Heredity

Unit 2

Contents

2.1 Mitosis and meiosis

By the end of this section you should be able to:

- Define a chromosome.
- Define DNA as the genetic material.
- Define genes.
- Describe the structure of the chromosomes.
- Describe the components of DNA.
- Define mitosis and describe its stages.
- Define meiosis and describe its stages.
- Relate the events of meiosis to the formation of the sex cells.
- Compare mitosis and meiosis.

Almost all the cells of your body – with the exception of your mature **red blood cells** – contain a nucleus, the 'control room' of the cell. The nucleus contains all the plans for making a new cell, and for making a whole new you.

Think of the plans for building a car. They would cover many different sheets of paper. Yet in every living organism, the nucleus

KEY WORDS

red blood cell *type of blood cell that carries oxygen around the body*

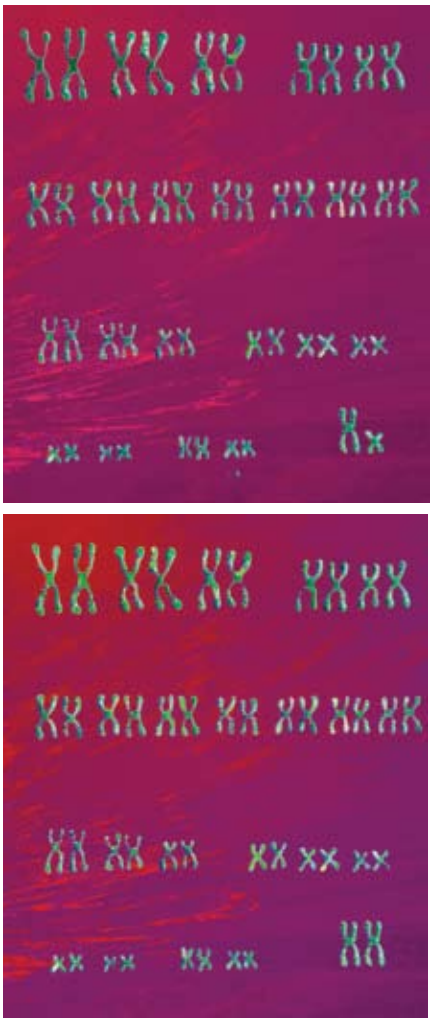


Figure 2.1 *Karyotypes, like these of a healthy man and woman, have helped scientists find out more about the mysteries of inheritance.*

of the cells contains the information needed to build a whole new animal, plant, bacterium or fungus. A human being is far more complicated than a car – so where does all the information fit in?

Inside the nucleus of every cell there are thread-like structures called **chromosomes**. This is where the genetic information passed on from parent to child is stored.

The chromosomes are made up of **DNA** (**deoxyribonucleic acid**). This amazing chemical carries the instructions needed to make all the proteins in your cells. Many of these proteins are actually enzymes. These control the production of all the other chemicals that make up your body, and affect what you look like and who you are.

- A chromosome is a structure in the nucleus of a cell consisting of genes.
- Chromosomes are made up of the genetic material DNA in a DNA–protein complex.
- DNA is the genetic material contained in the nucleus.

Each different type of organism has a different number of chromosomes in the cells – humans have 46 chromosomes and tomatoes have 24, while elephants have 56. You inherit half your chromosomes from your mother and half from your father. Chromosomes come in pairs known as **homologous** pairs. So people have 23 pairs, tomatoes have 12 pairs and elephants have 28 pairs of chromosomes.

Scientists can photograph the chromosomes in human cells when they are dividing and arrange them in pairs to make a special picture known as a **karyotype**.

Human karyotypes show 23 pairs of chromosomes. In 22 of the pairs, both chromosomes are the same size and shape, regardless of whether you are a boy or a girl. These 22 pairs of chromosomes are known as the **autosomes**. They control almost everything about the way you look and the way your body works. The remaining pair of chromosomes is different for boys and girls. A girl has a pair of two similar X chromosomes, but a boy has one X chromosome and another, much smaller, Y chromosome. These are known as the sex chromosomes because they determine whether you are male or female. Everyone inherits an X chromosome from their mother. If this joins with a sperm carrying another X chromosome, you will be a girl. If it is fertilised by a sperm carrying a Y chromosome, you will be a boy. X chromosomes carry information about being female, but they also carry information about many other things – like the way your blood clots, and the formation of your teeth, body hair and sweat glands. Y chromosomes mainly carry information about maleness.

Activity 2.1: Making a karyotype

You are going to make a human karyotype. You will be provided with a photograph or worksheet showing a photograph of unordered human chromosomes, exactly as a real scientist would take. Your task is to cut out each of the chromosomes and arrange them in pairs as you have seen in figure 2.1. Try and identify each pair and stick them onto a sheet of paper, labelling them carefully. Is your person male or female?

Chromosomes, genes and DNA

The chromosomes you inherit from your parents carry all the information needed to make a new you. The information is kept in the form of genes. Each gene is a small section of DNA. Life as we know it depends on the properties of this complicated chemical, so it seems amazing to think we have only understood it for about 50 years!

- A gene is a unit of hereditary material located on the chromosomes.

DNA is a long molecule, made up of two strands twisted together to make a spiral known as a **double helix** – imagine a ladder that has been twisted round. The big DNA molecule is actually made up of lots of smaller molecules (nucleotides) joined together. A nucleotide consists of a phosphate group, a sugar and a base. In DNA there are four different bases that appear time after time in different orders, but always paired up in the same way. The **bases** link the two strands of the DNA molecule together. Genes are made up of repeating patterns of bases in the DNA. (See page 22.)

By the 1940s, most scientists had decided that DNA was probably the molecule that carried inherited information from one generation to the next. But how did it work?

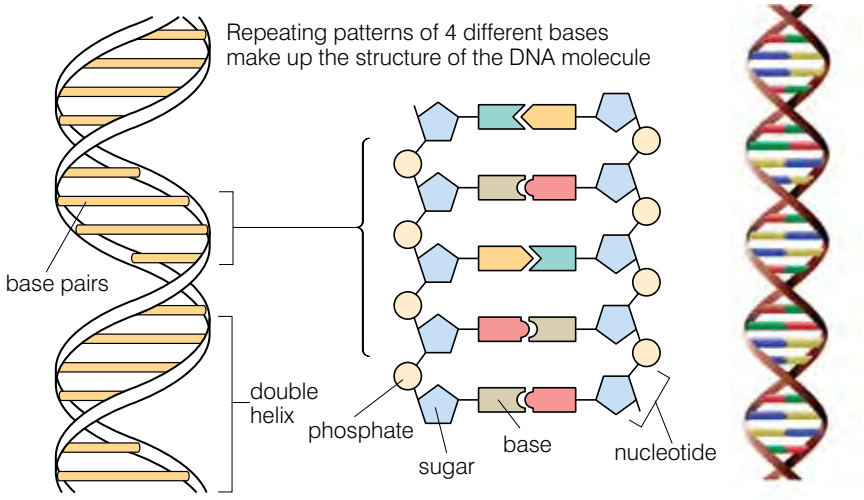


Figure 2.3 *The double helix structure of the DNA molecule takes you deep into the chemistry of life. A small change in the arrangement of bases in your DNA would have meant a very different you.*

By the 1950s, two teams in the UK were getting close to understanding the structure of this amazing molecule. Maurice Wilkins and Rosalind Franklin in London were taking special X-ray photographs of DNA and looking at the patterns in the X-rays in the hope that they would show them the structure of the molecule. At the same time, James Watson (a young American) and Francis Crick (from the UK) were working on the DNA problem at Cambridge. They took all the information they could find on DNA – including the X-ray crystallography from London – and kept trying to build a model of the molecule that would explain

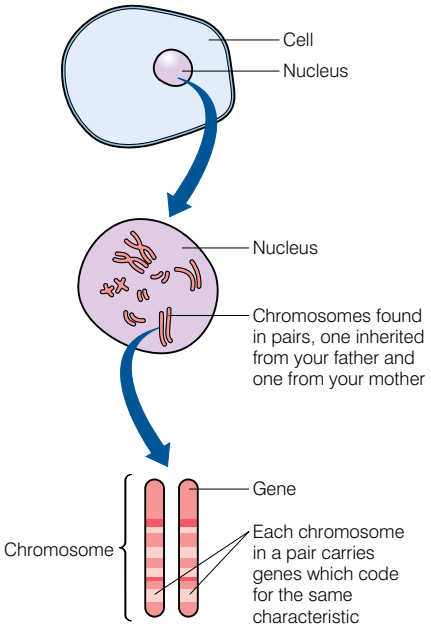


Figure 2.2 *The nuclei of our cells contain the chromosomes that carry the genes that control the characteristics of our whole body.*

KEY WORDS

chromosome *strand of DNA carrying genetic information*

DNA *nucleic acid containing the genetic instructions used in the development and functioning of all known living organisms and some viruses*

homologous chromosomes *a pair of chromosomes having the same gene sequences, each derived from one parent*

karyotype *map of the chromosomes in the nucleus of a single cell*

autosomes *chromosomes that are not sex chromosomes*

double helix *pair of parallel helices intertwined about a common axis*

KEY WORDS

adenine *one of the four bases that comprise DNA which pairs with thymine*

thymine *one of the four bases that comprise DNA which pairs with adenine*

guanine *one of the four bases that comprise DNA which pairs with cytosine*

cytosine *one of the four bases that comprise DNA which pairs with guanine*

nucleotide *a building block of DNA or RNA which consists of a sugar, a phosphate, and one of the four bases*

polynucleotide *long chains of linked nucleotides*

DID YOU KNOW?

The Human Genome Project has cost around 3 billion US dollars so far. Scientists have worked out the 3 billion base pairs that make up human DNA – and have shown that everyone shares around 99.99% of their DNA. It looks as if human beings have only between 20 000 and 25 000 genes, far fewer than scientists originally predicted.

everything they knew. When they finally realised that the bases always paired up in the same way, they had cracked the code. The now famous double helix was seen for the first time. Watson, Crick and Wilkins all received the Nobel Prize for their work. Rosalind Franklin died of cancer before the prizes were awarded.

Since the structure of DNA was revealed, there has been an enormous explosion in the amount of research done on genetics. We now know that the bases that make up DNA are called **adenine**, **thymine**, **guanine** and **cytosine**. The two DNA strands are linked by these bases, where adenine pairs with thymine and cytosine pairs with guanine. The upright strands are made of deoxyribose sugar and phosphate. Each base, sugar and phosphate together form a **nucleotide**. DNA is therefore a **polynucleotide** chain.

The genes found on the chromosomes control everything that goes on in your cells by organising all the proteins that are made. As you learned in grade 9, a protein is a long chain of amino acids. Different combinations of amino acids can be joined together to make different proteins. So the order of the bases in the DNA acts as a code to instruct the cell about the order in which to join up the amino acids to make a particular protein. This is how the genes control what goes on in the cells and in the whole organism.

The Human Genome Project has been a massive international effort by scientists from many countries who set out to read the DNA of the entire human genome. This work is showing us exactly what genes we all have in common, and which characteristics they code for.

Mitosis

New cells are needed for an organism, or part of an organism, to grow. They are also needed to replace cells that become worn out and repair damaged tissue. However, the new cells that are produced must contain the same genetic information as the originals, so that they can do the same job.

In animals and plants that have asexual reproduction it is necessary for one cell to split into two genetically identical cells for the organism to reproduce.

Figure 2.4 *As we grow, it is important that we can make new cells which are just the same as the old ones, so we can grow and repair any damage that occurs during our life.*

KEY WORDS

somatic cells *any of the cells of a plant or animal except the reproductive cells*

mitosis *cell division in which the nucleus divides into nuclei containing the same number of identical chromosomes*

chromatids *the two strands of a chromosome that separate during mitosis*

daughter cells *the two identical cells that are formed when a cell reproduces itself by splitting into two*

Body cells (also known as **somatic cells**) divide to make new cells. The cell division that takes place in the normal body cells and produces identical cells is known as **mitosis**. As a result of mitosis, every body cell has the same genetic information. In asexual reproduction, the cells of the offspring are produced by mitosis from the cells of their parent. This is why they contain exactly the same genes with no variety.

- Mitosis is division of the somatic cells to make identical daughter cells.

How does mitosis work? Before a cell divides, it produces new copies of the homologous pairs of chromosomes in the nucleus. Each chromosome forms two identical **chromatids**. Then the chromatids divide into two identical packages, and the rest of the cytoplasm divides as well to form two genetically identical **daughter cells**. Once the new cells have formed, the chromatids are again referred to as chromosomes. The daughter cells each have exactly the same number of chromosomes as the original cell. To make it easier to understand what is going on, we divide this process into stages – interphase, prophase, metaphase, anaphase and telophase (figure 2.5) – but in fact mitosis is one continuous process.

In some areas of the body of an animal or plant, cell division like this carries on rapidly all the time. Your skin is a good example – thousands of cells are constantly being lost from the surface, and new cells are constantly being formed by cell division to replace them. As food passes along your gut (grade 9 biology), cells are scraped off the gut lining. Fortunately, there is a layer of cells underneath that is constantly dividing by mitosis to replace those that are lost.

DID YOU KNOW?

Your red blood cells have a finite life because they lose their nuclei as they mature. Worn-out red blood cells are destroyed, at a rate of around 100 billion per day, by your spleen and liver. Fortunately, mitosis takes place in your bone marrow just as quickly to make the new red blood cells you need.

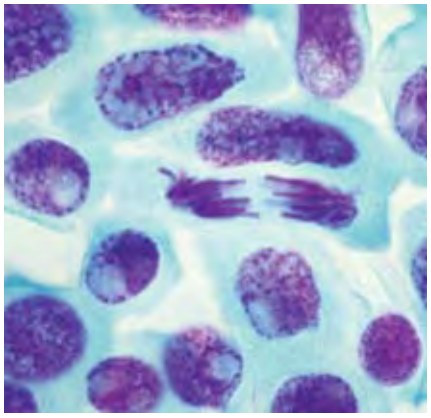


Figure 2.6 *These cells are in the growing root tip of an onion, so they are dividing rapidly and the chromosomes have taken up a red stain. You can see mitosis taking place, with the chromatids in different positions as the cells divide.*

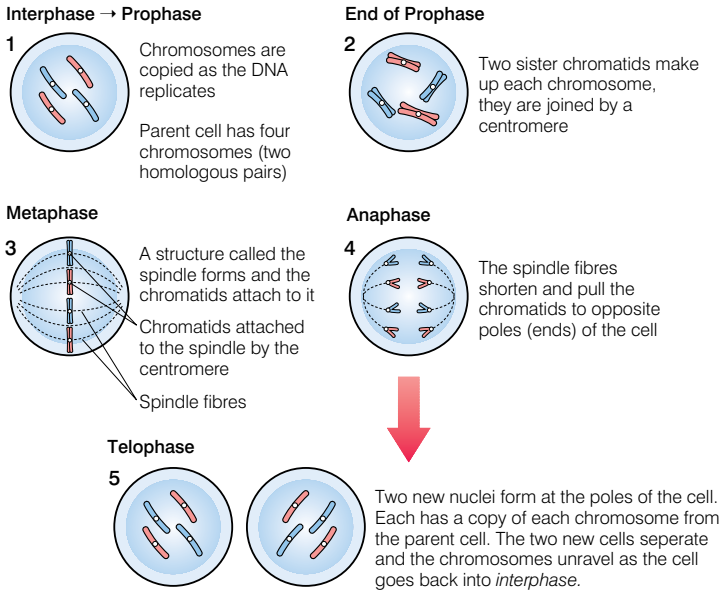


Figure 2.5 *The formation of identical daughter cells by simple division takes place during mitosis. It supplies all the new cells needed in your body for growth, replacement and repair. (Your cells really have 23 pairs of chromosomes – but for simplicity this cell is shown with only two pairs.)*

Most of the time, you can't see the chromosomes in the nucleus of a cell, even under the microscope. However, when a cell is splitting in two, the chromosomes become much shorter and denser, and will take up special colours called **stains**. At this stage you can see them under the microscope. The name 'chromosome' means 'coloured body', referring to what the chromosomes look like when they have taken up the stain.

Activity 2.2: Seeing chromosomes

This experiment was done for the first time by Walther Fleming, a German scientist, and is now carried out regularly in school labs across the world. It allows you to see mitosis in action in the actively dividing cell in an onion root tip.

You will need:

- a light microscope

and either

- actively growing root from an onion
- watch glass
- acidified ethanoic orcein stain
- hot plate
- tweezers
- mounted needle
- microscope slide and coverslip
- blotting paper

or

- a prepared longitudinal section of an actively growing onion root tip stained with acidified ethanoic orcein stain

Method

If you are preparing your own slide:

1. Cut off the end of a growing root tip about 5 mm from the end of the root.
2. Pour a little acidified ethanoic orcein stain into the watch glass and add the root tip.
3. Place the watch glass, stain and root on a warm hot plate for five minutes.
4. Remove the watch glass from the hot plate and, using the tweezers, place the root tip on the slide with a drop of ethanoic orcein stain.

5. Break up the root tip with the needles to spread out the cells as much as possible.
6. Place a coverslip over the crushed root tip, place the blotting paper over it and press down gently – this will crush the root tip further. The slide is now ready to use.

Whether you have prepared your own root tip slide or have a ready made one, you are now going to make observations and drawings:

7. Look at your slide under the microscope, first using the low-power lens and then moving to higher magnifications.
8. Make careful observations of the chromosomes and the ways they are arranged in the cells. Make drawings of your observations. On your slide, try to find cells that are: resting, about to divide, in the middle of dividing, or just completing a division.

The cells of early animal and plant embryos (known as **stem cells**) are unspecialised. Each one of them can become any type of cell that is needed. In many animals, the cells become specialised very early in life. By the time a human baby is born, most of its cells have become specialised for a particular job, such as liver cells, skin cells and muscle cells. They have **differentiated**. Some of their genes have been switched on and others have been switched off. This means that when a muscle cell divides by mitosis, it can only form more muscle cells. Liver cells can only produce more liver cells. So in adult animals, cell division is restricted because differentiation has occurred. Some specialised cells can divide by mitosis, but this can be used only to repair damaged tissue and replace worn-out cells. Each cell can only produce identical copies of itself.

The cell cycle

The cells in your body divide on a regular basis to bring about growth. They divide in a set sequence, known as the cell cycle, which involves several different stages.

- A period of active cell division – this is when mitosis takes place and the number of cells increases.
- A long period of non-division – when the cells get bigger, increase their mass, carry out normal cell activities and replicate their DNA ready for the next division.

The length of the cell cycle varies considerably. It can take less than 24 hours, or it can take several years, depending on which cells are involved and at which stage of life. There are many cycles during the years of growth and development, but it slows down once puberty is over in the adult.

Mitosis is taking place all the time in tissues all over your body. But mitosis is not the only type of cell division. There is another type that takes place only in your reproductive organs.

Meiosis

The reproductive organs in humans, as in most animals, are the **ovaries** and the **testes**. This is where the sex cells (the gametes) are made. The female gametes, or **ova**, are made in the ovaries; the male

KEY WORDS

stem cells *cells that have the ability to grow into other kinds of cells*

differentiated *made different*

ovary *the female sex organ that produces ova*

testes *the male sex organ that produces sperm*

ova *egg cells (reproductive cells) produced by the ovary*

DID YOU KNOW?

Your body cells are lost at an amazing rate – 300 million cells die every minute. Fortunately, mitosis takes place all the time to replace them.

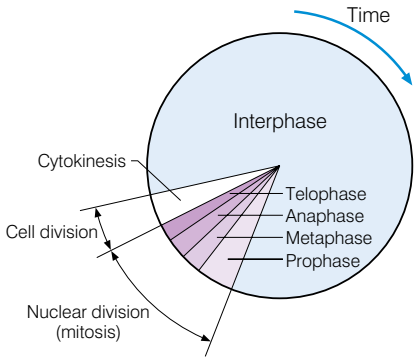


Figure 2.7 *The cell cycle. In rapidly dividing tissue and in cancer cells, interphase may only be a few hours. In other tissues, or in an adult animal, interphase may last for years.*

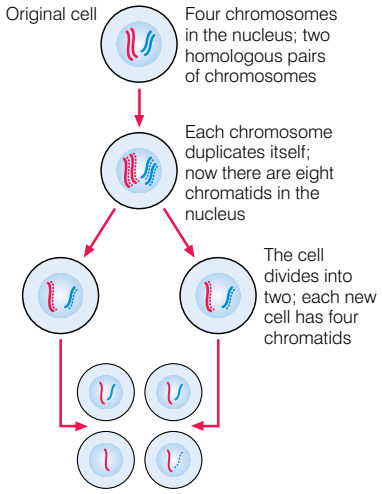


Figure 2.8 *This simple diagram sums up the main stages of meiosis – see figure 2.9 for the details.*

KEY WORDS

sperm *male reproductive cells produced by the testes*

meiosis *the type of cell division that creates egg and sperm cells*

DID YOU KNOW?

One testis can produce over 200 million sperm each day by meiosis. As most boys and men have two working testes, that gives a total of 400 million sperm produced every 24 hours! Only one sperm is needed to fertilise an egg. However, as each tiny sperm needs to travel 100 000 times its own length to reach the ovum, fewer than one in a million ever complete the journey – so it's a good thing that plenty are made.

gametes, or **sperm**, are made in the testes. In plants, the sex cells are the pollen and the ovules. The cells in the reproductive organs (also known as germ cells) divide to make sex cells. The cell division that takes place in the reproductive organ cells and produces gametes is known as **meiosis**.

Meiosis is a special form of cell division where the chromosome number is reduced by half. When a cell divides to form gametes, the chromosomes are copied so there are four sets of chromatids. The cell then divides to form two identical daughter cells. These cells then divide again immediately, without the chromatids doubling again, in the second meiotic division. This forms four gametes, each with a single set of chromosomes. The details of this process are shown in figures 2.8 and 2.9. As in mitosis, the process is shown as being broken up into different stages, but in real life it is a single, flowing process that has been described, rather poetically, as the 'dance of the chromosomes'.

- Meiosis is the division of the sex cells resulting in daughter cells with half the original number of chromosomes.

Why is meiosis so important? Your normal body cells have 46 chromosomes in two matching sets, 23 from your mother and 23 from your father. If two body cells joined together in sexual reproduction, the new cell would have 92 chromosomes, which simply wouldn't work. As a result of meiosis, your sex cells contain only one set of chromosomes, exactly half the full chromosome number. So when the gametes join together at fertilisation, the new cell that is formed contains the normal number of 46 chromosomes.

Gametogenesis

Meiosis occurs as part of a process known as gametogenesis, or gamete formation. In females this is called oogenesis. In a baby girl, the first stage of meiosis is completed before she is even born. The tiny ovaries of a baby girl contain all the ova she will ever have. The second meiotic division begins as the eggs mature in the ovaries during the monthly cycle.

In males, meiosis doesn't start until puberty, when the testes start to produce sperm. The production of sperm is called spermatogenesis, and carries on throughout a man's life.

Each gamete you produce is slightly different from all the others. The combination of chromosomes will be different. What's more, there is some exchange of genes between the chromosomes during the process of meiosis, which means that no two eggs or sperm are the same. This introduces a lot of variety into the genetic mix of the offspring.

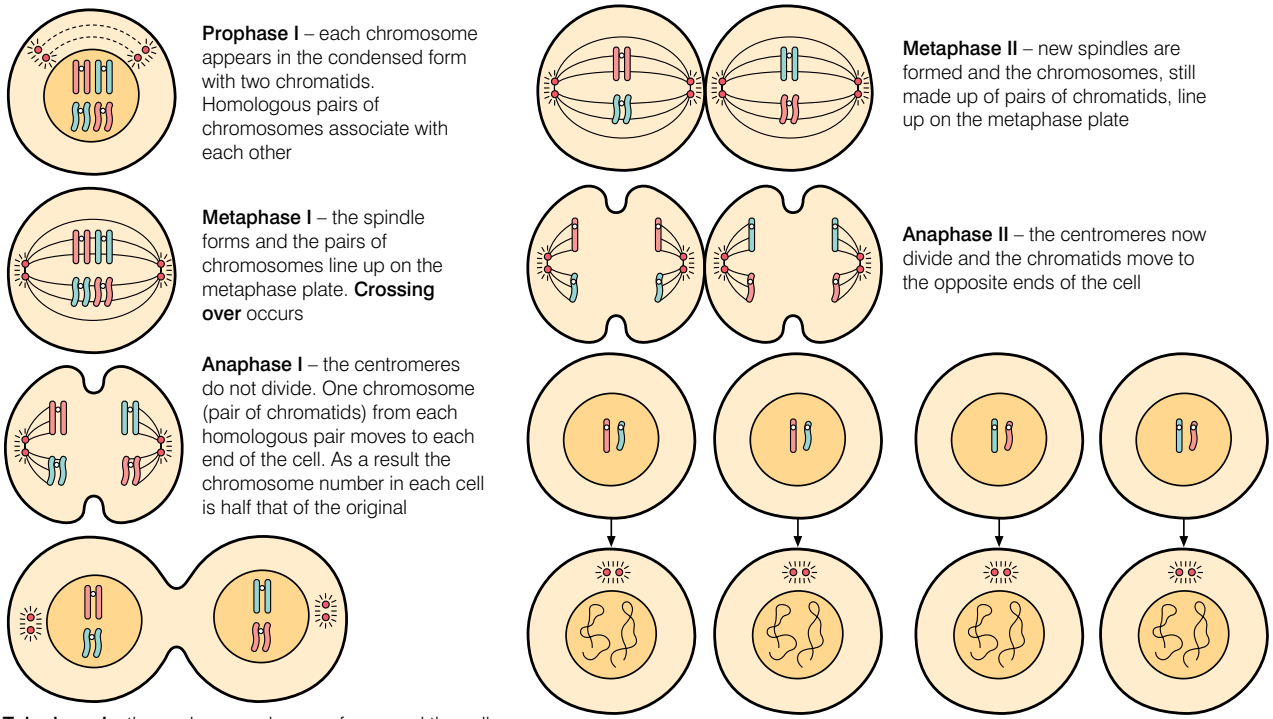


Figure 2.9 *The formation of sex cells in the ovaries and testes involves a special kind of cell division – meiosis – to halve the chromosome number. (The cell is shown with only two pairs of chromosomes, to make it easier to follow what is happening.)*

Activity 2.3: Making models of meiosis

It makes it much easier to understand and follow a process like meiosis if you can see the movement of the chromosomes. This is almost impossible in a school unless you have a video of the process, but it is possible to make models of the process to help you see what is going on. These models can range from something very simple using coloured string or modelling clay, through to computer animations or drama, depending on the time and materials available to you.

Plan two different models of meiosis, one as simple as possible and the other more complex. Show your plans to your teacher and then – with their approval – make one of your models and demonstrate it to your classmates.

Comparison of mitosis and meiosis

In some ways, mitosis and meiosis are very similar – both involve replication of DNA and the formation of daughter cells. But they are also very different because they play very different roles in your body. The table below compares the two processes.

Feature	Mitosis	Meiosis
Where does it take place?	Somatic cells (normal body cells)	Germ cells found in reproductive (sex) organs
Chromosomes in daughter cells?	Same number of chromosomes as original cell	Half the chromosome number of original cell
Number of daughter cells?	2	4
Variety?	Daughter cells identical to parent cells	Daughter cells different from parent cells – always variety
DNA replication?	Always occurs	Always occurs at first meiotic division, never at second meiotic division
How often?	Varies from every few hours to every few years, depending on cell type and age	In girls – first division before birth; second division monthly, completed on fertilisation Stops at menopause In boys – doesn't start until puberty, then continues steadily throughout life

Table 2.1 *Comparing mitosis and meiosis*

Summary

In this section you have learnt that:

- A chromosome is a structure, in the nucleus of a cell, consisting of genes. Chromosomes are made up of the genetic material DNA in a DNA–protein complex.
- Chromosomes contain genes that carry genetic information about an individual, which is passed on from one generation to another.
- DNA is the genetic material contained in the nucleus. It is a long molecule made up of two strands twisted together to make a double helix. The DNA molecule is made up of many smaller units called nucleotides that are joined together. Each nucleotide is composed of a sugar, phosphate and one of the four bases (adenine, thymine, guanine and cytosine).
- A gene is a unit of hereditary material located on the chromosomes.
- In the body's cells, chromosomes are found in homologous pairs.
- Humans have 46 chromosomes arranged in 23 pairs.
- 22 pairs of chromosomes carry information about the body generally. The final pair are the sex chromosomes, which determine whether you are female (XX) or male (XY).

- Mitosis is division of the somatic cells to make identical daughter cells.
- The stages of mitosis are interphase, prophase, metaphase, anaphase and telophase.
- Body cells divide by mitosis to produce more identical cells for growth, repair, replacement and, in some cases, asexual reproduction.
- Cells divide in a regular pattern known as the cell cycle.
- Body cells have two sets of chromosomes; gametes have only one set.
- Meiosis is the division of the sex cells resulting in daughter cells with half the original number of chromosomes.
- The process of meiosis introduces variety because no two gametes are ever the same.
- Meiosis is divided into two divisions. The first meiotic division is very similar to mitosis. The second is again similar, but there is no more replication of chromosomes, so the number of chromosomes in the final cells is halved.
- Meiosis takes place in the ovaries of girls and women. It is called oogenesis, and forms the ova. The first stage takes place before birth. The second stage occurs as the eggs ripen during the menstrual cycle and is completed after fertilisation of the egg.
- Meiosis takes place in the testes after puberty. Spermatogenesis produces sperm.
- Mitosis and meiosis show both similarities and differences.

Review questions

1. Chromosomes are made up of:

   A RNA
   B protein
   C DNA
   D acetic orcein

2. How many chromosomes would you expect to find in a normal human body cell?

   A 23
   B 50
   C 84
   D 46

3. Which combination of chromosomes would result in a human male?
   A XXX
   B XY
   C XX
   D YY
4. Which of the following statements is *not true* of mitosis?
   A In the initial stages of cell division, the chromosomes divide to form daughter chromatids.
   B Mitosis is used to replace old, worn-out cells.
   C Two identical daughter cells, known as clones, are formed.
   D Genetic variety is introduced during the process.
5. Which of the following statements is true of meiosis?
   A Genetic variety is introduced during the process.
   B Meiosis is used to replace old, worn-out cells.
   C Two identical daughter cells, known as clones, are formed.
   D Meiosis is involved in asexual reproduction.

2.2 Mendelian inheritance

By the end of this section you should be able to:

- Explain the work of Mendel on garden peas.
- Relate Mendel's work to the principle of inheritance.
- Illustrate Mendelian inheritance.
- Explain the difference between a gene and an allele.
- Relate the difference between dominant and recessive alleles.
- Describe homozygous and heterozygous individuals for a particular gene.
- Explain the inheritance of a single pair of characteristics (monohybrid inheritance).
- Carry out simple genetic crosses.
- Explain the patterns of Mendelian genetics in organisms including plants, cattle and people.
- Demonstrate the principle of inheritance using beads.
- Relate that in some situations no allele is dominant and describe codominant alleles in terms of the inheritance of roan coat colour in cows and ABO blood groups.

In the previous section you looked at the processes of mitosis and meiosis. In this section you are going to look in more detail at genetics and inheritance – the science of how information is passed from parents to their children.

In the 21st century we know a lot about genetics, chromosomes and genes. Yet for hundreds of years people had no idea about how information passed from one generation to the next.

Mendel's discoveries

For centuries people thought that the characteristics of the parents blended together so that the distinct characteristics of each parent were lost. In other words, a cross between a black dog and a white dog would give grey puppies. The birth of Gregor Mendel in 1822 was the beginning of the end for those theories. Mendel was born into a very poor family but he was very clever. The only way in those days for a poor person to get an education was to join the church. Mendel became a monk at a monastery in Brunn in Austria, and he became fascinated by the breeding patterns of the peas in the monastery gardens. He carefully bred different pure strains of peas – round peas, wrinkled peas, green peas, yellow peas – and then carried out breeding experiments with them.

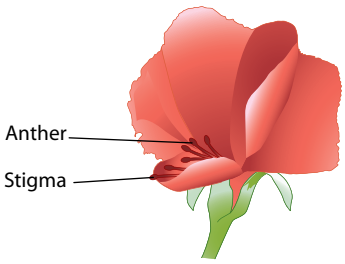
KEY WORDS

dominant *an allele where the characteristic is expressed in the phenotype even if only one copy of the allele is present*

recessive *an allele where the characteristic is only expressed in the phenotype if two copies of the allele are present*

How did Mendel breed his peas?

Both the male and the female parts of a pea flower are held inside a hood-like petal, so the flower often pollinates itself. Mendel opened the bud of his pea flowers before the pollen matured. He fertilised the stigma by brushing it with ripe pollen from another chosen flower. In this way he could control the cross. Mendel used seven clearly different, pure-breeding traits of the pea plant for his experiments. They are shown here in both their **dominant** and **recessive** forms. You will learn what these terms mean later in this chapter.



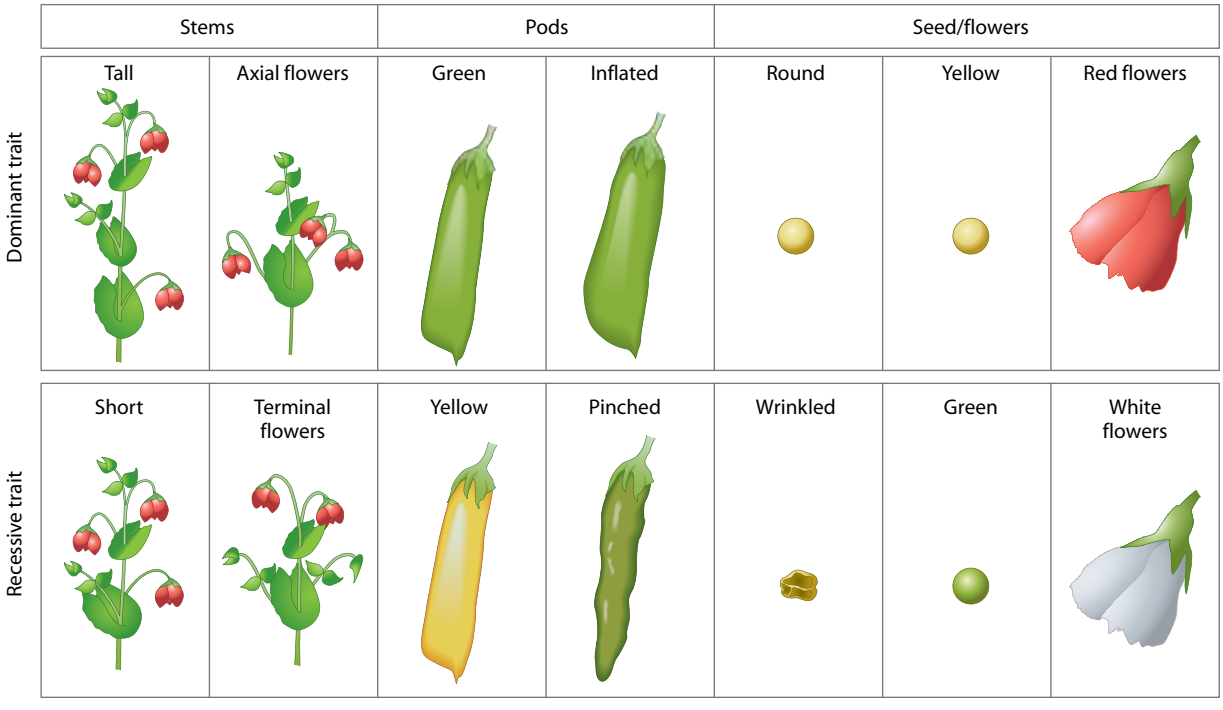


Figure 2.10 *Some of the features of the pea plant studied by Gregor Mendel*

Mendel developed a theory to explain his observations, based on independent particles of hereditary material, some of which were dominant over others but never mixed together. The abbot of the monastery supported his work and built him a large greenhouse in which to carry it out.

Mendel observed, for example, that the round shape of peas seemed to dominate the wrinkled shape, but that the information for a wrinkled shape continued to be carried and could emerge again in later generations – in other words there were unique units of inheritance that were not blended together.

Mendel kept precise records of everything he did, and made a statistical analysis of his results – something almost unheard of in those times. Finally in 1866, when he was 44 years old, Mendel published his findings; they explained some of the basic laws of genetics in a way we still refer to today.

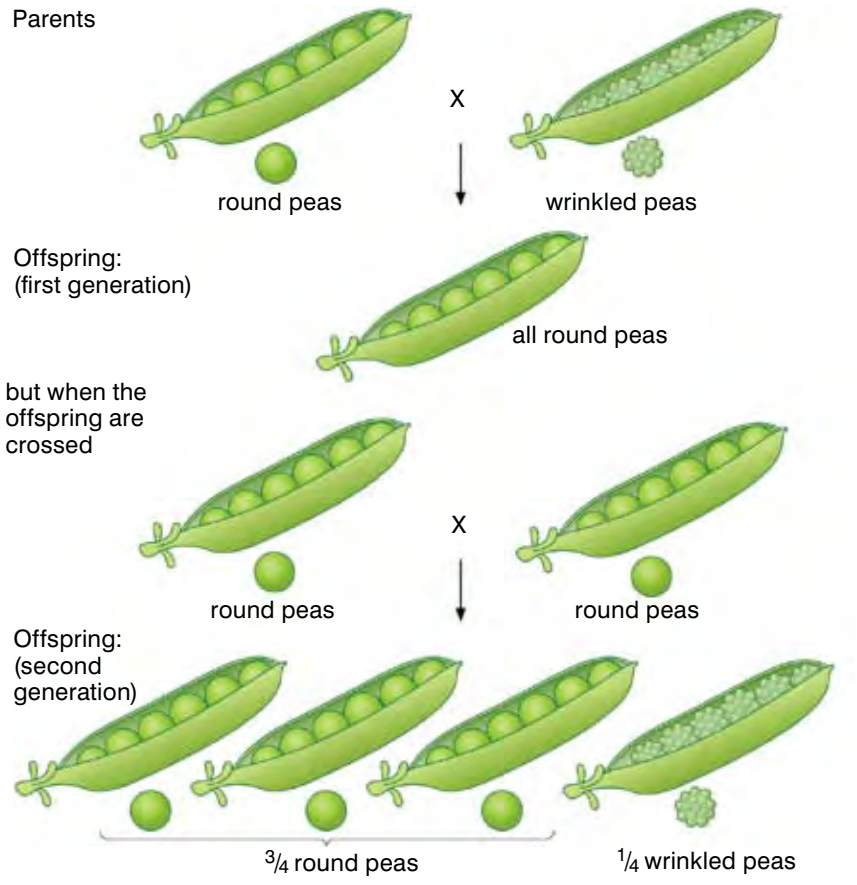


Figure 2.11 *It was experiments like this with peas that led Gregor Mendel to his ground-breaking conclusions.*

Sadly no one listened to Mendel. He was ahead of his time. Nobody yet knew of the existence of chromosomes, let alone genes, so there was no model to help people understand Mendel's new ideas. He died nearly 20 years later with his ideas still ignored – but still sure that he was right.

Sixteen years after his death, Gregor Mendel's work was finally recognised. By 1900 people had seen chromosomes through a microscope. Three scientists, Hugo de Vries, Eric von Seysenegg and Karl Correns, discovered Mendel's papers and duplicated his experiments. When they published their results, they gave Mendel the credit for what they observed. From then on ideas about genetics developed fast – it was suggested that Mendel's units of inheritance might be carried on the chromosomes seen beneath the microscope, and the science of genetics as we know it today was born.

Figure 2.12 *Gregor Mendel tending his pea plants. When he died in 1884 Mendel was still convinced that before long the whole world would acknowledge his discovery. In the 21st century we know just how right he was!*

How inheritance works

If we take a closer look at Mendel's findings and other observations, it becomes clear how inheritance works.

The chromosomes we inherit carry our genetic information in the form of genes. Many of these genes have different forms, known as **alleles**. A gene can be pictured as a position on a chromosome. An allele is the particular form of information in that position on an individual chromosome for example, the gene for dimples may have the dimple or the no-dimple allele in place. Most of your characteristics, like your eye colour and nose shape, are controlled by a number of genes. However, some characteristics like dimples and having attached earlobes are controlled by a single gene. Often there are only two possible alleles for a particular feature, but sometimes you can inherit one from a number of different possibilities. When we are trying to understand genetics, we tend to stick to traits that are controlled by a single pair of genes, because they are much simpler. Characteristics that are inherited through different forms of a single gene are examples of **monohybrid** inheritance. Almost every example you consider in this book will be a case of monohybrid inheritance.

There are genes that decide whether:

- your earlobes are attached closely to the side of your head or hang freely
- your thumb is straight or curved
- you have dimples when you smile
- you have hair on the second segment of your ring finger

We can use these genes to help us understand how inheritance works.

KEY WORDS

alleles *different forms of the same gene*

monohybrid *hybrid between two parents that have a difference of only one gene*

Dominant and recessive alleles (genes)

Some alleles control the development of a characteristic even when they are only present on one of your chromosomes. These alleles are dominant for example, dimples and dangly earlobes. Some alleles control the development of a characteristic only if they are present on both chromosomes – in other words, no dominant allele is present. These alleles are recessive.

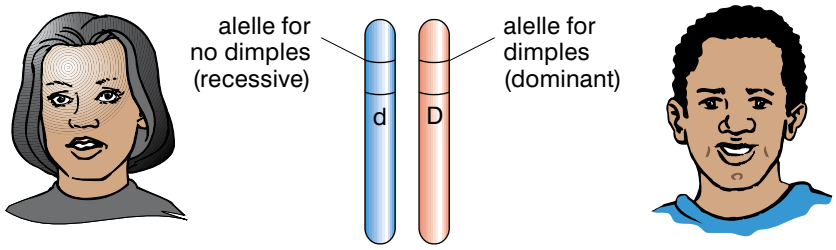


Figure 2.13 *The different forms of genes, known as alleles, can result in the development of quite different characteristics. Here the mother has passed on an allele for no dimples, and the father an allele for dimples. You can see the difference the alleles make to their appearance. The child represented by the pair of chromosomes will have dimples.*

The gene that controls dimples has two possible forms – an allele for dimples, and an allele for no dimples. The gene for dangly earlobes also has two possible alleles – one for dangly earlobes and one for earlobes that are attached. You will get a random mixture of alleles from your parents – which is why you don't look exactly like either of them. If you inherit two identical alleles – whether they are dominant or recessive – you are **homozygous** for that trait. If you inherit one of each type of allele, you are **heterozygous** for the trait.

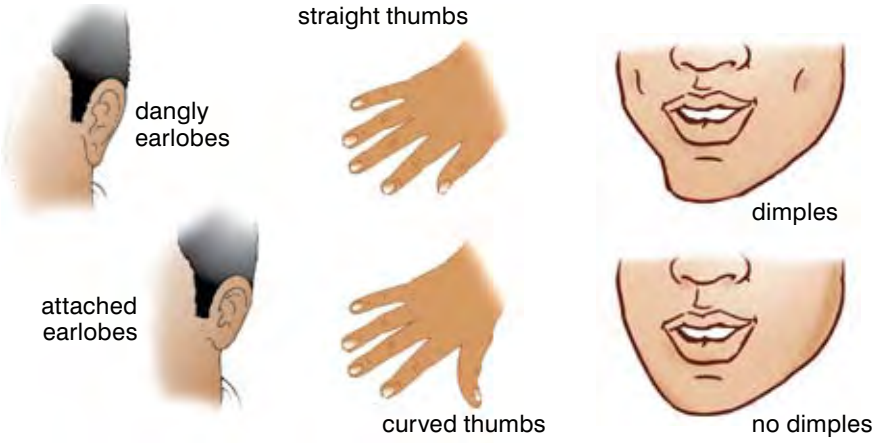


Figure 2.14 *These are all human characteristics that are controlled by a single pair of genes, so they can be very useful in helping us to understand how sexual reproduction introduces variety and how inheritance works.*

How does it work?

We can use a simple model to help us understand how sexual reproduction produces variety:

Imagine you have two bags, each containing the same number of beads. Each bag contains a random mixture of red and blue beads.

One bag represents the possible genes from the father and the other bag represents possible genes from the mother.

If you put your hand in and – without looking – picked out one bead from the father bag and one bead from the mother bag, what pairs might you get? If the bags contained only red beads or only blue beads, the pairs would all be the same. But if each bag held a mixture of red and blue beads you could end up with three possible pairs – two blue beads, two red beads or one of each.

This represents the random way in which you may inherit different genes from your parents, depending on the different alleles they have. For example, if both of your parents have two alleles for dimples (like the red beads) you will definitely inherit two dimple alleles – and you will have dimples!

KEY WORDS

homozygous *having two identical alleles for a particular feature*

heterozygous *having two different alleles for a particular feature*

If both of your parents have two alleles for no dimples, you will inherit alleles for no dimples and you will be dimple-free. But if your parents both have one allele for dimples and one for no dimples, you could end up with two dimple alleles, two no dimple alleles – or one of each!

If you happen to inherit one of each type of dimple allele, how does your body know whether to produce dimples or not? The allele for dimples is dominant so it will always be seen over the allele for no dimples. If you get one of each type of allele, you will have dimples.

What's more, if you have brothers and sisters, they could inherit a different combination to you, and so have different characteristics. This is why family members look similar – but different!

Figure 2.15 *Although these children have some family likenesses, the variety that results from the mixing of their parents' genetic information can clearly be seen!*

Monohybrid inheritance

You are going to start looking at how to work out genetic problems using the same organisms as Mendel did. You are going to be looking at inheritance of different forms of one gene at a time. This is called monohybrid inheritance.

Mendel started all his crosses using homozygotes because they are true breeding. This means that if you cross two individuals who are homozygous for the same characteristic, all of the offspring of all the generations that follow will have the same characteristic – unless a change in the DNA takes place. Heterozygotes are not true breeding. If you cross two heterozygotes, then the offspring may include a mixture of genotypes and phenotypes as you will see.

Look back to figure 2.11. We are going to look at a cross between a pea plant which is homozygous for the dominant round pea shape, and a pea plant which is homozygous for the recessive wrinkled pea. The first generation of any cross is called the F1 (first filial generation) and you can see in figure 2.11 that they all have the same heterozygous genotype for the characteristic. They also all have the same phenotype – the round pea shape – because the round allele is dominant. There is no sign of the wrinkled pea allele.

If we then cross members of the F1 generation we call the next generation the F2 (second filial generation). You can see in figure 2.11 that Mendel's theory predicts that the genotypes will be one homozygous round pea, two heterozygous round peas and one homozygous wrinkled pea. The recessive trait for the wrinkled pea has become visible again, after being 'hidden' in the F1 generation.

Genetic crosses can be shown with the use of simple genetic diagrams called Punnett squares like those shown below. A genetic diagram shows you the alleles for a characteristic carried by the parents, the possible gametes that can be formed from these and how they could combine to form the characteristic in their offspring.

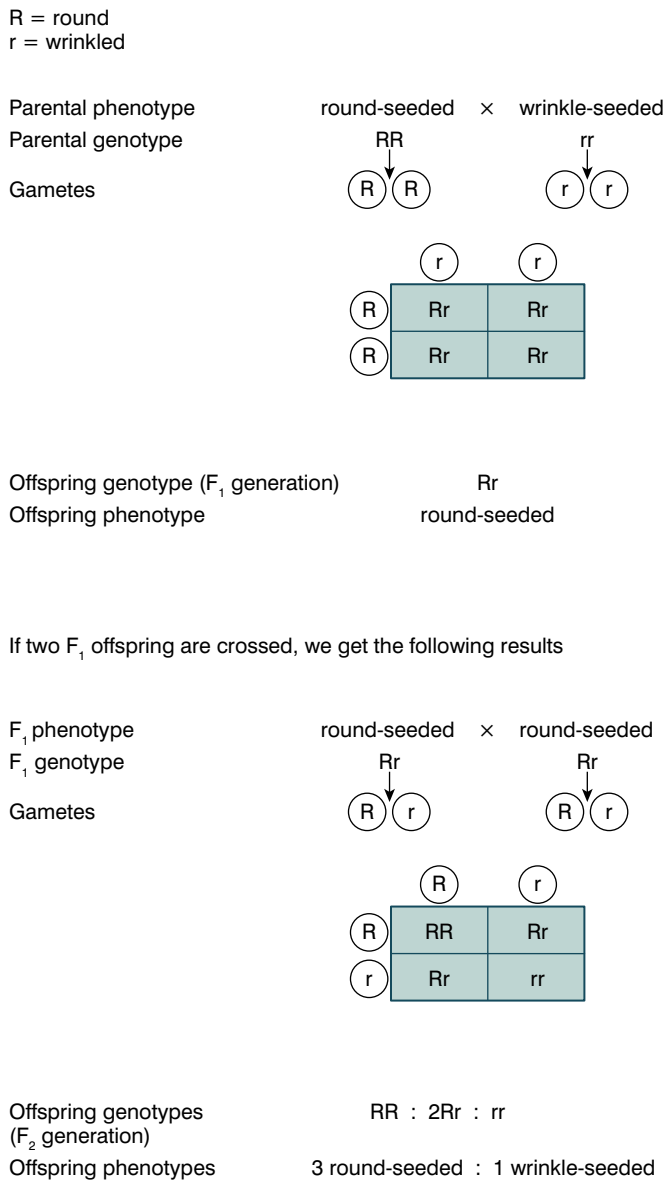


Figure 2.16 *A cross between a pea plant homozygous for the round pea allele, and a plant homozygous for the wrinkled pea allele, through the F1 and F2 generations.*

Test crosses

As can be seen from figures 2.11 and 2.16, individuals which are homozygous dominant or heterozygous will look exactly the same. They have identical phenotypes. This can give you all sorts of difficulties if you want to breed plants or animals. A breeder needs to know that the stock will breed true – in other words, that it is homozygous for the desired feature. If the feature is inherited through recessive genes then what you see is what you get. However, if the required feature is inherited through a dominant gene the physical appearance does not show whether the organism is homo- or heterozygous. To find out the genotype of an individual showing the effect of a dominant allele it must be crossed with a homozygous recessive individual. Because the recessive genes have no effect on the phenotype of the offspring unless they are in the homozygous state, this type of cross can reveal the required parental genotype (see figure 2.17). It is known as a test cross.

For example, the colour of the pea seed is inherited as a dominant allele Y for yellow seeds or a recessive allele y for green seeds. Thus a

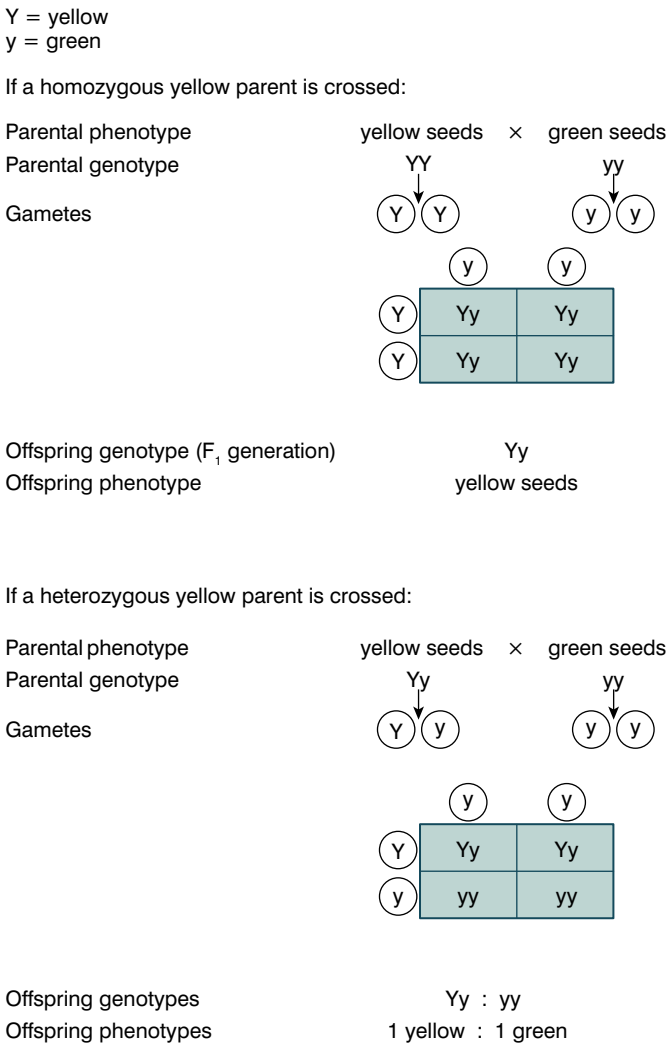


Figure 2.17 *Test crosses to show the genotype for seed colour of a parent pea plant: discovering the unknown genotype of a parent.*

plant producing yellow seeds could have the genotype YY or Yy. The phenotypic ratios of the progeny of the test cross reveal whether the yellow parent was homo- or heterozygous.

Mendelian genetics in people

The patterns of inheritance and the ratios of genotypes and phenotypes that Mendel saw in his peas apply to most organisms, including people. We will look at the way we inherit the shape of our ear lobes. There are two possible alleles controlling this characteristic – the allele to have dangly ear lobes (represented by a capital D because it is a dominant allele) or the allele to have attached earlobes (represented by a small d because it is the recessive allele).

If we inherit a dangly allele from both our parents (DD) or only from one (Dd), we will have dangly ear lobes. If we inherit an attached allele from both our parents (dd), we will have attached ear lobes. We will be looking at how we can use information like this to predict what offspring a couple might have. Using simple crosses such as Gregor Mendel used in his breeding experiments with peas, or situations in humans where a characteristic is inherited by a single pair of genes, we can begin to build up a way of predicting what offspring might result from a particular cross.

KEY WORDS

genotypes *a description of the alleles of an individual for a given genetic trait*

phenotype *a description of the physical appearance of an individual relating to a given genetic trait*

Figure 2.18 *Genetic diagrams like this show us the parents, the possible gametes that can be formed and the possible offspring that could result. They enable us to work out the likelihood of particular combinations of alleles being passed on. These genetic diagrams, known as Punnett squares, are very compact and easy to follow.*

To work out the possible gametes, you need to look at the genotypes of each of the parents. So, to use our dangly ear lobes again, if you have the genotype DD, both of the possible alleles you could pass on in your gametes are D. If you have attached earlobes, you have genotype dd and both of the possible gametes you might produce would carry the recessive allele d. But if you are heterozygous, Dd, your gametes may contain either the dominant allele D or the recessive allele d – and it is completely a matter of chance which one will meet up with another gamete.

In a genetic diagram you will end up with all the possible **genotypes** of the offspring – that is, the alleles they might inherit. From this you can work out their possible **phenotypes** – the physical characteristics that they will have as a result of their

Dangly earlobes

a) D = dangly earlobes
d = attached earlobes

Phenotype of parents	Dangly		Attached
Genotype of parents	DD	x	dd
Gametes	D D		d d

Possible genotypes of offspring

	D	D
d	Dd	Dd
d	Dd	Dd

All Dd

Phenotype: all dangly earlobes

b)

Phenotype of parents	Dangly		Attached
Genotype of parents	Dd	x	dd
Gametes	D d		d d

Possible genotypes of offspring

	D	d
d	Dd	dd
d	Dd	dd

Phenotype: 1 : 1

dangly : attached

Attached earlobes

c)

Phenotype of parents	Dangly		Dangly
Genotype of parents	Dd	x	Dd
Gametes	D d		D d

Possible genotypes of offspring

	D	d
D	DD	Dd
d	Dd	dd

Phenotype: 3 : 1

dangly : attached

genotype. For example, someone with a genotype DD or Dd will have dangly ear lobes as their phenotype. Only someone with the genotype dd will have attached ear lobes as their phenotype.

You can use simple diagrams to work out genetic crosses. Figure 2.18 provides you with some clear examples to follow. You need to choose suitable symbols to represent the dominant and recessive alleles. This is usually the capital and lower case version of a single letter. You also need to give a key to explain which symbol is which. You need to indicate clearly the genotypes of the parents, the possible gametes, the possible genotypes of the offspring and also the ratio of the different possible phenotypes of the offspring.

If one of your parents has a characteristic caused by a dominant allele (for example, dangly earlobes) you have a 50% chance of inheriting it. If both parents have a single recessive allele for a characteristic (for example, attached earlobes) you have a 25% chance of inheriting that characteristic. This doesn't matter when you are looking at a harmless characteristic such as earlobes, but it becomes more important when serious genetic diseases such as sickle cell disease are involved.

In most of the examples of monohybrid inheritance that you will be looking at, there is simple dominance of one allele over another. But it is important to realise that this isn't always the case. Not all genes show dominance so aspects of both characteristics show through. This is common in the colour of the coat of certain cattle. If a homozygous red cow is crossed with a homozygous white cow, the calves that result will all have roan coats, a mixture of red and white hairs.

Example: R = red r = white

Phenotype of parents	Red bull	x	White cow
Genotype of parents	RR	x	rr
Gametes	R R		r r

Possible genotypes of offspring

	R	R
r	Rr	Rr
r	Rr	Rr

F1 genotype: Rr

F1 phenotype: roan

Figure 2.19 *An example of a roan cow*

The same thing happens in the inheritance of the human ABO blood groups. There are three possible alleles that you might inherit – A, B and O. The O allele is recessive to A and B, but neither A nor B show dominance over the other one. This means that if you have blood group O, your genotype is OO. However, if you have blood group A you could have the genotype AA or AO, while blood group B could be BB or BO. However, if you inherit an A allele from one parent and a B allele from the other parent you have blood group AB. You will learn more about this if you study biology further.

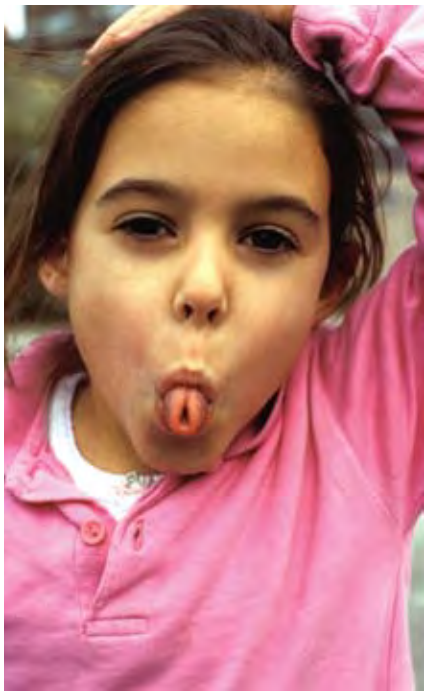


Figure 2.21 *We have many characteristics which – like tongue rolling – are genetic but are inherited through more than one gene, or are affected by environmental factors as well.*

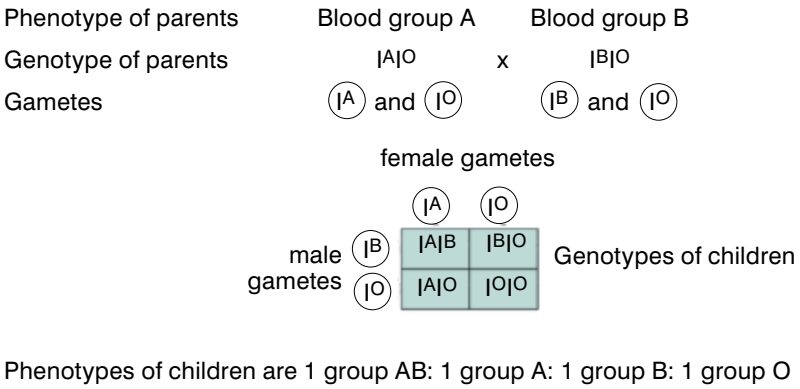


Figure 2.20 *If a couple are heterozygous for blood groups A and B, their children could have any one of the four possible ABO blood groups!*

Tongue rolling – a new discovery

For many years people thought tongue rolling was a single gene character. This idea changed when it was observed that in some pairs of identical twins, one can roll their tongue and the other can't! Now geneticists are left trying to work out exactly what happens in this case, and tongue rolling is no longer seen as a simple example. Scientists now think tongue rolling may be inherited by two genes which are closely linked together, so they often appear as one. You will learn more about these kinds of inheritances in Grade 12.

Activity 2.4: Investigating genetics

You are going to investigate some of the simple, single-gene genetic traits you possess. You are then going to collect as much information about your fellow students as possible and draw bar charts to show the frequency of different traits in your class. It would be good to collect data from all the students in grade 10 in your school.

Method

1. Choose a number of single-gene or clear discontinuous traits, e.g. dimples or not, attached or unattached earlobes, straight or curved thumbs, the presence of hair on the second segment of the ring finger, tongue rolling (not clear cut genetically but fun to look at!).
2. Draw up a table showing each of the characteristics you have chosen. You can make up a table similar to the example below for each feature you investigate.
3. Make a tally of all the people in the class who possess each feature and record it in your table.
4. Display your data as bar charts, pie charts. etc.
5. Write up your investigation and results. Can you draw any conclusions? For example, are characteristics related to dominant alleles more common than characteristics related to recessive alleles or does it vary?

Section	Total number	Straight thumb		Curved thumb	
		Number	%	Number	%
1					
2					
3					
4					

More human inheritance

Your genetic inheritance from your parents often contains nothing worse than a big nose or a tendency to gain weight easily. However, sometimes the genetic combination you receive has more noticeable and dramatic effects. There are a number of genetic conditions which cause serious health problems and even death. Many other combinations have a relatively simple but very noticeable effect. One of these is albinism.

The high levels of melanin (black pigment) in Ethiopian skin gives a natural protection against UV radiation from the sun but even so it is still sometimes useful to have additional protection from sunscreens. People with paler skins are much more likely to suffer severe sun damage.

Figure 2.22 *Albinism is particularly noticeable in areas where most people have a high level of melanin in the skin, such as Africa. The appearance of an albino in a family can appear quite random, but it is the result of hidden recessive alleles.*

a) How two carriers can produce an albino child

Parental genotype Aa x Aa

Possible gametes A a A a

Possible F1 genotypes

	A	a
A	AA	Aa
a	Aa	aa

1AA : 2Aa : 1aa

Possible F1 phenotypes 3 normal : 1 albino

b) How an albino and someone with a normal phenotype but heterozygous might produce an albino child or a normal child

Parental genotype Aa x aa

Possible gametes A a a a

Possible F1 genotypes

	A	a
a	Aa	aa
a	Aa	aa

1Aa : 1aa

Possible F1 phenotypes 1 normal : 1 albino

c) how an albino and a homozygous normal individual would never have an albino child

Parental genotype AA x aa

Possible gametes A A a a

Possible F1 genotypes

	A	A
a	Aa	Aa
a	Aa	Aa

All Aa

Possible F1 phenotypes All normal

KEY WORDS

albinism *a genetic condition in which no melanin pigment is formed in the cells*

For example, in the inherited condition known as **albinism** the melanin pigment in the skin, hair and eyes does not develop. The normal allele for pigment to develop is A and it is dominant. The allele for albinism, a, is recessive. Albinism is found throughout the animal kingdom and people are no exception. Albino individuals are very vulnerable to sun damage to their skin, so they have a greatly increased risk of developing skin cancer. They have to take great care to protect their vulnerable skin from sunlight. Their eyes are also very sensitive to light and they often have problems with their vision – but apart from this they lead completely normal lives.

If people do not understand genetics, the arrival of an albino baby can cause great distress and, in the past, albinos often suffered discrimination as a result of their unusual appearance. However, for albinism and indeed any other genetic traits, looking at the family history can show exactly how a characteristic has been passed on.

One way of investigating this is to build up a pedigree or family tree for a particular characteristic. On a family tree, men are usually shown as squares and women as circles. Individuals affected by a particular trait are shaded. Once a pedigree is built up, it is possible to see when a mutation may have taken place, and to work out the possible genotypes of many of the individuals.

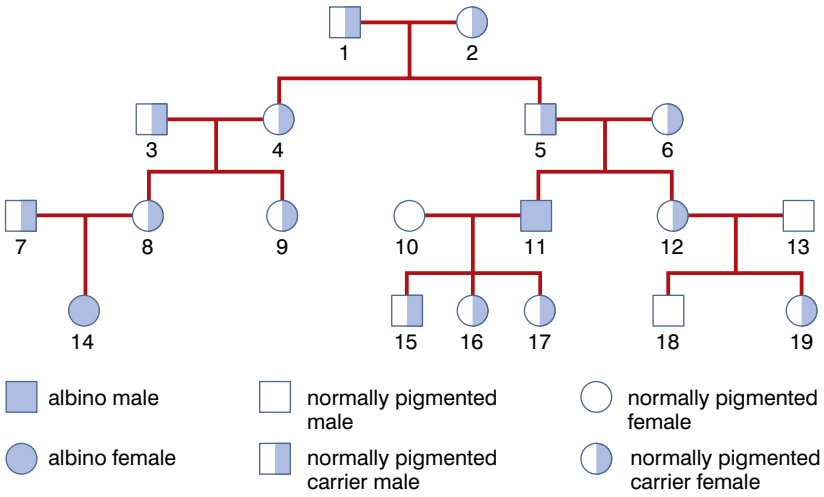


Figure 2.23 *In this family tree, you can see that albinism is relatively rare, because it depends on both partners carrying the recessive albino allele. The chances of two carriers marrying and having children are relatively small.*

Activity 2.5: Investigating genetics

It can be hard to imagine how a genetic cross works. Design and make a model that could be used to help teach genetics. It can be very simple – models which have been tried before include using beads, cutting out paper people and genes, modelling clay people in different colours, etc. Using what you have available, plan and make your model and use it to demonstrate how a genetic cross works to your peers. Let your teacher decide which model would be most useful in the classroom next year!

Activity 2.6: Genetics in other animals

You have looked at genetics in plants, people and roan cattle. The same principles work in all other animals. In some breeds of cattle the allele P for being *polled* (not having horns) is dominant to the allele p for horns.

Draw genetic diagrams to show the following:

1 A farmer with polled cattle gets a new bull who also does not have horns. Some of his cows give birth to horned calves.

2 A farmer has horned cattle. He decides polled cattle would be easier to handle. He gets a polled bull to breed with his horned cattle. Most of the calves born are polled, but several of his cows give birth to horned cows.

Summary

In this section you have learnt that:

- Gregor Mendel was the first person to suggest separately inherited factors, which we now call genes.
- Gregor Mendel carried out his experiments on seven different characteristics of garden peas.
- Genes can have different forms called alleles.
- Genes come in pairs. A pair of genes controls a particular characteristic or set of characteristsics.
- Each member of a pair of genes may have a different allele.
- The term genotype describes the genetic makeup of an individual, while their phenotype describes their physical characteristics.
- A characteristic controlled by a dominant allele will be present even if only one of these alleles is inherited (present on only one chromosome).
- A characteristic controlled by a recessive allele is only present if the allele is inherited from both parents (present on both chromosomes).
- In some cases alleles are codominant. This means that in a heterozygote features of both characteristics appear. Examples include human ABO blood groups and sickle cell anaemia.
- If an individual is homozygous for a genetic trait, they have two identical alleles for that characteristic.
- If an individual is heterozygous for a genetic trait, they have two different alleles for that characteristic.
- In human body cells the sex chromosomes determine whether you are female (XX) or male (XY).
- You can illustrate Mendelian inheritance (genetic crosses) – the parents, the gametes and the possible offspring – using simple genetic diagrams known as Punnett squares.
- Some features or characteristics are controlled by a single gene and you can use these to look at monohybrid inheritance. Examples include dangly or attached earlobes, dimples and straight or curved thumbs.
- Albinism is an inherited condition where melanin pigment is not produced in the body.

Review questions

1. The basic unit of inheritance is:

   A DNA

   B a chromosome

   C the nucleus

   D a gene

2. Bekele has dangly earlobes. He has inherited one allele for dangly lobes from his mother, and one for attached lobes from his father. Which of the following terms best describes Bekele's genotype for his earlobes?

   A homozygous

   B heterozygous

   C homologous

   D autosomal

3. Which of the following statements is a definition of a recessive allele?

   A An allele that controls the development of a characteristic even when it is only present on one of your chromosomes.

   B An allele that controls the development of characteristics alongside another different allele that is also expressed in the phenotype.

   C An allele that only controls the development of a characteristic if it is present on both chromosomes.

   D An allele that only occurs on the sex chromosomes.

4. Which of the following conditions is imherited?

   A TB

   B albinism

   C anaemia

   D HIV/AIDS

2.3 Heredity and breeding

By the end of this section you should be able to:

- Describe methods of breeding farm animals and crops.
- Explain the importance of selective breeding for society.
- Explain the difference between selective breeding and cross-breeding.
- Give examples of selective breeding from your own experience.

One area where understanding genetics is very important indeed is in the breeding of farm animals and crop plants. People manipulated the genetics of domestic animals and plants long before anyone understood how genetics works!

For example, in Ethiopia we have 25 types of cattle, 13 types of sheep, 15 types of goats, four types of camels, five types of chickens, four types of donkeys, two of horses and two types of mules! All of these have come about as a result of careful breeding, which has given us animals with the features we need. It might be giving plenty of milk, or laying many eggs; it might be making lots of muscle to provide meat, or the ability to survive on very poor food plants. We have an amazing pool of genetic resources in our farm animals. What are the main ways in which we get the characteristics we want in our animals? To understand this you need to apply all the material on genetics you have learnt so far.

Selective breeding

One way to improve the performance of a crop plant or domestic animal is to select the best possible individuals of that type and use them to build up your stock.

Selective breeding is used to breed for particular traits. You need to select true-breeding plants or animals, so it is important that the history of the organism is known. If the characteristic you want to select for is recessive, it is easy to be sure that the parents are true breeding. If they show the characteristic, they will be homozygotes. If the trait you want is dominant, you may need to carry out a test cross using a known homozygous recessive on the parents to make sure they are homozygous.

For selective breeding to work, it is important to use only the best animals which have the characteristics you want in the breeding programme. This means that the male and female animals which have the characteristics you want should be allowed to mate, but animals which do not have the characteristic should be castrated or prevented from mating.

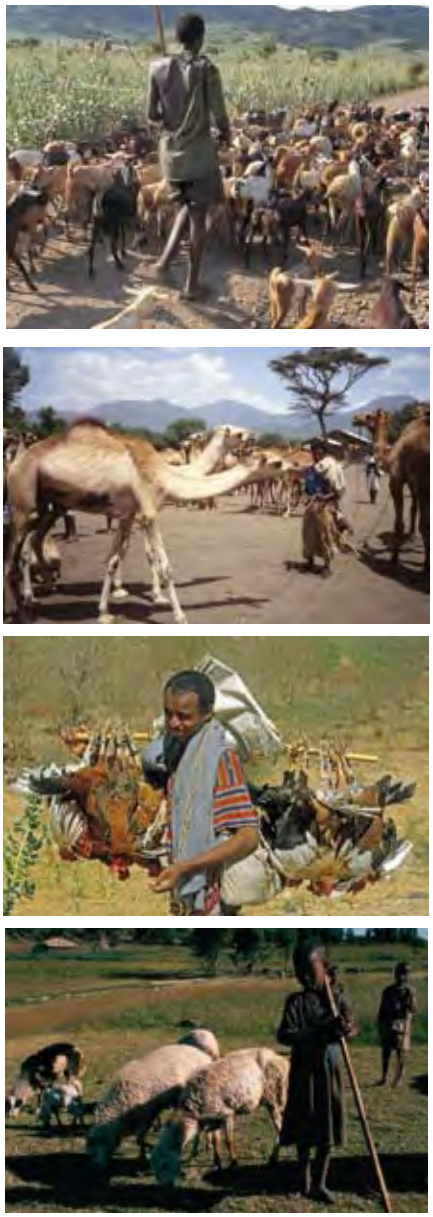


Figure 2.24 *The animals you can see here – goats, camels, chickens and sheep are all the result of selective breeding which have given us animals well suited to particular areas of the country.*

Sometimes it can be difficult to do this – everyone in the area needs to control their animals to make selective breeding work. Sometimes it is hard to select the animals or plants you want. For example, animals which grow fast and gain lots of muscle are very desirable both for meat and for their strength as work animals. However, farmers will often kill these young, fast-growing males to take to market – leaving the weaker, slower-growing males to reach sexual maturity and mate with the females. This can result in negative selection, so that the breed becomes slower growing and weaker. You also need to avoid the animals becoming too inbred – close relatives being used for breeding can eventually lead to genetic weakness. However, if care is taken, selective breeding is an excellent way of improving the performance of animals and plants, and giving you the characteristics you need.

Activity 2.7: Ethiopian breeds

Find out as much as you can about the breeds of animals and plants which are farmed in your area of the country. For each type of animal you study, list the characteristics of that breed which make it well suited to your area.

If possible, also find out about the breeds in another very different area of Ethiopia. Compare the characteristics that have been selected for in those animals and plants with your local breeds.

Selective breeding for particular traits usually takes place within a type or breed of animal or plant. An alternative approach is shown below.

Combination of traits – cross-breeding

An alternative way of improving a breed of animals or plants is to combine good traits from two different breeds. Take an example. One family has a herd of goats which give good milk yields, but do not cope well without shade. Another family has goats which give less milk but are very hardy and resistant to the heat of the sun. If both families selected their best male and female goats, and cross-bred them, some of the offspring would inherit both the genes for good milk production and the genes for heat resistance. By selecting the offspring carefully and breeding again and again, eventually a new, true breeding type of goat would emerge.

However, this is a long process – look back to section 2.2 and you will see that F1 generations do not breed true. It takes a lot of work to develop a new true breeding strain. Farmers often simply continue to cross-breed to get the benefits of each F1 generation. So perhaps they will have a good bull from one breed and let him service their cows from another breed, so that the calves all have the combination of characteristics that is desired.

Figure 2.25 *All cattle had similar ancestors in the distant past, but selective breeding has given us some very different breeds – here you can see a zebu, a Belgian Blue (bred purely for meat) and a Holstein Friesian, bred purely for milk.*

Around the world, a combination of selective breeding and cross-breeding has produced cattle which come in an enormous range of shapes and sizes, as you can see in figure 2.25.

We must be careful with our breeding programmes, however. The Belgian Blue cattle which you can see in figure 2.25 have 'double muscles', which means they produce a very large amount of low-fat meat. However, the calves are often so big that the cows cannot deliver them and they have to be born surgically, by Caesarean section. Some European countries want to ban this breed completely.

The Borene story

One example of the effect of selective breeding is the Borena breed of cattle. Borenes were originally developed by the Borena people in the south of Ethiopia, probably from the zebu breed. As the Borena people moved northwards, they settled with their cattle around Lake Tana and these populations bred cattle adapted to this new area – the Tanaland Borene. The Borene has spread throughout east Africa and in each different country or area selective breeding has led to changes which suited the needs of the people using them. Now in Ethiopia some farmers are crossing their Borenes with Holstein Friesians and Simmentals imported from Europe. The crosses have more calves and better milk yields, but maintain many of the positive characteristics of the Borenes. At the same time, Borenes have been exported and breeders in many countries around the world including Brazil, the USA and Australia are both breeding pure-bred Borenes and also using them to cross with indigenous breeds in order to improve them.

Figure 2.26 *Borene cattle have proved to be very hardy and suited to African climates; they also breed well with other types of cattle to give specialised and adaptable stock.*

Activity 2.8: Selective breeding

a) If possible, visit a local farmer and discuss the breeds of animals that he raises. Talk to him about selective breeding and cross-breeding and see if he carries out these practices.

b) Select an example of breeding from your own experience. It might be of sheep, goats, cattle, camels, cats or dogs, chickens, horses, crop plants or any other organism. Make a presentation about the process and the characteristics that are important in this animal. You may be asked to tell the rest of the class about your choice.

Importance of breeding for society

Ethiopia is a very big country. Many people rely on their crops and livestock for food, for milk, for hides and for their personal wealth. We have an enormous amount of genetic diversity in our farm animals and plants, which is important not just to Ethiopia but to the whole world as a source of new genetic material to help overcome changes in the world climate. If we can maintain our specialised breeds, we help ourselves and our international partners.

Within our country, selective breeding to maintain the best possible performance in our local breeds means those breeds will be maintained, and people will gain the biggest possible benefit from them. They will get the best possible yield from their crops, and the most milk from their cows, sheep, goats or camels, their animals will make the most of the food available to them as well as other such useful traits.

By cross-breeding and combining useful traits such as a good temperament with a fast growth rate, or a better milk yield with an ability to thrive on poor forage, we can create new breeds even better suited to the different areas of our country. The more food we can produce, the stronger and healthier both we and our children will be. This is good for each individual and for society as a whole.

Summary

In this section you have learnt that:

- Farm animals and plants are the result of selective breeding.
- In selective breeding, only the animals or plants with the characteristic you want are allowed to breed. In time, every member of the breed shows that characteristic.
- Another way of getting desirable characteristics is to cross -breed between two different breeds. This gives you a combination of traits from the two different breeds – the best of both can be used to develop a new breed.
- The many different breeds of Ethiopian cattle are the result of selective breeding and cross-breeding over many years. They, and all our breeds of other animals and plants, represent an important genetic heritage for our country.
- Breeding animals and plants to develop the best possible characteristics is very important for society, to enable us to make the best possible use of our resources, to feed our population, to maintain our genetic diversity and to provide new and useful genes for the international community.

Review questions

1. Which of the following is not an Ethiopian breed of cattle?
   A Borena
   B Zebu
   C Holstein Friesian
   D Raya
2. Cross-breeding is also known as:
   A selective breeding
   B genetic engineering
   C horticulture
   D combination of traits
3. Selective breeding involves:
   A choosing a weak characteristic and selecting for it
   B choosing a strong characteristic and selecting for it
   C mating your animals with a different breed
   D none of the above
4. Which of the following is NOT true of cross-breeding?
   A The offspring immediately form a new breed of animal or plant.
   B The offspring are the F1 generation.
   C The offspring do not breed true.
   D The offspring may combine the best traits of both breeds.

End of unit questions

1. Copy this statement and fill in the gaps with the appropriate terms:

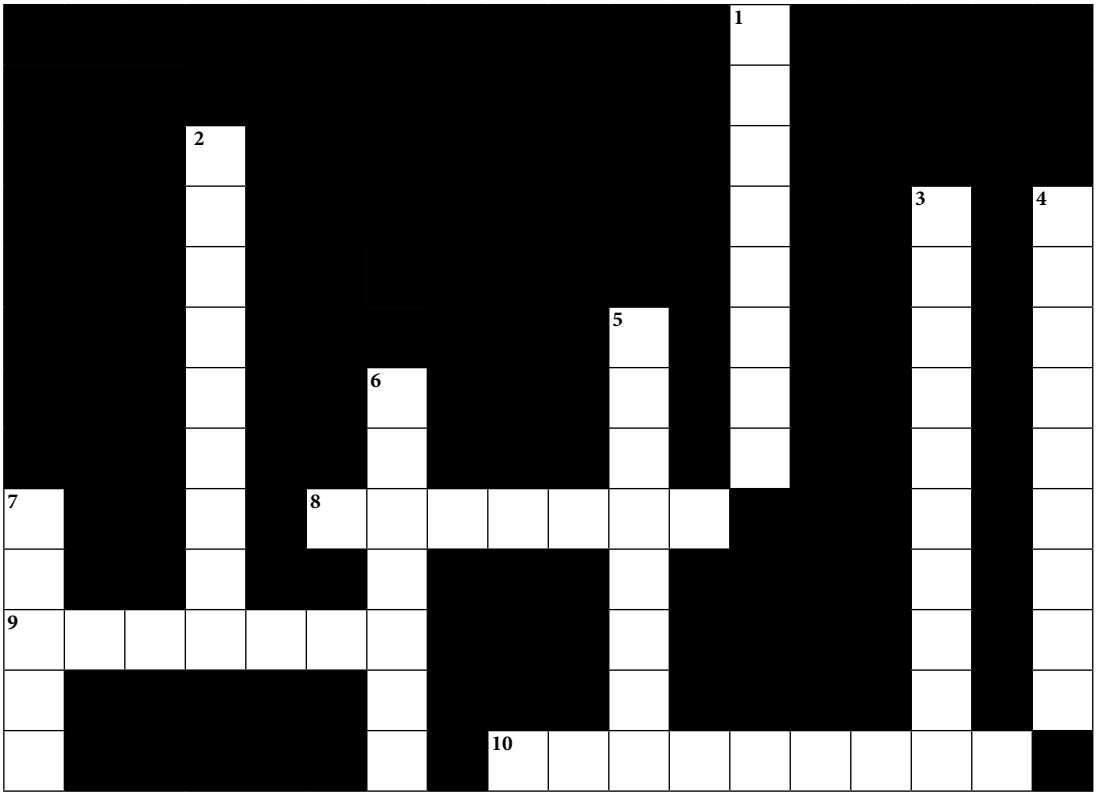
   New cells are needed for _____ and to _____ worn-out cells. The new cells must have the same _____ in them as the originals. Each cell has a _____ containing the_____ grouped together on _____. The type of cell division that produces identical cells is known as _____ .
2. Division of the body's cells is taking place all the time in living organisms.
   a) Why is mitosis so important?
   b) Explain why the chromosome number must stay the same when the cells divide to make other normal body cells.
   c) Describe the process of mitosis, and explain the experimental procedure that enables us to see this process taking place.
3. What is meant by the term differentiation, and why is it so important?
4. a) How many pairs of chromosomes are there in a normal human body cell?
   b) How many chromosomes are there in a human ovum?
   c) How many chromosomes are there in a fertilised human ovum?
   d) What happens to the chromosomes when an ovum and a sperm meet at fertilisation?
   e) Explain how sex is determined in a human at the moment of fertilisation.
5. a) What is the name of the special type of cell division that produces gametes from ordinary body cells?
   b) Where in your body would this type of cell division take place?
   c) Why is this type of cell division so important in sexual reproduction?
   d) Describe the process of cell division by which gametes are formed – draw diagrams if necessary.

6. a) How did Mendel's experiments with peas convince him that there were distinct 'units of inheritance' that were not blended together in the offspring?
   b) Why didn't people accept his ideas?
   c) The development of the microscope played an important part in helping to convince people that Mendel was right. How?
   d) Gregor Mendel did his work on peas. What would be the genotypes and phenotypes of the possible F1 offspring of a cross between:
      i) pure breeding round peas (RR) with pure breeding wrinkled peas (rr)
      ii) a round pea carrying a wrinkled gene (Rr) and a wrinkled pea (rr)

   Show all your workings.
7. Define the following words:
   a) gene
   b) allele
   c) dominant allele
   d) recessive allele
   e) homozygous
   f) heterozygous
8. The allele that gives you dimples is dominant over the allele for no dimples. One partner in a couple has dimples and the other has no dimples. Would you expect their children to have dimples? Explain as fully as you can, using genetic diagrams to explain your answer.
9. Whether you are albino or not is decided by a single gene with two alleles. The normal allele A is dominant to the albino allele a. Use this information to help you answer the following questions. Show any working out you may do.

   Demissie is albino but Seble is not. They are expecting a baby.
   a) We know exactly what Demissie's alleles are. What are they and how do you know?
   b) If the baby has normal colouring, what does this tell us about Seble's possible genotype?
   c) If the baby is albino, what does this tell us about Seble's possible genotype?
10. How does the inheritance of dominant traits differ from the inheritance of recessive traits?
11. Look at your thumbs. Are they straight or curved? This is a characteristic inherited on a single gene. The allele for straight thumbs is dominant to the allele for curved thumbs. Chose suitable symbols and draw a genetic cross between:
    a) two heterozygotes
    b) a heterozygote and a homozygous recessive individual
12. List the main ways in which careful breeding of animals and plants benefits society.
13. Explain carefully the difference between selective breeding and cross-breeding as a way of improving the characteristics of your animals or plants.

Copy the crossword puzzle below into your exercise book (or your teacher may give you a photocopy) and solve the numbered clues to complete it.



ACROSS

8 Cell division which results in two identical daughter cells (7)

9 Different forms of the same gene (7)

10 The chromosomes which control everything about the body and the cells (not the sex chromosomes) (9)

DOWN

1 DNA base that pairs with guanine (8)

2 Physical appearance of an individual relating to a particular genetic trait (9)

3 Strand of DNA carrying the genetic material (10)

4 Map of the chromosomes in the nucleus of a single cell (9)

5 Allele which is expressed in the appearance even if only one copy is present (8)

6 Cell division which produces four non-identical sex cells with half the original number of chromosomes (7)

7 Female sex organ that produces ova (5)