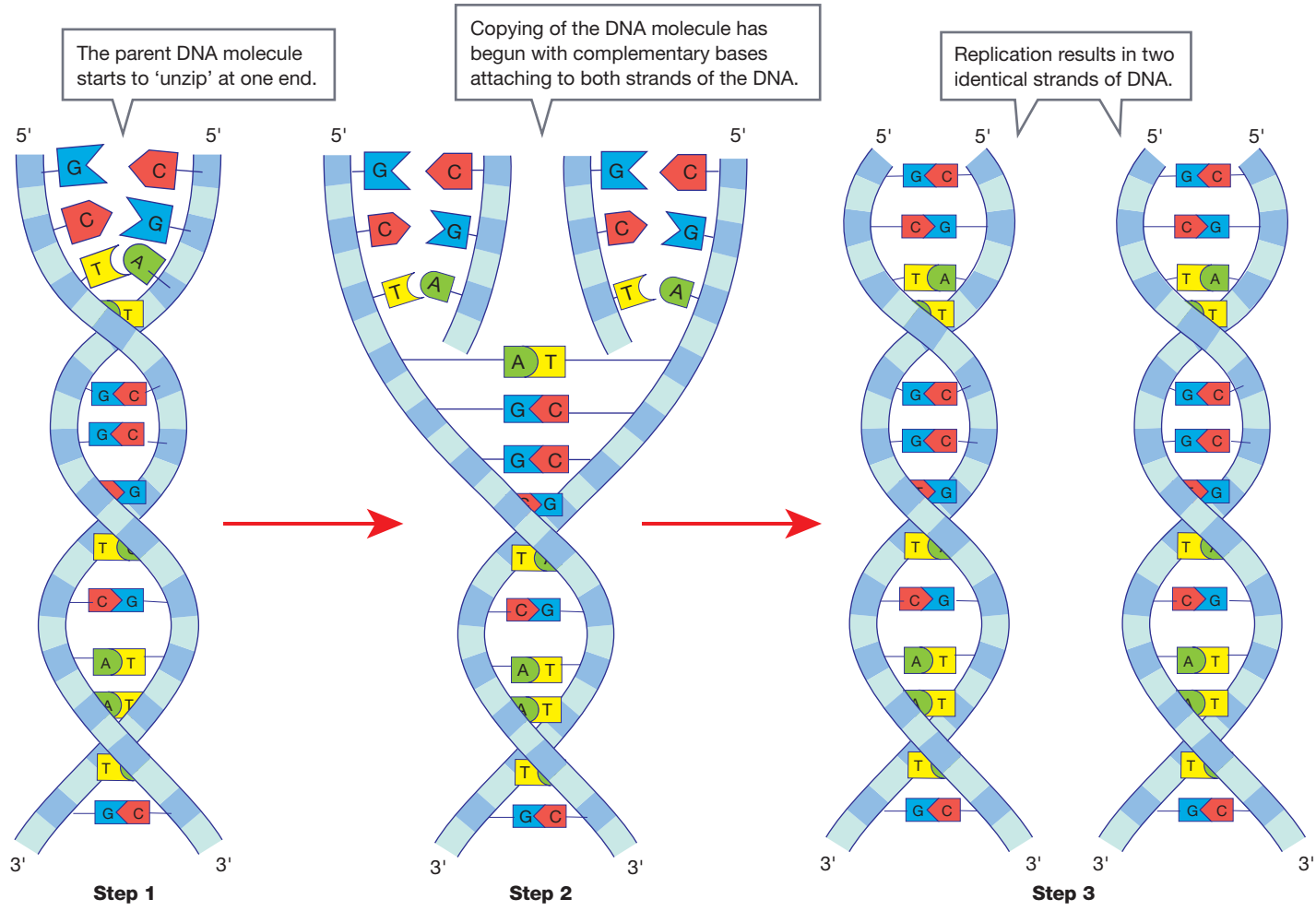


Figure 1.2.1 DNA replication involves three distinct stages.

Cell division

There are two types of cell division:

- **Mitosis** produces two daughter cells that are identical to the parent cell. This is the type of cell division involved in growth and repair of the body.
- **Meiosis** produces gametes (eggs and sperm) that have half the number of chromosomes of the parent cell.

Mitosis

Mitosis is a continuous process. However, scientists have identified several distinct stages in the process. These can be seen in Figures 1.2.3 and 1.2.4.

In the period between the actual divisions of the cell, the DNA replicates. At this stage, individual chromosomes are not visible.

When the cell begins to divide, the DNA coils up and separate chromosomes become visible. Each chromosome comprises two chromatids. The membrane surrounding the nucleus breaks down. Chromosomes line up across the equator (middle) of the cell and a network of fibres appears, extending from the poles of the cell to each chromosome.

The chromatids separate to become two independent chromosomes. The network of fibres contracts, pulling the chromosomes to opposite poles (ends) of the cell. A nuclear membrane encloses the chromosomes at each pole. The chromosomes uncoil and are no longer visible as individual strands.

Division of the nucleus is complete. The cytoplasm divides and the result is two identical daughter cells. The daughter cells grow in size in preparation for the next round of cell division.

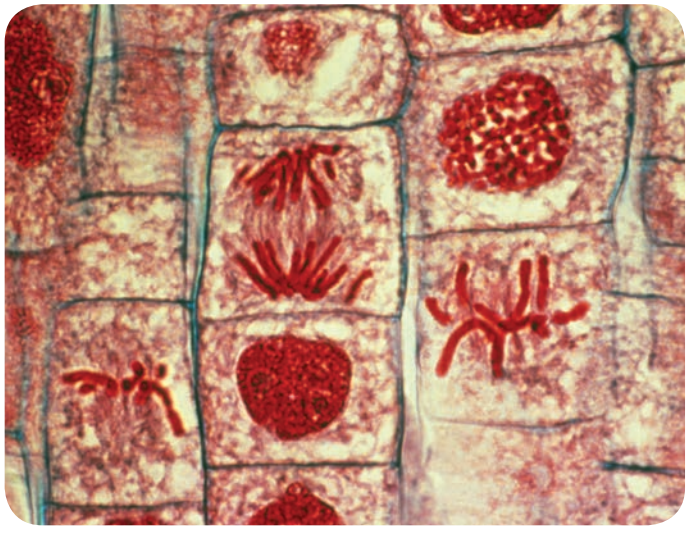


Figure 1.2.3 Light micrograph of phases of mitosis in cells from an onion

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1.3

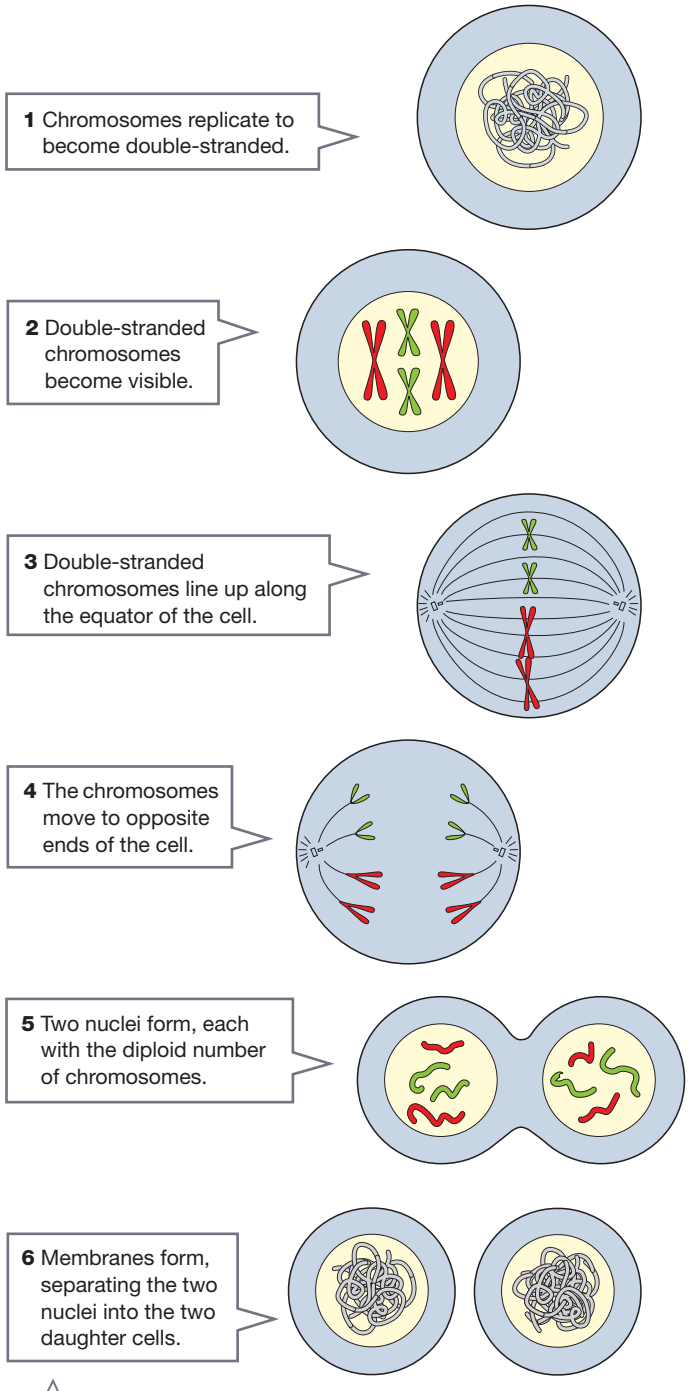

Figure 1.2.4 The stages of mitosis

Chromosome number

In your body cells, there are 46 chromosomes, half of which came from your father and half from your mother. The number of chromosomes in your body cells is the **diploid number**. The diploid number is also described as 2N, which means two sets.

In your gametes, there has to be half this number of chromosomes. If each parent passed on their complete set of genetic information, then their offspring would have 4N chromosomes and then the next generation would have 8N and so on. By halving the number of chromosomes in the

gametes, the number of chromosomes from generation to generation is kept constant at 2N.

Of the 46 chromosomes in your cells, two are **sex chromosomes**—the ones that determine whether you are male or female. The other 44 chromosomes are not sex chromosomes and are known as **autosomes**. In human females, the sex chromosomes are a pair of X chromosomes (XX). In males, the sex chromosomes are one X and one Y chromosome (XY).

The autosomes in your cells are grouped into 22 pairs. The chromosomes in the pair are homologous. **Homologous chromosomes** are the same length, have the **centromere** (the point where the two chromosomes join) in the same position. Homologous chromosomes also have genes for particular characteristics at the same location along their length. For example, the gene for hair curliness is found in the same position on the pair of homologous chromosomes shown in Figure 1.2.5. Therefore, each new cell formed by mitosis of the zygote has two copies of the gene for each characteristic, one on each chromosome of the homologous pair.

One chromosome from each homologous pair must end up in each gamete that is produced. Therefore, the gametes have 23 chromosomes in total. This is the **haploid number** or N.

The female sex chromosomes are a homologous pair. The male X and Y chromosomes are not homologous but they behave as a pair during meiosis.

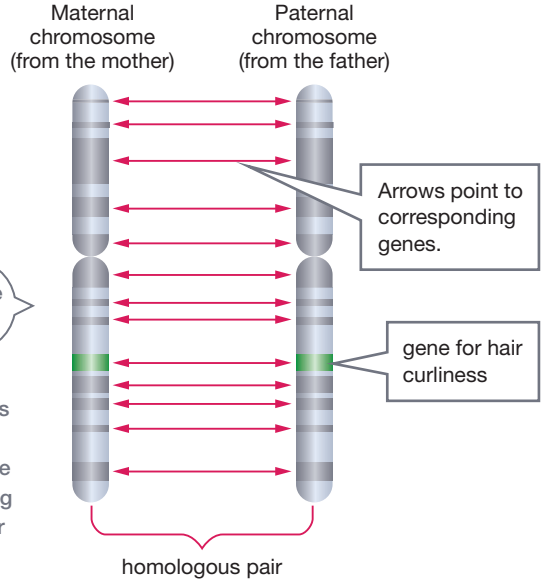

Figure 1.2.5 Homologous chromosomes showing the position of the corresponding genes for hair curliness

Meiosis

Meiosis is the process of cell division that produces gametes. The chromosomes replicate in preparation for division just as they do for mitosis. The stages of meiosis are seen in Figure 1.2.6.

The nuclear membrane breaks down and then, in preparation for the first part of meiosis, the homologous pairs of chromosomes line up on the equator of the cell. A network of fibres extends from the poles of the cell to each chromosome pair. The fibres contract, drawing one chromosome from each pair to opposite poles of the cell. At this stage, each chromosome is still two chromatids.

A new network of fibres forms at right angles to the first. The fibres attach to the chromosomes that have lined up on the equator of the cell. This time when the fibres contract, the chromatids are pulled apart towards the poles of the cells.

There are now bundles of 23 chromosomes. New nuclear membranes form and the cytoplasm divides to produce four new cells, each containing the haploid number of chromosomes. These cells are the gametes or sex cells.

2 p17 1.4

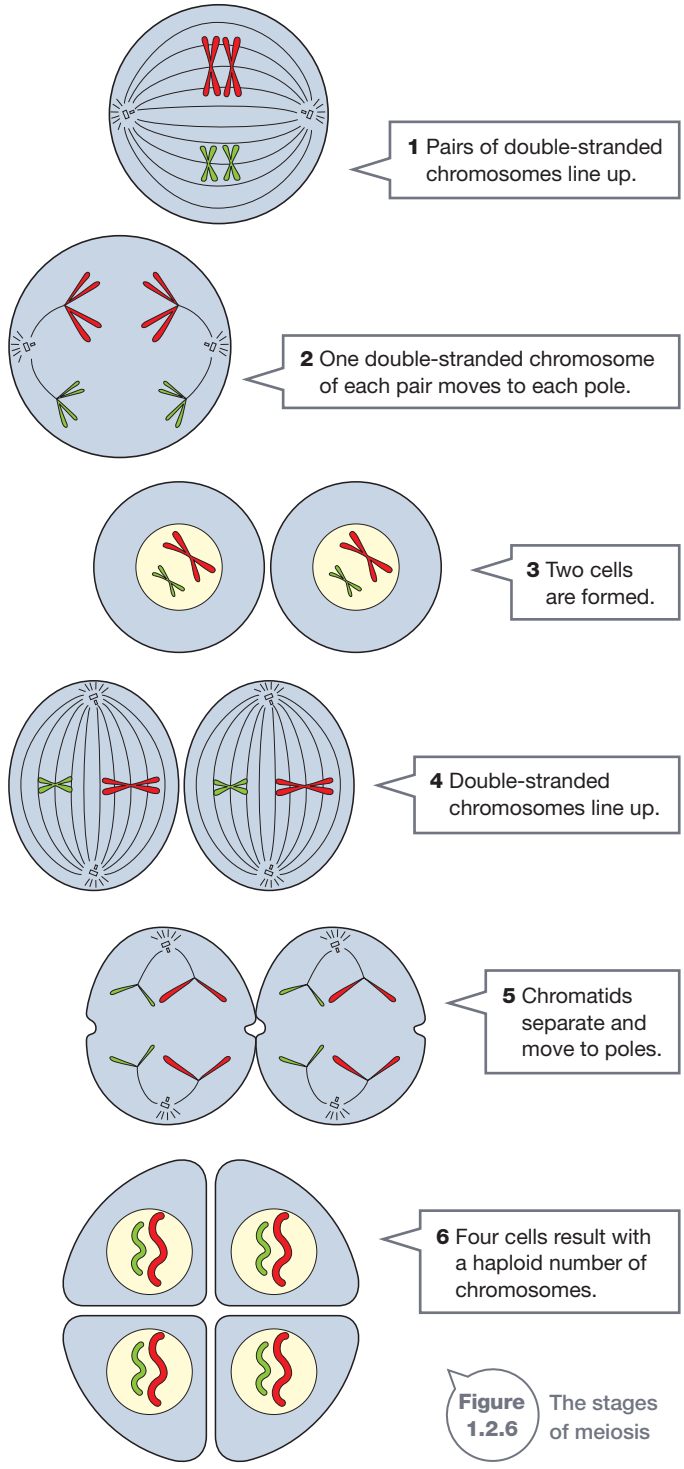

Figure 1.2.6 The stages of meiosis

Asexual and sexual reproduction

There are plants and animals that sometimes reproduce asexually. This means that offspring are produced through mitosis of particular cells without any union of gametes. Hydra and grasses are examples of organisms that use asexual reproduction. The hydra in Figure 1.2.7 is a simple multicellular organism that reproduces by budding when conditions are favourable. Cells on the side of the body multiply by mitosis and a new hydra forms.

Figure 1.2.7

This small hydra will grow to almost adult size and then break off from the parent to become an independent organism.

Figure 1.2.8

This grass is reproducing using asexual reproduction.

Many grasses, such as the one in Figure 1.2.8, form stems (known as runners) that grow over the ground surface. At intervals, roots grow down, anchoring the runners. Shoots grow up at this point, creating a new individual. In both these examples the offspring inherit all the genetic information from one parent only. Parent and offspring are genetically identical.

Sexual reproduction creates variation in a population. The four gametes produced by meiosis of one cell are all different. They all have the same number of chromosomes and carry the information about the same characteristics. However, the specific information is different. All the gametes your body ever produces will be different from each other.

Figure 1.2.9 is an example of a homologous pair of chromosomes carrying the gene for eye colour. In this example, one chromosome holds information for blue eyes, while the other specifies brown eyes. When this cell forms gametes, half will have the chromosome carrying information for blue eyes and the other half will have the information for brown eyes.

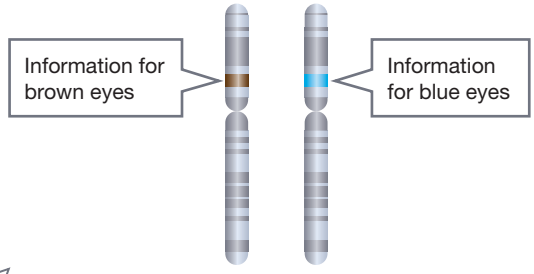

Figure 1.2.9 Homologous pair of chromosomes carrying the gene for eye colour

Another example is shown in Figure 1.2.10, in which a different pair of homologous chromosomes carries information about the length of the second toe. Some people have a second toe that is longer than their big toe. In others the second toe is shorter. If one chromosome has the information for a long second toe and the other has the information for a short second toe, then half the gametes will have information for a short toe and half will have information for a long toe.

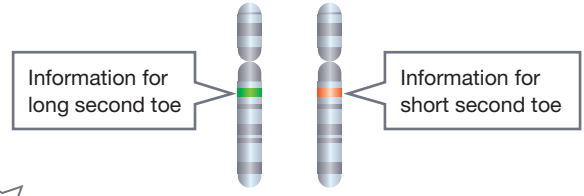

Figure 1.2.10 Homologous chromosomes for toe length

Consider the chromosomes for eye colour and toe length in one person. During meiosis when the chromosomes in a pair separate, the homologous chromosomes randomly go to either end of the cell. Figure 1.2.11 demonstrates that the four gametes produced could carry different combinations of the information about eye colour and toe length.

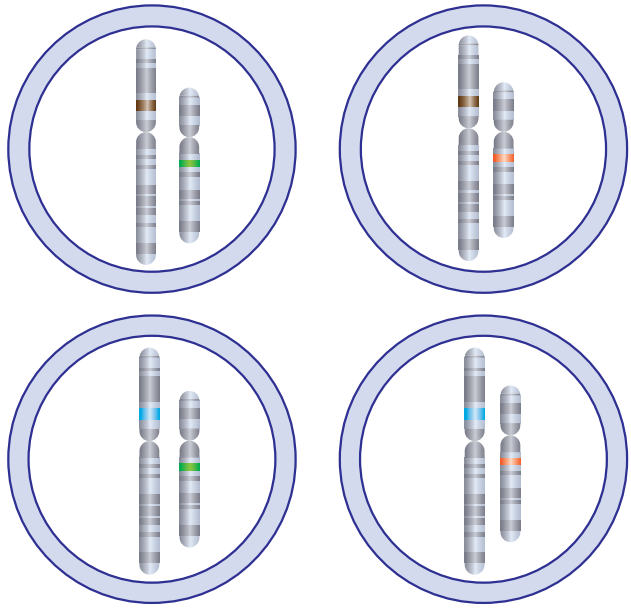

Figure 1.2.11 The gametes produced from the homologous chromosomes shown in Figures 1.2.9 and 1.2.10

1.2 Unit review

Remembering

1 **Name** the type of cell division that is responsible for growth and repair in the body.

2 **Recall** the key terms described by:
- a one of the strands of a chromosome following replication
- b the process of making copies of DNA.

3 **State** the type of cell division that produces gametes.

Understanding

4 **Explain** why it is essential for chromosomes to replicate before cell division occurs.

5 A gamete (sex cell) is haploid. **Explain** what this means.

6
- a **State** the types of cell division involved in creating a puppy.
- b **Explain** the role of each type of cell division.

7 **Describe** the role of the network of fibres in cell division.

8 **Explain** why it is important that the number of chromosomes is reduced when gametes are formed.

9 **Explain** what happens in the cell nucleus between cell divisions.

Applying

10 A horse has 64 chromosomes in its body cells. **Calculate** how many chromosomes will be in each of its gametes.

11 **Calculate** how many chromosomes will be in the cells of a tomato plant where there are 12 chromosomes in a gamete.

12
- a **Use** a diagram to **demonstrate** the structure of a double-stranded chromosome.
- b **Label** the chromatids.

13 **Identify** what Figure 1.2.12 represents.

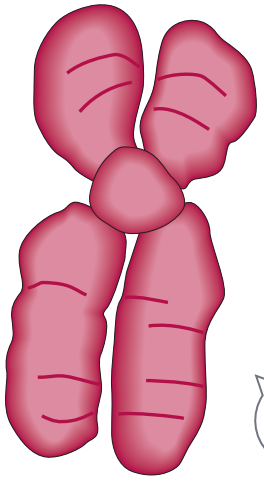

Figure 1.2.12

14 **Identify** the homologous pair in the chromosomes in Figure 1.2.13.

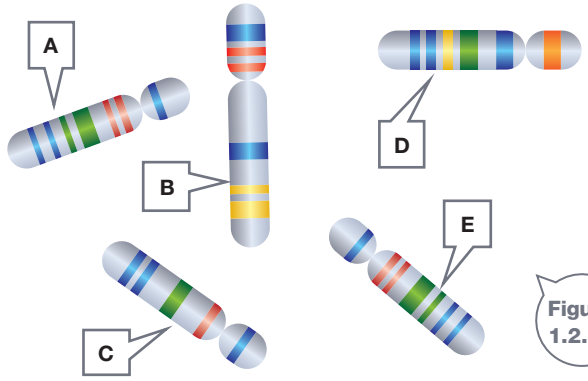

Figure 1.2.13

Analysing

15 **Contrast** haploid with diploid cells.

16 **Compare** chromosomes and chromatids.

17 Characteristics of two pairs of chromosomes are shown in Figure 1.2.14. **Demonstrate** all the combinations that would be possible in gametes if this cell were to undergo meiosis.

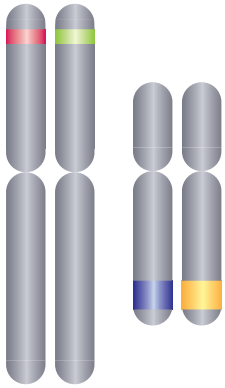

Figure 1.2.14

Evaluating

18
- a Figure 1.2.15 represents a section of single-stranded DNA. **Deduce** what the strand would be like after replication and **use** a diagram to represent your idea.
- b **Justify** your structure in part A.

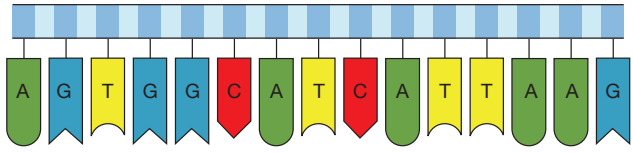

Figure 1.2.15

1.2 Unit review

19 The following table shows the number of chromosomes in the body cells of different organisms.

- **a** Copy the table into your workbook.
- **b** **Deduce** the number of homologous pairs and the number of chromosomes in the gametes to complete the table.

Organism	Number of chromosomes diploid number	Number of pairs of chromosomes	Number of chromosomes in the gametes
Dog	78		
Kangaroo	12		
Ant	2		
Mango	40		
Tomato	24		

20 **Propose** what is happening in the cells labelled A, B and C in Figure 1.2.16.

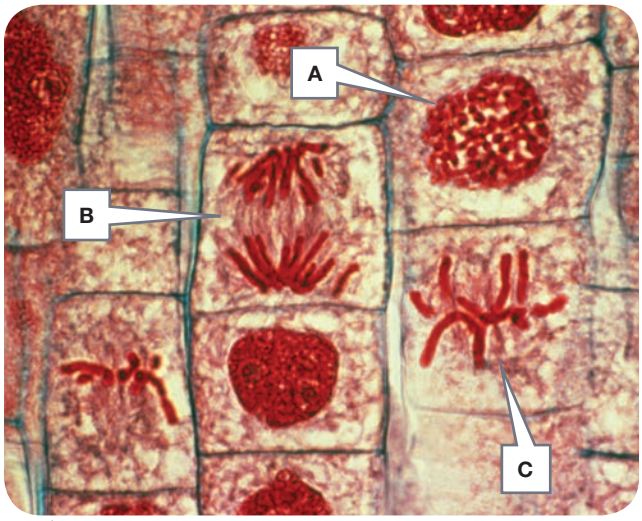

Figure 1.2.16 These cells are undergoing mitosis.

Creating

21 **Construct** a table to compare mitosis and meiosis.

22 **Construct** a flow diagram for the process of DNA replication.

23 **Use** strips of paper to **construct** a simulation of mitosis in an organism with four chromosomes. You need to be able to move the chromosomes around and show where they go. Don't forget to make chromatids.

24 **Design** an activity where making kebabs could be used to demonstrate the concept of homologous chromosomes.

Inquiring

1 Research whether there is a relationship between the diploid number of chromosomes in a species and the level of complexity and intelligence of that species.

2 Research how living things grow and what controls the rate of cell division.

3 Research the relationship between mitosis and cancer.

1.2 Practical activities

1 Observing mitosis

Purpose

To observe mitosis in plant roots.

Materials

- prepared slides of onion root tips
- microscope

Procedure

1. Using a prepared slide and the low power on the microscope, focus on cells just behind the tip of the root (Figure 1.2.17).
2. Search for nuclei that appear to contain threads instead of appearing as dark circles. These are the cells that will be undergoing mitosis.
3. Focus on these cells and then switch to high power and focus on a cell where the chromosomes are clearly visible.
4. Find other cells that seem to be in different stages. For example, look for evidence of two newly formed cells.

Results

1. Draw diagrams of the cells you have found.
2. Organise your diagrams so that they represent the process of mitosis.
3. Draw a diagram showing where in the root mitosis is taking place.

Discussion

1. **Discuss** whether or not you would expect all cells in a root to be undergoing mitosis.
2. **Use** your observation to **assess** whether all of the cells in the area of the root tip you looked at were undergoing mitosis.
3. Growth due to mitosis occurs near the tip of the root rather than right on the tip or further back. **Propose** the benefits to the plant of this arrangement.

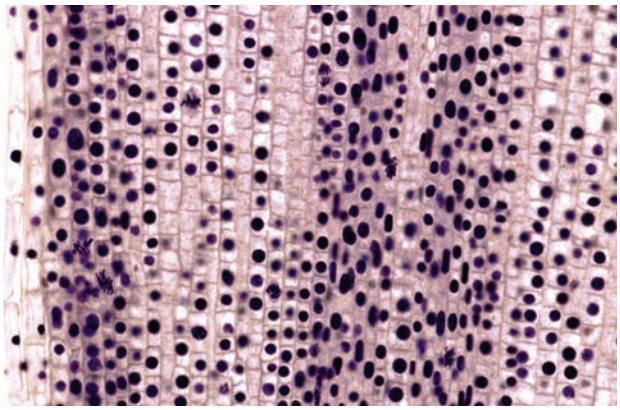

Figure 1.2.17 Stained onion root tip cells

2 Observing meiosis

Purpose

To observe meiosis in the anther of a flower.

Materials

- prepared slide of an anther
- microscope

Procedure

1. Using a prepared slide and the low power on the microscope, focus on cells inside the anther.
2. Search for nuclei that appear to contain threads instead of appearing as dark circles. These are the cells that will be undergoing meiosis.
3. Focus on these cells and then switch to high power and focus on a cell where the chromosomes are clearly visible.
4. Find other cells that seem to be in different stages. For example, look for evidence of two or four newly formed cells.

Results

Draw diagrams of the cells you have found.

Discussion

1. **Compare** your drawings and then place a number beside each diagram to represent the order they would appear in the process of meiosis.
2. **Explain** why meiosis would be occurring in the anther of a flower.
3. **Explain** how many chromosomes the gametes will have compared with the cell that divided to form them.
4. a **Propose** where else in a flower you could look for meiosis taking place.
   b **Justify** your proposal.