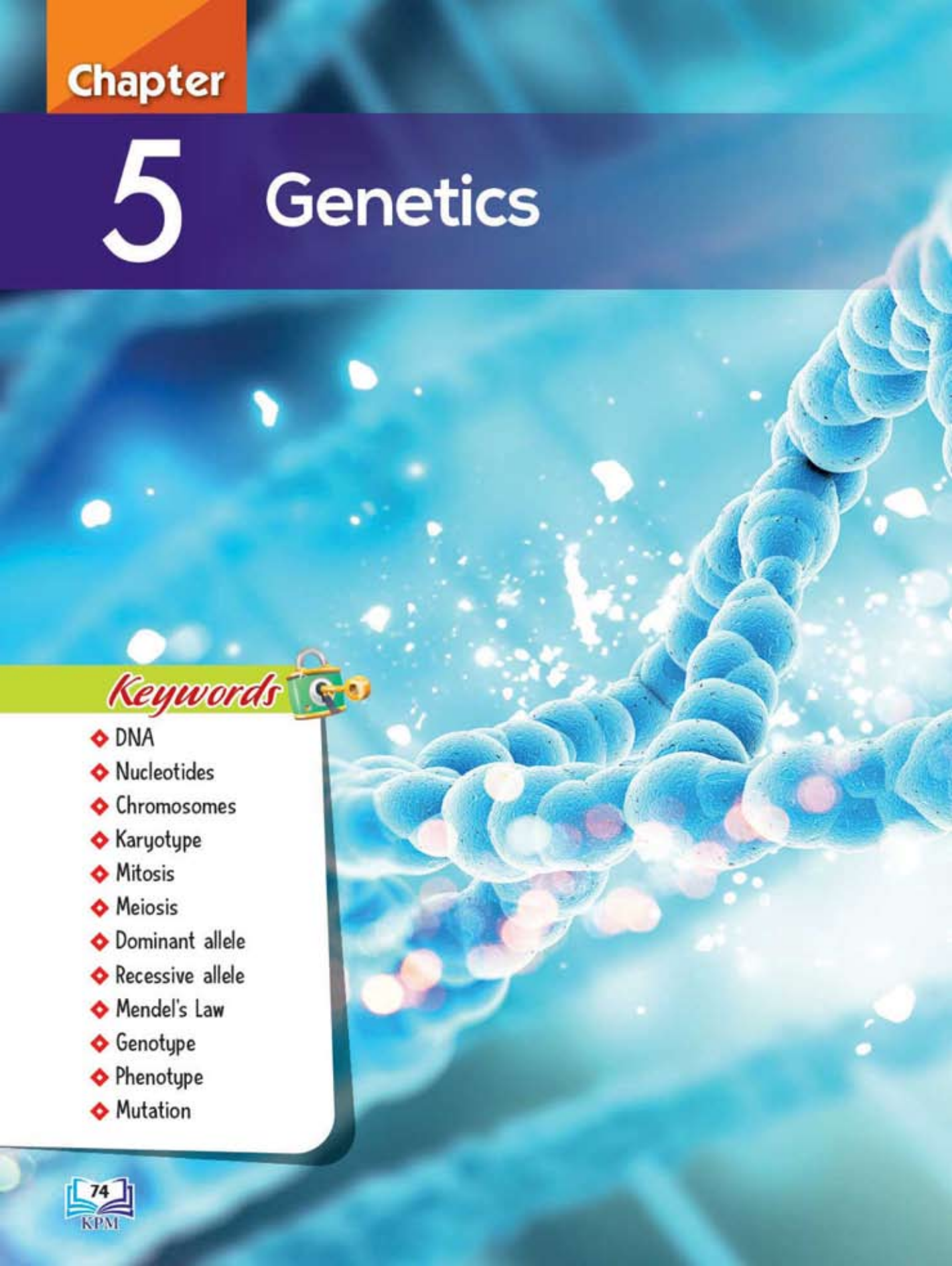
Chapter

5 Genetics



Keywords

- DNA
- Nucleotides
- Chromosomes
- Karyotype
- Mitosis
- Meiosis
- Dominant allele
- Recessive allele
- Mendel's Law
- Genotype
- Phenotype
- Mutation

What is meant by cell division process?

Is it true that our characteristics can be inherited?

What is mutation?

How does genetic engineering affect our daily life?

Science Digest

DNA Evidence

You might have watched popular crime investigation dramas on the television. The dramas are very interesting as they give us exposure to investigation techniques in forensic science.

Crime cases can be solved by collecting DNA evidences. DNAs left behind by the criminal can be identified by an investigator or forensic scientist using modern techniques and equipment. In a criminal case, the criminal might leave evidences such as fragments of skin, hair or droplets of blood at the crime scene. Forensic scientists can analyse the DNA from these specimens by comparing these DNA samples to the suspect's DNA.

You will learn about:

- cell division
- inheritance
- mutation
- genetic engineering technology
- variation

5.1 Cell Division

Gene, Deoxyribonucleic Acid (DNA) and Chromosomes

You learned about cells and cell division in Form 1. You have also learned that nucleus is a structure in the cell which controls all activities in the cell. Do you know which substance in the nucleus controls the cell division process?

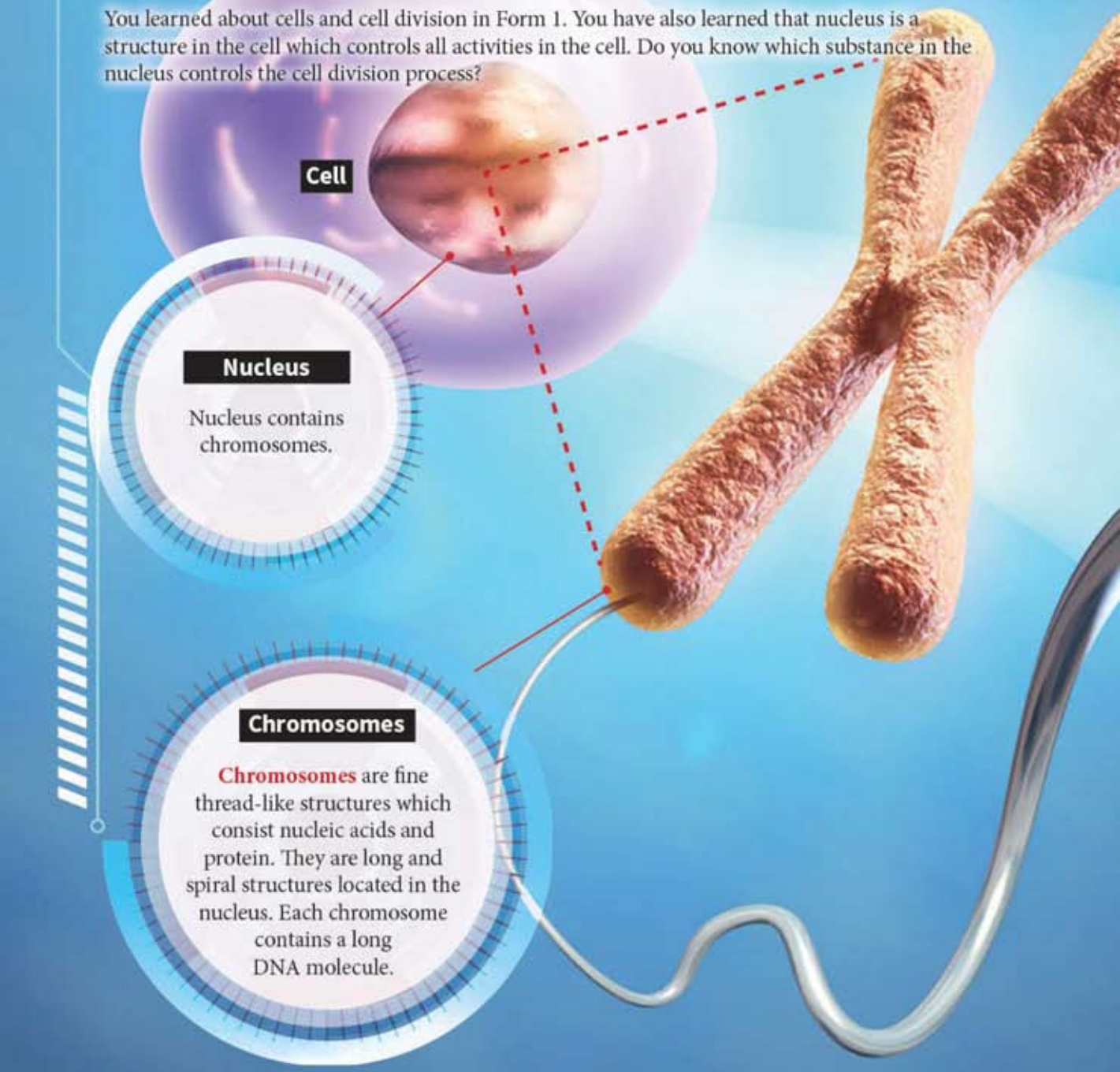


Figure 5.1 *Chromosome, gene and DNA*

Scan Me AR

3D Model

DNA

Deoxyribonucleic acid or **DNA** is made up of basic units known as nucleotides. Each unit of nucleotide consists of three components, deoxyribose sugar, a nitrogenous base and a phosphate group. DNA is made of two twisted antiparallel polynucleotide chains forming a structure known as double helix.

Science Gallery

Genetics is a study of genes, hereditary and variations in organisms.

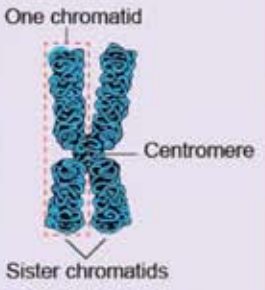
Gene

A **gene** is a basic hereditary unit that determines an individual's characteristics. The function of the gene is to control the inherited characteristics in an organism such as tongue-rolling ability in humans, the shape of the green pea and the colour of the cat's fur. Genes are arranged as segments in the DNA along the chromosomes. There are thousands of genes in a DNA molecule.

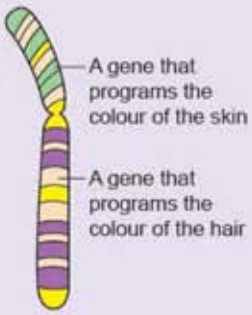
5.1.1

Science Gallery

Chromosome structure:



Each chromosome has several types of genes, from 200 – 300 genes for each chromosome.



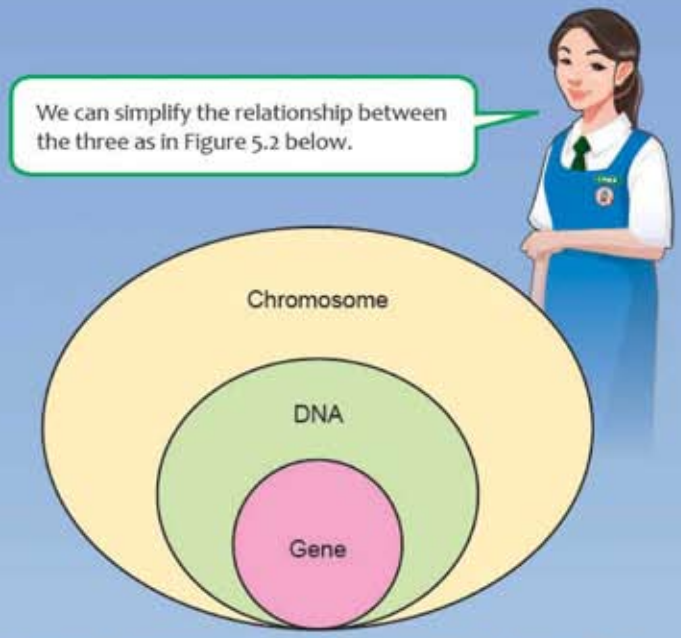


Figure 5.2 *Relationship between chromosome, DNA and gene*

Each species on Earth has a fixed number of chromosomes. The human body cell contains 46 chromosomes. Each chromosome exists in pairs of similar shapes and sizes. Such a pair of chromosomes is known as **homologous chromosomes**. The human homologous chromosomes can be arranged according to their shapes and sizes. Figure 5.3 shows the arrangement of human homologous chromosomes. This arrangement is called **karyotype**.

Chromosome
http://bukutekskssm.my/Science/F4/Pg78
INFORMATION

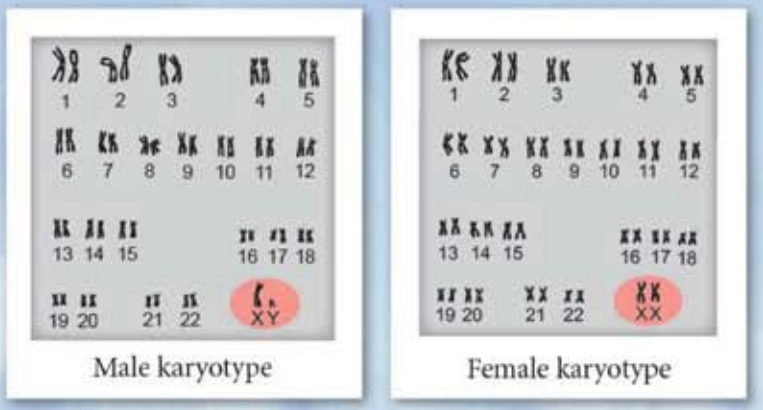


Figure 5.3 *Human karyotype*

In humans, the chromosomes can be divided into two, **autosomes** and **sex chromosomes**. **Autosomes** carry genes that control **characteristics** such as the colour of the eyes, ability to roll the tongue and the type of hair of a human. **Sex chromosomes** on the other hand, carry genes that determine **gender**, whether male or female.

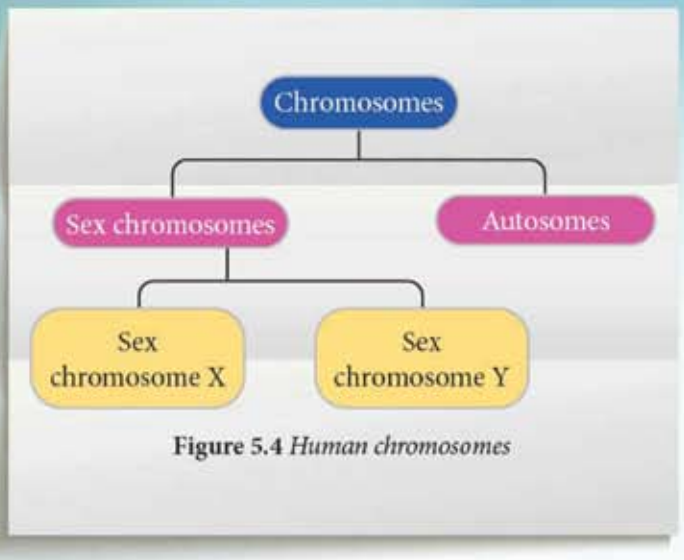


Figure 5.4 *Human chromosomes*

Mitosis and Meiosis

How are genes inherited? To know further, we have to understand cell division first. There are two types of cell division that take place in a cell, **mitosis** and **meiosis**.

Mitosis is a cell division process that forms two identical daughter cells, each having the same number of chromosomes and genetic content as the parent cell. Mitosis takes place in the somatic cells of the human and animal bodies. Mitosis also takes place in the meristematic tissue such as the tip of the roots and the shoot of the plants. Figure 5.5 shows the stages in mitosis.

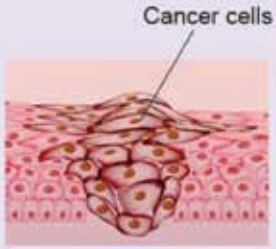
Meiosis is a process where the cell divides into four distinct cells, each containing half the number of chromosomes in the parent cell. Meiosis takes place in the **reproductive organ** to produce gametes for sexual reproduction. Meiosis in humans takes place in the male's testes and the female's ovary. In plants, meiosis takes place in the anther and the ovary. Figure 5.6 shows the stages in meiosis.

Science Gallery

The human somatic cell has 46 chromosomes but the human gamete cells, sperm and ovum, have only half the number of chromosomes, 23 chromosomes.

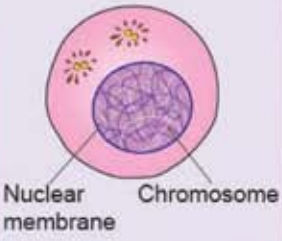
Science Gallery

Cancer is caused by uncontrolled and abnormal cell division. These cells divide faster than they are supposed to in normal conditions.

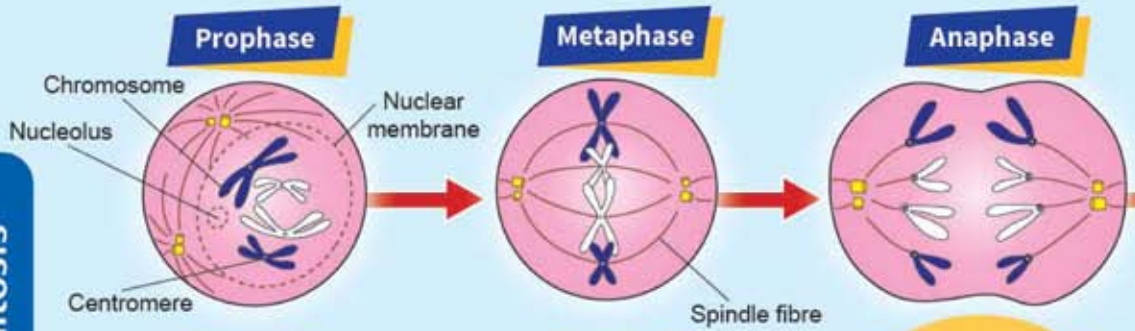


Science Gallery

Interphase is the stage before the process of mitosis and meiosis occurs. At this stage, DNA replication occurs and cells undergo growth and prepare for cell division.



Mitosis



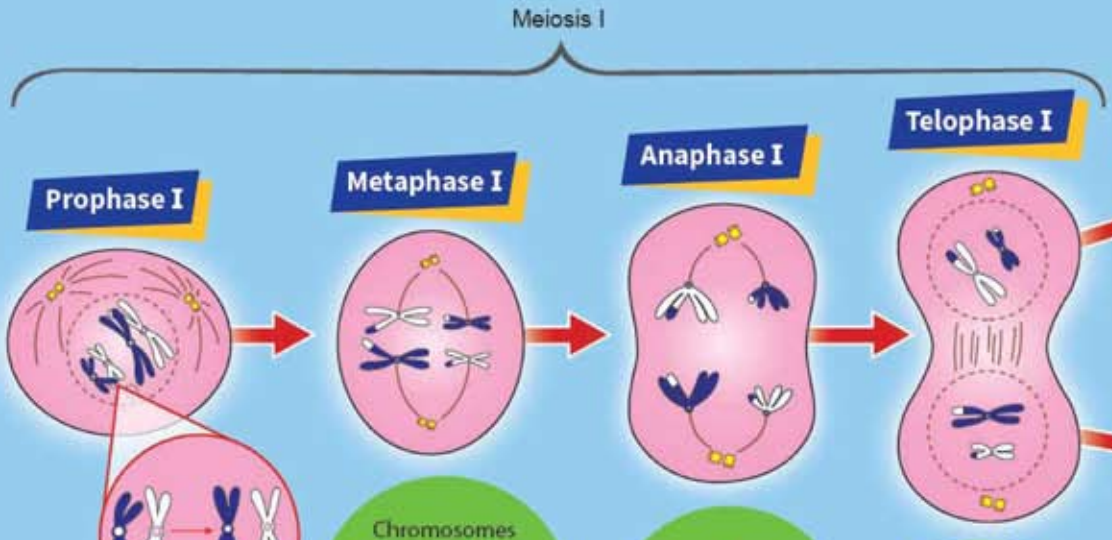
Chromosomes shorten and thicken and later become visible. Each chromosome consists of two chromatids joined at the centromere. Spindle fibres begin to form. Nuclear membrane and nucleolus disintegrate.

Chromosomes are arranged in an equatorial plane. The spindle fibres are attached to the centromere.

Centromere splits into two, each sister chromatid separates and moves towards the opposite poles of the cell (polarisation).

Figure 5.5 *Mitosis*

Meiosis



Chromosomes shorten and thicken and then become visible. Homologous chromosomes pair together. Crossing over occurs, that is the exchange of genetic information between the homologous chromosomes.

Chromosomes are arranged in an equatorial plane. The spindle fibres are attached to the centromere.

Homologous chromosomes separate and move towards the opposite poles of the cell.

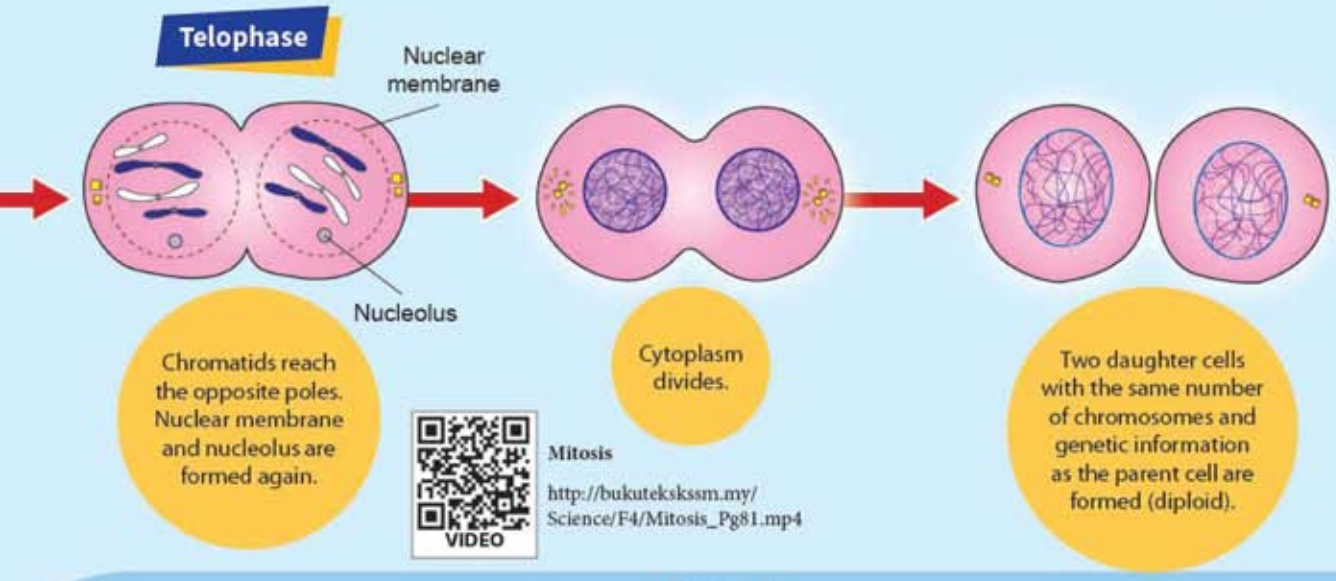
Cytoplasm divides. Last stage of meiosis I ends.

VIDEO

Meiosis

http://bukutekskssm.my/Science/F4/Meiosis_Pg80.mp4

Figure 5.6 *Meiosis*



VIDEO

Mitosis

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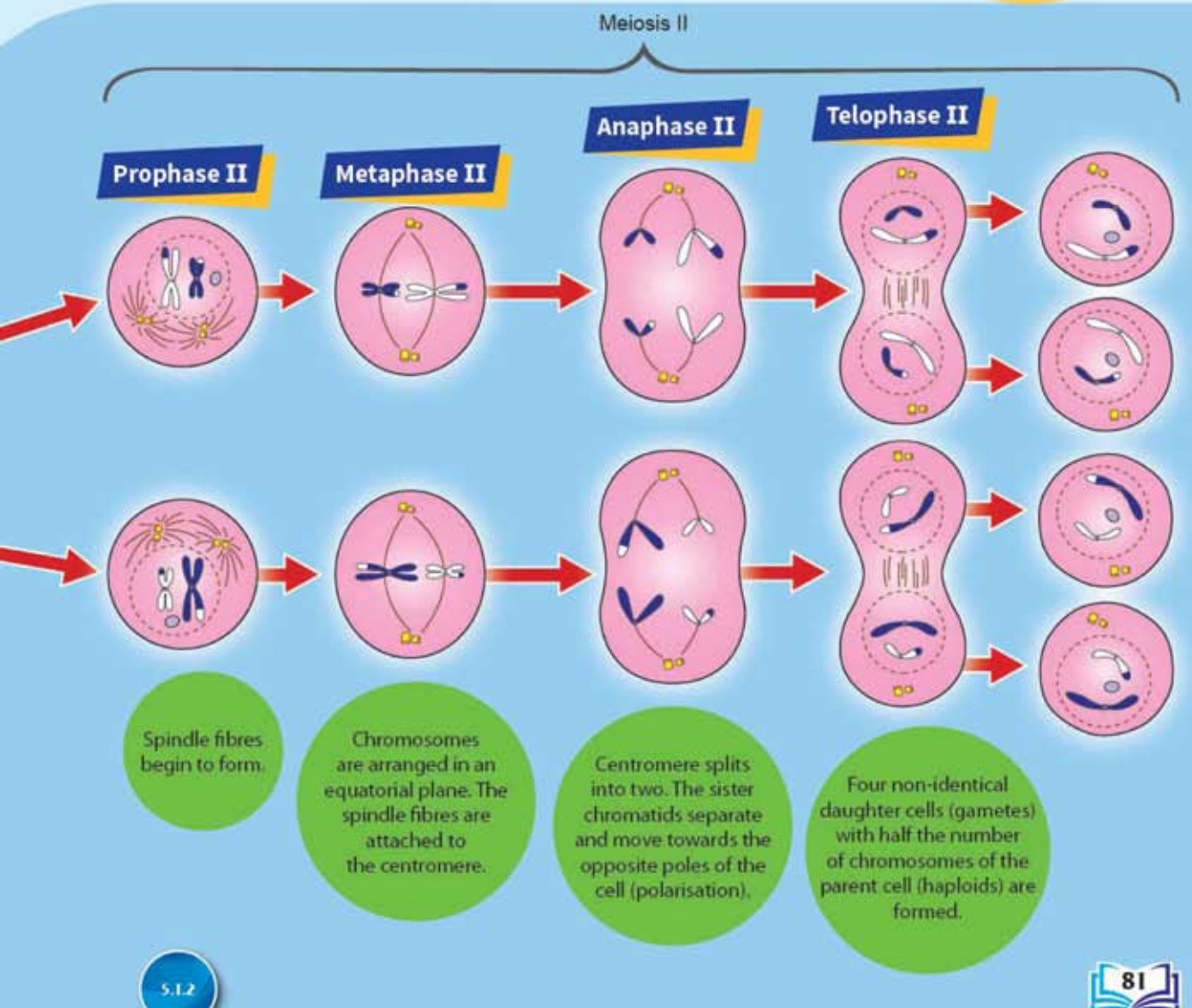


5.1.2

Figure 5.7 shows the similarities and differences between mitosis and meiosis.

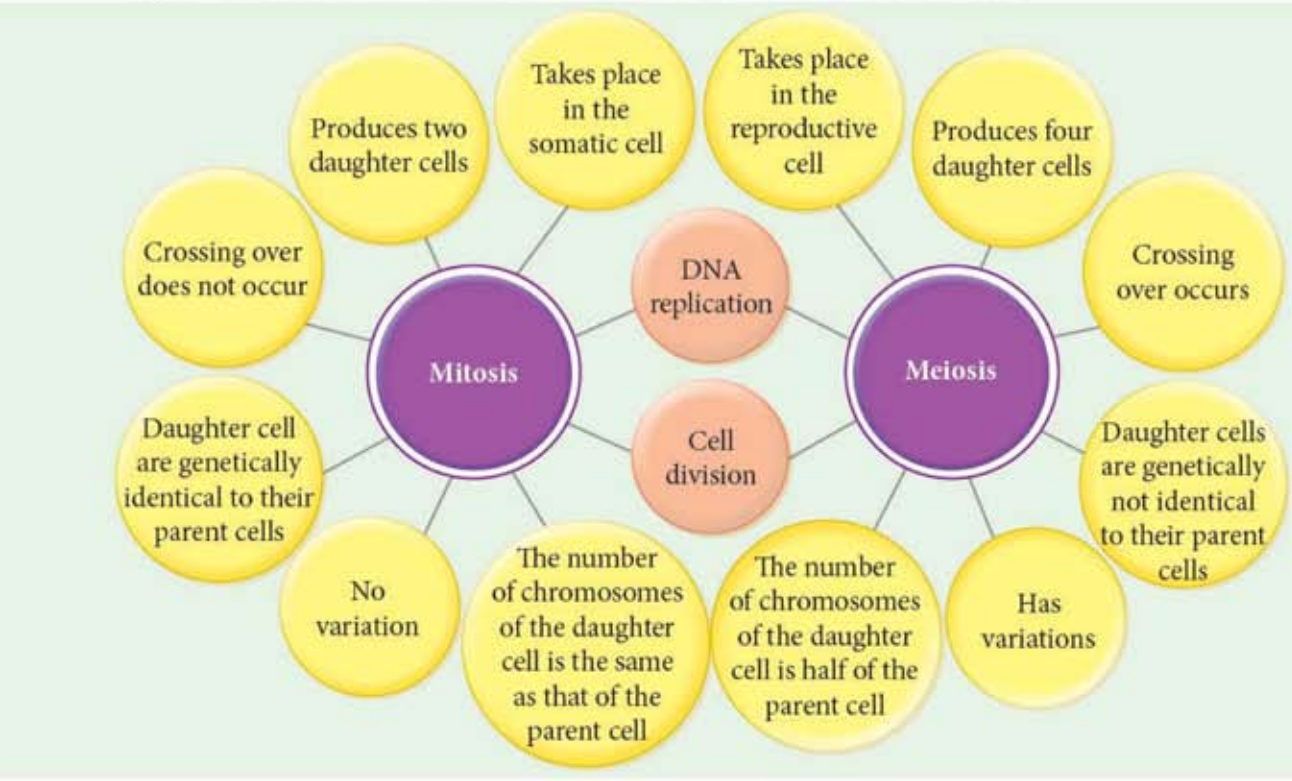
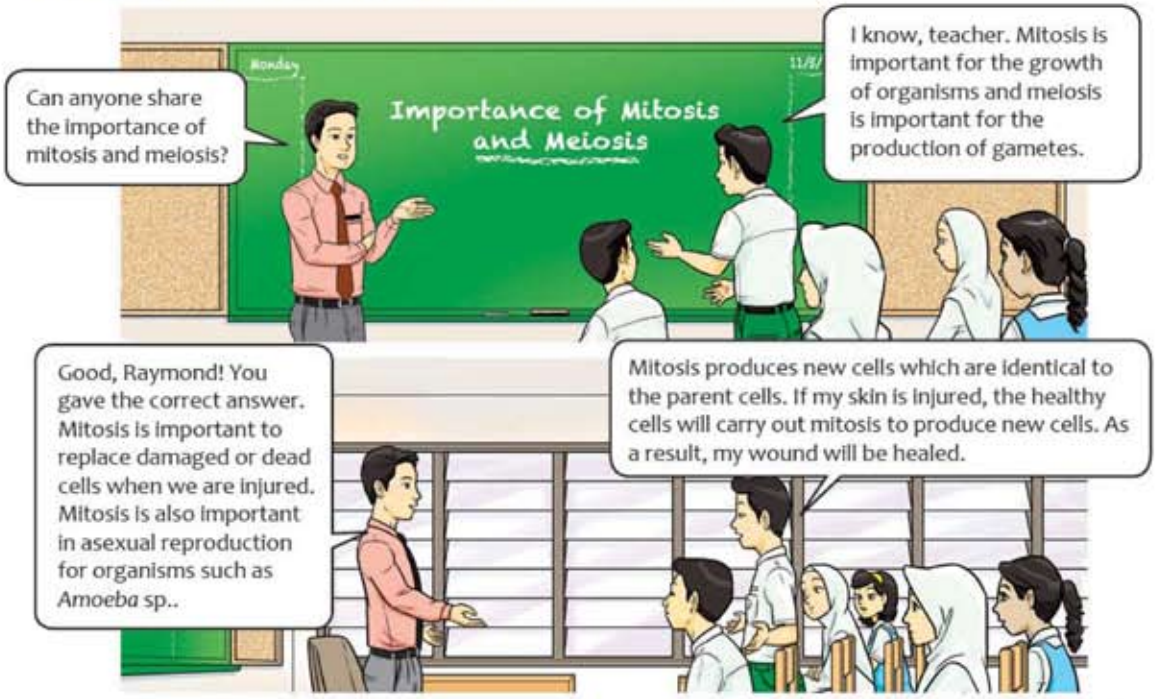
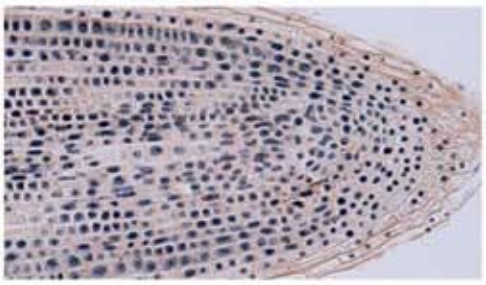


Figure 5.7 *Similarities and differences between mitosis and meiosis*

The Importance of Mitosis and Meiosis





Photograph 5.1 *Growth process that takes place at the tip of the root of a plant*

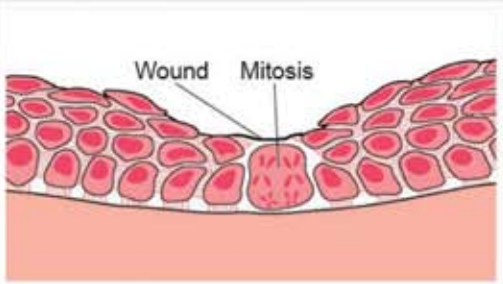


Figure 5.8 *Process that replaces damaged cells*

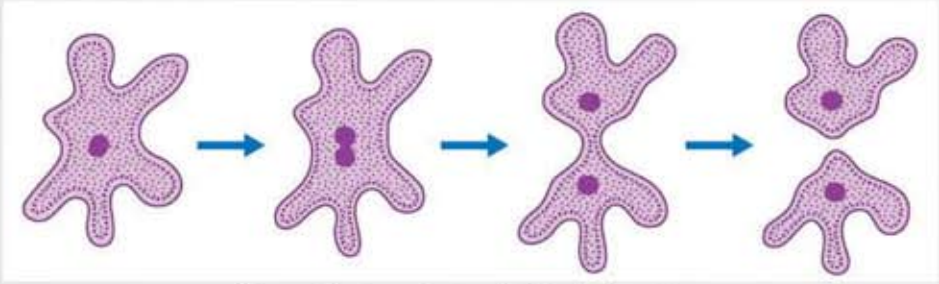


Figure 5.9 *Asexual reproduction in Amoeba* sp.

Activity 5.1

Multimedia Presentation

21st Century Skills

Aim: To create a multimedia presentation on the importance of mitosis and meiosis.

Instructions:

1. Carry out this activity in groups.
2. Gather information:
   (a) the importance of mitosis in the growth process, replacement of damaged cells and asexual reproduction
   (b) the importance of meiosis in the production of gametes
3. Use various sources such as the Internet and the library to gather the information above.
4. Present the outcomes of your group discussion in the form of multimedia presentation.

FORMATIVE PRACTICE 5.1

1. What is meant by
   (a) gene (b) chromosomes (c) DNA
2. Where do mitosis and meiosis take place in the human body?
3. State the similarities and differences between mitosis and meiosis.

5.2 Inheritance

Inheritance in Humans

Look at the following family photographs. Do they look identical? Do children inherit all the characteristics of their parents? Each child inherits certain characteristics from their parents. The transmission of these characteristics from the parents to the children is known as **inheritance**.

Science Gallery

What is the difference between characteristics and traits? Characteristics are tangible properties that are inherited and determined by genes such as the colour of the pupil. Traits are variants for specific characteristics that differentiate individuals. So, the traits for the colours of the pupils are black, brown and blue.

Photograph 5.2 *Inheritance of characteristics in humans*

Characteristics such as the types of hair and the colours of pupils are examples of characteristics that can be inherited by the children from their parents.

These characteristics are passed down from the parents to the children through genes. As you have studied in subtopic 5.1, genes are the basic units of inheritance found in the chromosomes. Genes control certain characteristics in an organism. A **pair of genes** at the same locus or position in the homologous chromosome will control one trait of the organism. The pair of genes at the same locus is known as the **allele**. Alleles can be found in dominant or recessive forms.

The characteristics that are controlled by the dominant allele will be shown whereas the recessive allele will be covered. The recessive allele would only show the characteristics it controls when dominant allele is absent. Therefore, the recessive characteristics would only be shown when both alleles are recessive.

The dominant allele is represented by capital letters while the recessive allele is represented by small letters. For example, 'T' is used to represent tall and 't' represents short.

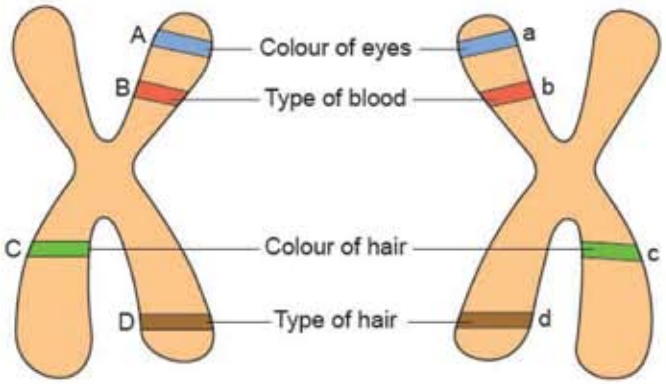
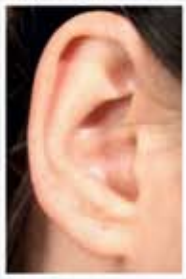
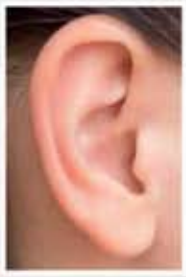


Figure 5.10 *Example of dominant and recessive alleles in chromosomes*

Attached earlobe



Free earlobe



Photograph 5.3 *Attached earlobe and free earlobe*

Figure 5.10 shows a pair of homologous chromosomes in the nucleus. For every trait, we inherit two copies of the genes, one from our mother and the other from our father. Capital letters A, B, C and D represent the dominant alleles while the small letters a, b, c and d represent the recessive alleles.

Do you know which human traits are dominant and recessive? Table 5.1 shows some dominant and recessive traits in humans.

Table 5.1 *Examples of dominant and recessive traits in humans*

Dominant trait	Recessive trait
Ability to roll the tongue	Inability to roll the tongue
Black hair	Blonde hair
Free earlobes	Attached earlobes

Brain Teaser

Is dimple a dominant or recessive trait?

Renowned Scientists

Gregor Mendel
(1822-1884)
"Father of Genetics"

Inheritance Mechanism

Gregor Mendel is the first person to discover the inheritance mechanism in a systematic and detailed manner. Mendel used pure-breeding pea plant in his experiment on monohybrid cross. Monohybrid cross involves research on one characteristic at a time, such as height, which could either be tall or dwarf.

Mendel crossed a pure-breeding tall pea plant with a pure-breeding dwarf pea plant. The genotype of a pure-breeding tall plant can be represented as "TT" in the previous generations. The genotype of a pure-breeding dwarf plant can be represented as "tt" in the previous generations.

The first generation produced by a cross is called first filial generation (F_1) (Figure 5.11). When individuals from F_1 are crossed, the second filial generation (F_2) is formed (Figure 5.12).

Genotype is the **genetic information** in an organism.
Phenotype is the **physical characteristics** shown in an organism.

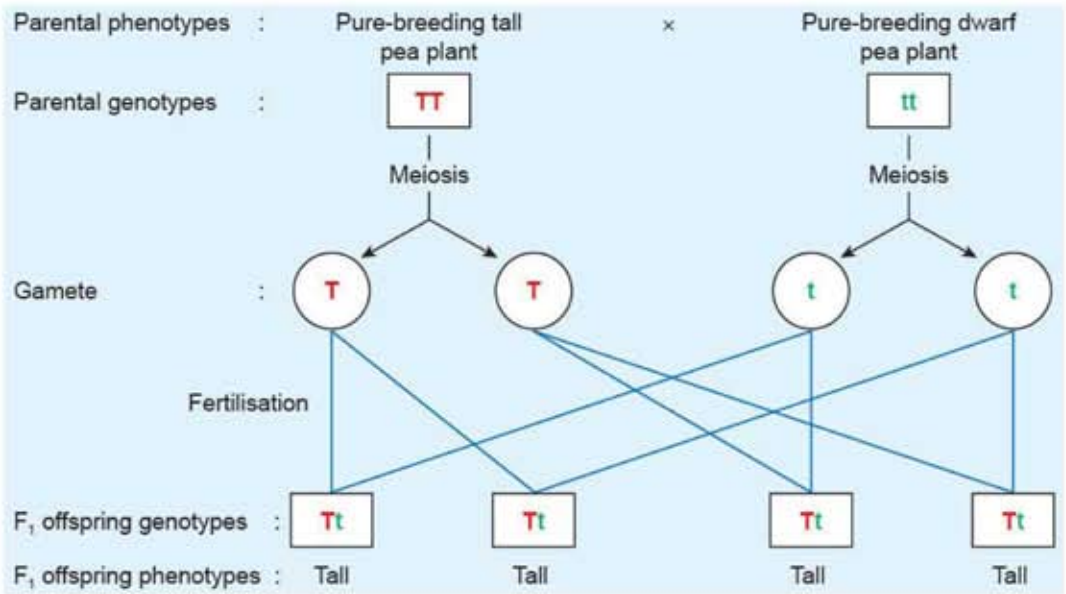


Figure 5.11 *Schematic diagram of monohybrid crossing for height*

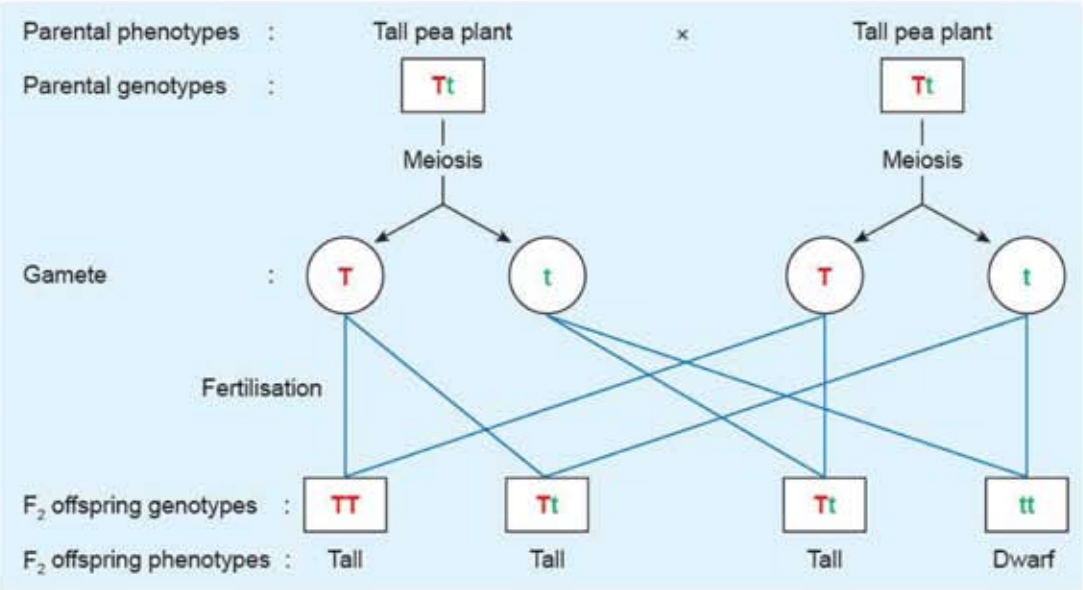


Figure 5.12 *Schematic diagram of monohybrid crossing of the second filial generation for height*

The inheritance of characteristics from the Mendel's experiment can be used to explain the inherited characteristics of humans. The characteristics inherited by a person depend on the genes inherited from his parents. The inheritance mechanism is shown in the schematic diagram below (Figure 5.13).

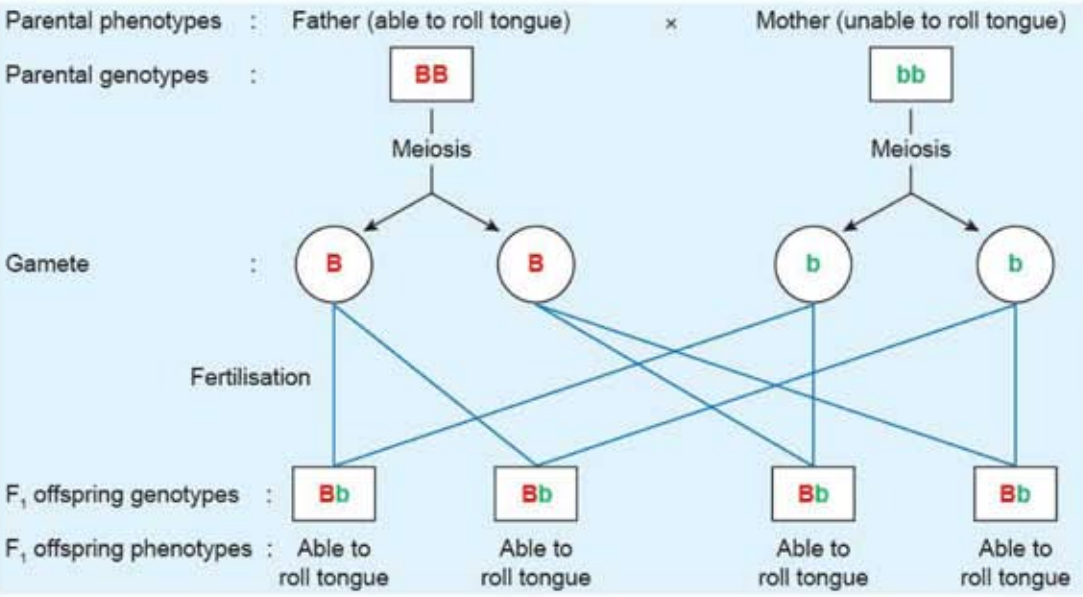
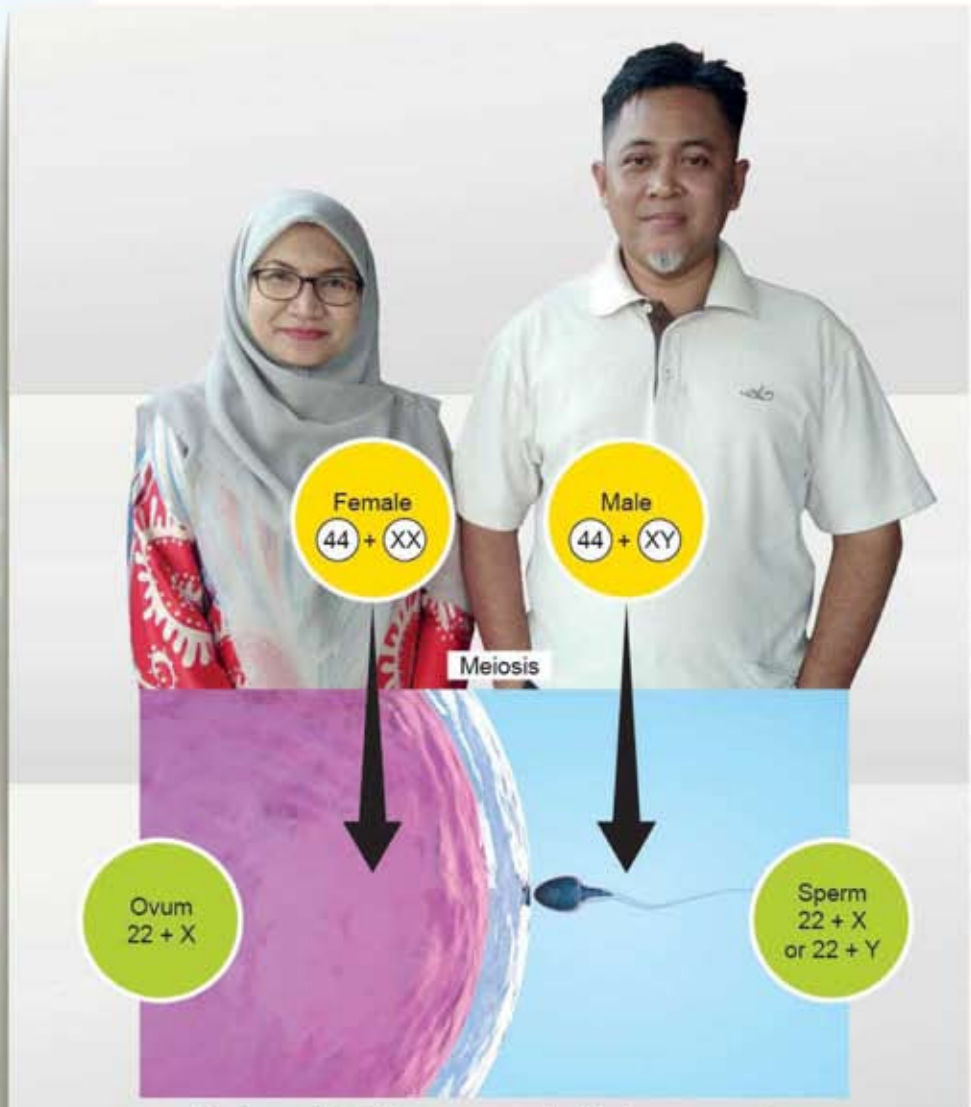


Figure 5.13 *Schematic diagram of the inheritance of the ability to roll tongue*

Unlike the inheritance of the ability to roll the tongue as discussed earlier, the inheritance of the sex of a child is determined by the sex chromosomes, received from the parents.

In subtopic 5.1, we studied about autosomes and sex chromosomes. A male and a female have 46 chromosomes each which are made up of 44 autosomes and two sex chromosomes. The male has two types of sex chromosomes which are X and Y, while the female has only two X chromosomes.

After meiosis, the sperm has only half the number of its parent chromosomes, that is 23 chromosomes (either 22 + X or 22 + Y). The ovum will also have half the number of its parent chromosomes, that is 23 chromosomes (22 + X). The gender of a child depends on the type of sperm that fertilises the ovum. If the sperm (22 + X) fertilises the ovum (22 + X), the gender of the child formed is a female, (44 + XX). If the sperm (22 + Y) fertilises the ovum (22 + X), a male child will be born, (44 + XY).



Photograph 5.4 *Chromosome content in human gametes*

Gender determination of an offspring is shown in Figure 5.14.

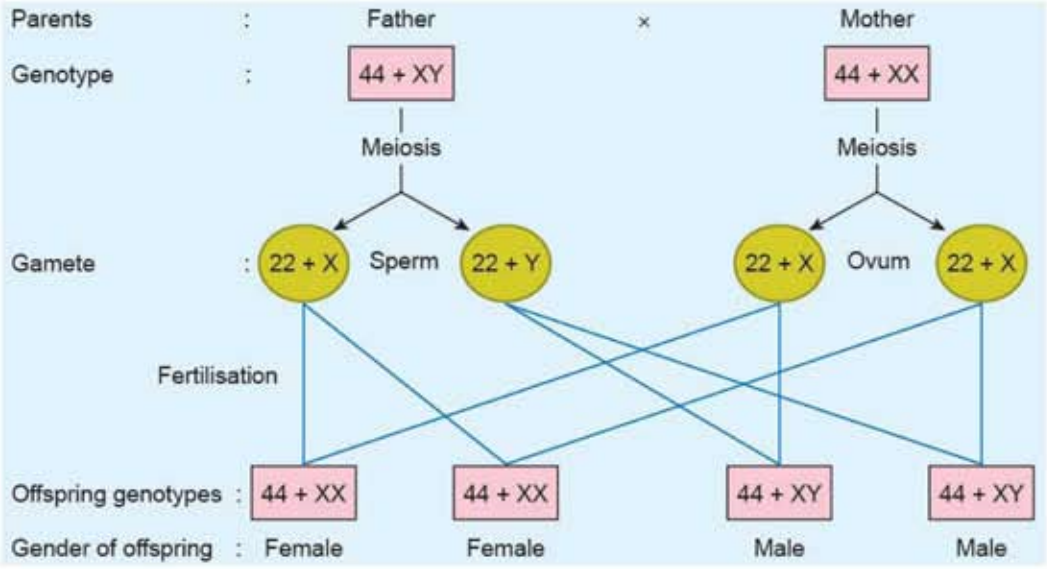


Figure 5.14 *Schematic diagram of determining a child's gender*

Based on the figure above, the chances of getting a male or a female offspring at each pregnancy is equal, which is 50%.

Activity 5.2

Windows Pane

21st Century Skills

Aim: To predict the genotype and phenotype ratio for monohybrid crosses.

Instructions:

1. Carry out this activity in groups.
2. Each group is given an incomplete schematic diagram of inheritance for monohybrid cross of a characteristic of the garden pea plant studied by Mendel.
3. Complete the schematic diagram of inheritance.
4. Present the results of your group to the class.

FORMATIVE PRACTICE 5.2

1. Explain the differences between the dominant allele and the recessive allele.
2. What are sex chromosomes?
3. What determines the gender of a child? Explain your answer.

5.3 Mutation

Types of Mutations

Look at Photograph 5.5 below. Can you see the differences in each individuals in the photographs compared to a normal individual? What causes the differences?

Photograph 5.5 *Differences in individuals*

Brain Teaser

Can the mother's eating habits during pregnancy cause mutation?

Science Gallery

The birth rate of Down syndrome babies is 1 to 800. The risk is higher if the mother's age is more than 35.

Have you heard of mutation? What is mutation? **Mutation** is a **spontaneous and random** change that takes place in the genes and chromosomes that can cause changes of characteristics to the offspring who inherits the modified genes. There are two types of mutations, **chromosome mutation** and **gene mutation**. Figure 5.15 shows the types of mutations and their examples.

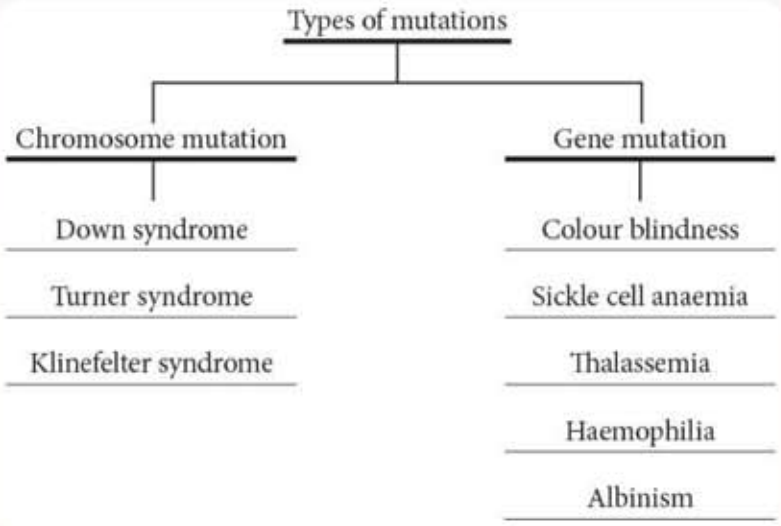


Figure 5.15 *Types of mutations and examples*

Chromosome Mutation

Chromosome mutation occurs when there are changes in the number or structure of the chromosome. These changes occur as a result of a defect during the cell division process.

(a) Down syndrome (Extra chromosome number 21)

Down syndrome occurs because there is an extra chromosome in **chromosome number 21**. A person with Down syndrome has 47 chromosomes compared to a normal person who has 46 chromosomes. A person with Down syndrome has characteristics such as physical and mental retardation, short neck, slanted eyes and short stocky body.

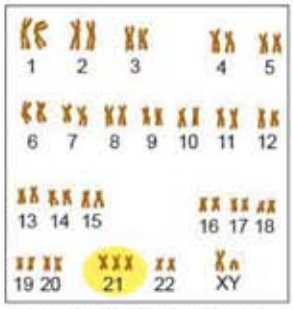


Figure 5.16 *Karyotype of a male with Down syndrome*

(b) Turner syndrome (XO)

A person with Turner syndrome has **less number of sex chromosomes** compared to a normal person. The total number of chromosomes is 45 chromosomes (44 + XO) only. A person with Turner syndrome is a **female** who has a missing X chromosome. A person with Turner syndrome will not undergo the development of secondary sexual characteristics of a female.

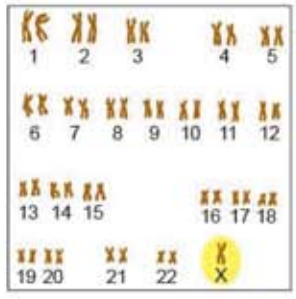


Figure 5.17 *Karyotype of a female with Turner syndrome*

(c) Klinefelter syndrome (XXY)

A person with Klinefelter syndrome has **more number of sex chromosomes** compared to a normal individual. The total number of chromosomes is 47 chromosomes (44 + XXY). A person with Klinefelter syndrome is a **male** with an extra chromosome X. A person with Klinefelter syndrome has female characteristics such as breasts and small testis as well as sterile.

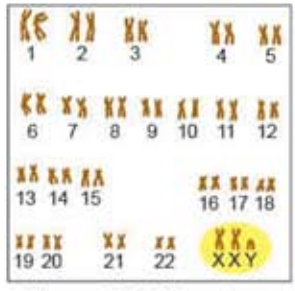


Figure 5.18 *Karyotype of a male with Klinefelter syndrome*

Gene Mutation

Gene mutation is caused by chemical changes that occur to a gene. Gene mutation causes changes in characteristics that are controlled by the gene.

Science Gallery

In November 2016, the Ministry of Health Malaysia launched a thalassemia check initiative that targeted the whole country involving Form 4 students. This step was taken to reduce the percentage of babies born with thalassemia. Counselling and appropriate guidelines will be given to individuals who are confirmed as carriers so that they do not choose a partner who has thalassemia.

(a) Colour blindness

A person who is colour blind has mutant recessive genes on chromosome X. These persons are unable to differentiate between red and green. This disease is controlled by a recessive gene on the X chromosome. This genetic disease usually occurs in males.

(b) Sickle cell anaemia

This disease is caused by the spontaneous change that occur at the gene responsible for production of haemoglobin. The person with sickle cell anaemia has an abnormal red blood cell shape that is sickle-shaped, affecting the transport of oxygen. This disease is caused by a recessive gene on the autosome.

Photograph 5.6 *Sickle-shaped red blood cell and normal red blood cell*

(c) Thalassemia

Thalassemia is a type of genetic disease that is caused by the mutation of the gene that controls the production of haemoglobin. A person with thalassemia has small red blood cells and the lifespan of the cells is shorter. This condition can cause severe blood deficiency.

(d) Haemophilia

A person with haemophilia has difficulty in the clotting of his blood. This is because mutation has occurred at the gene producing the blood clotting factor. This person will lose blood continuously if wounded or injured.

Factors that Cause Gene Mutation and Chromosome Mutation

Mutation may occur spontaneously (naturally) during cell division process. Mutation can also occur due to external factors known as **mutagens**. What are the mutagens that you know?

Activity 5.3

Gallery Walk

21st Century Skills

Aim: To gather information and prepare a presentation about the factors that cause gene mutation and chromosome mutation.

Instructions:

1. Carry out this activity in groups.
2. Gather separate information about the factors that cause gene mutation and chromosome mutation.
3. Gather the information related to the examples of gene mutation such as colour blindness, sickle cell anaemia, thalassemia and haemophilia.
4. Record the information on a flip chart paper.
5. Pin up your group's work product in the class so that it can be seen by other groups.
6. Write comments about the work product of other groups on the flip chart papers.

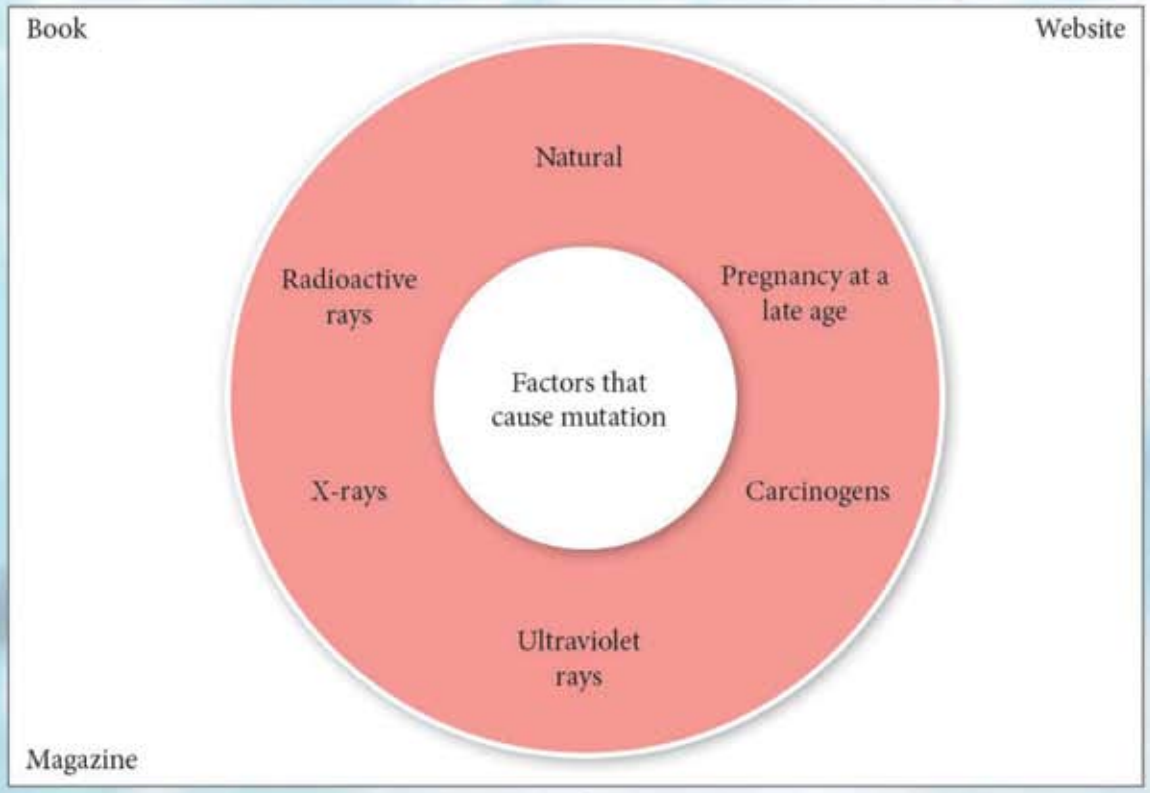


Figure 5.19 *Factors that cause mutation*

Gene Disorder Disease

Alleles also carry the disease trait that can be inherited in a family. Figure 5.20 shows the inheritance of a type of gene disorder disease when a man who **suffers from the gene disorder disease** marries a woman who is a **gene disorder disease carrier.**

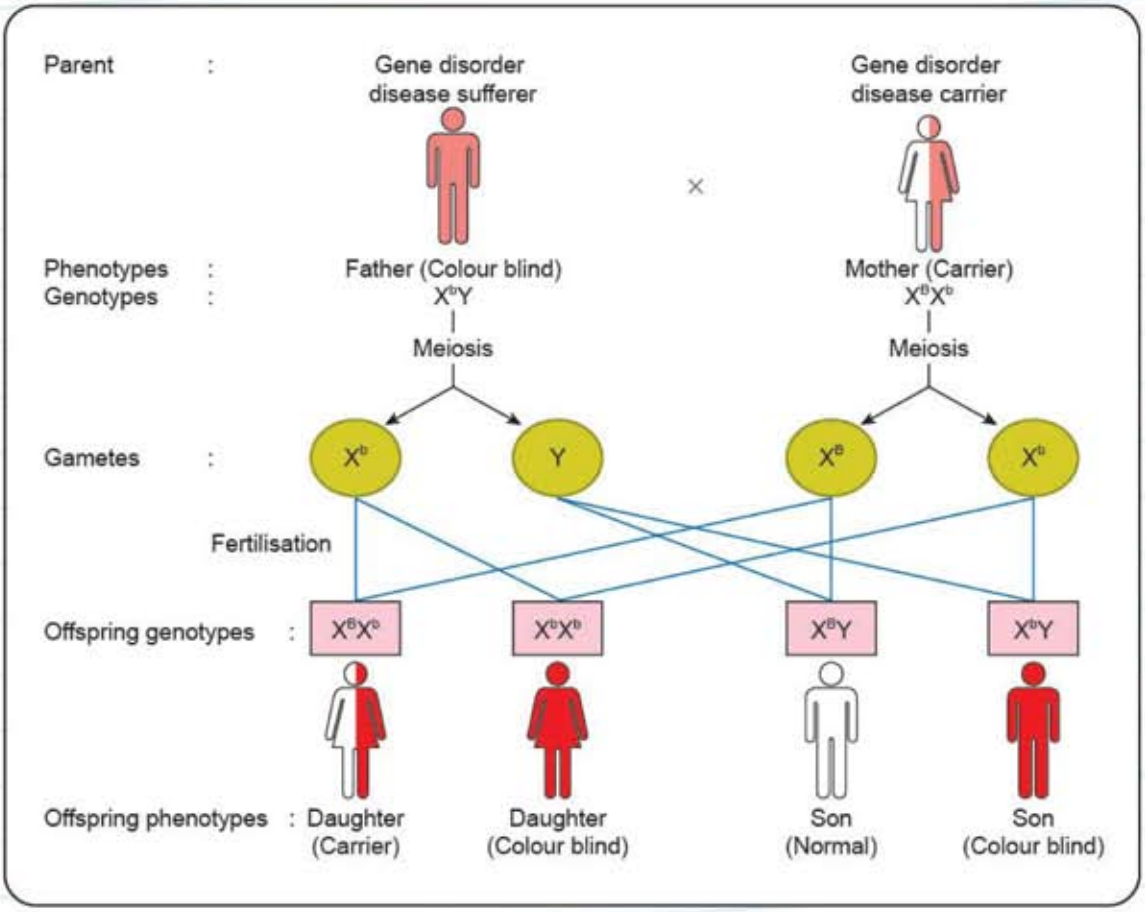


Figure 5.20 *Inheritance of a type of gene disorder disease*

Most of the genes that control a trait are located on autosomes. However, there are also traits that are located on **sex chromosomes**. This trait is known as the **sex-linked trait** and the genes that are located on the sex chromosomes are called **sex-linked genes**. For example, the blood clotting failure traits that cause haemophilia.

Haemophilia is a genetic disease that is experienced by a person when the blood at his wound takes a longer time to clot. Haemophilia is only inherited when there is a recessive allele that causes the diseases on the X chromosome. If there are no recessive alleles at X chromosomes, there is no haemophilia disease. Study the schematic diagram for haemophilia inheritance on the following Figure 5.21 and Figure 5.22.

X^H is the dominant allele (normal) and X^h is the recessive allele (haemophilia).

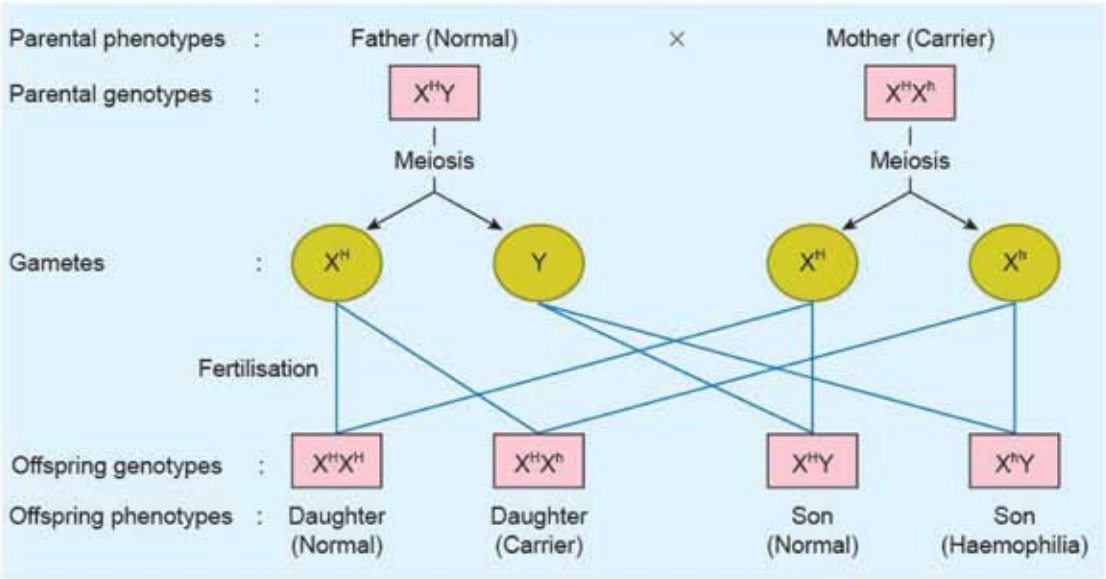


Figure 5.21 *Schematic diagram for inheritance of haemophilia if the father is normal and the mother is a carrier*

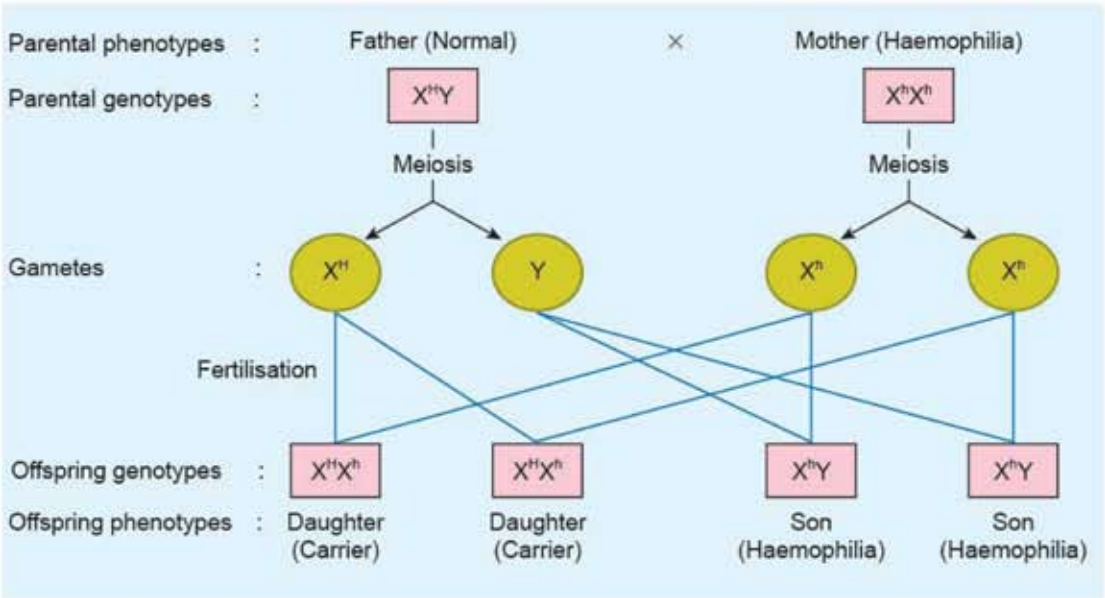


Figure 5.22 *Schematic diagram for inheritance of haemophilia if the father is normal and the mother is a haemophiliac*

There are two methods that can be used to identify gene disorder diseases:
- amniocentesis
- karyotyping

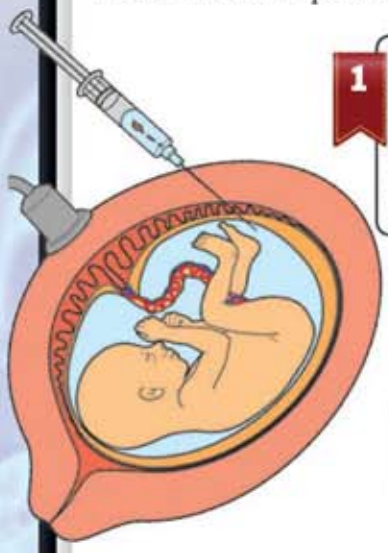
Karyotype produced from these methods will be used to identify any abnormalities in the chromosomes. This is to detect any gene disorder disease at an early stage.

VIDEO **Amniocentesis** http://bukuteksksm.my/Science/F4/Pg96_2.mp4

VIDEO **Karyotyping** http://bukuteksksm.my/Science/F4/Pg96_1.mp4

Amniocentesis

Amniocentesis is used to identify foetal cell abnormalities from the 15th to the 20th week of pregnancy. At the beginning, the position of the foetus in the uterus is detected using the ultrasound technique to ensure safe foetal position.



1. A needle will be inserted carefully through the mother's abdomen penetrating the wall of the uterus.
2. Amniotic fluid that contains floating foetal cells is extracted.
3. This amniotic fluid is then centrifuged to separate the amniotic fluid and foetal cells.
4. The separated foetal cells will be used to obtain the karyotype.

Figure 5.23 *Steps in amniocentesis*

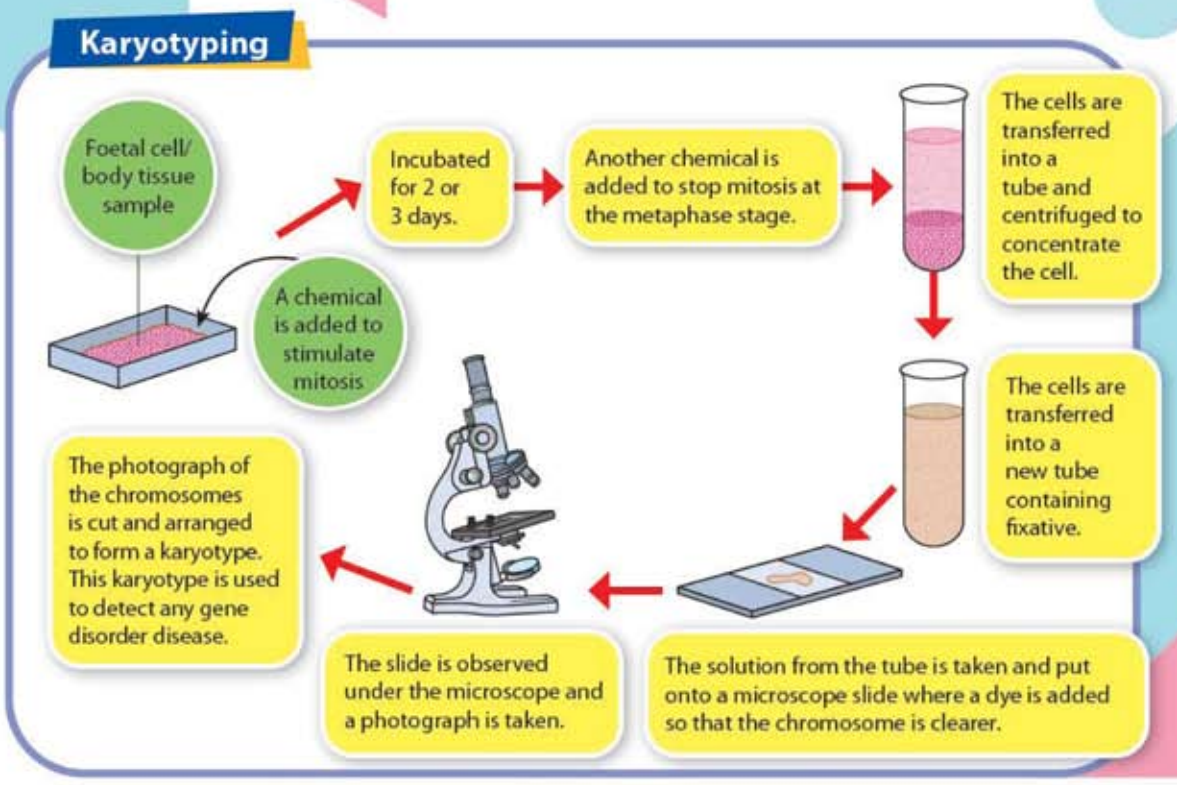


Figure 5.24 *Steps in karyotyping*

Application of Genetic Research to Improve Quality of Life

Genetic research has been carried out in various fields for the benefit of humans. Among the genetic researches that can increase the quality of human life are forensic science, gene therapy and genetic genealogy.

Photograph 5.7 *A forensic scientist examining fingerprints in the lab*

Forensic Science

Forensic science is one of the science and technological fields that carries out the study on crime investigation by identifying and confirming the chronology of an incident based on scientific evidence obtained.

Forensic science plays an important role in the legal system in terms of preparing scientific based information through physical evidence analysis. During an investigation, the evidence is gathered at the place of the incident or from the person involved, analysed in the laboratory and then, the analytical result is presented in the court.

5.3.3
5.3.4

Gene Therapy

Gene therapy is a technique that is still at an experimental stage. It is aimed at repairing the mutated genes (abnormal/defective) that cause diseases such as cystic fibrosis, haemophilia and sickle cell anaemia. This technique is carried out by introducing a normal gene into the cell or tissue of the patient to replace the defective genes.

INFORMATION
DNA and Forensic Science
http://bukutekskssm.my/Science/F4/Pg98_1

INFORMATION
Gene Therapy
http://bukutekskssm.my/Science/F4/Pg98_2

INFORMATION
Genetic Genealogy
http://bukutekskssm.my/Science/F4/Pg98_3

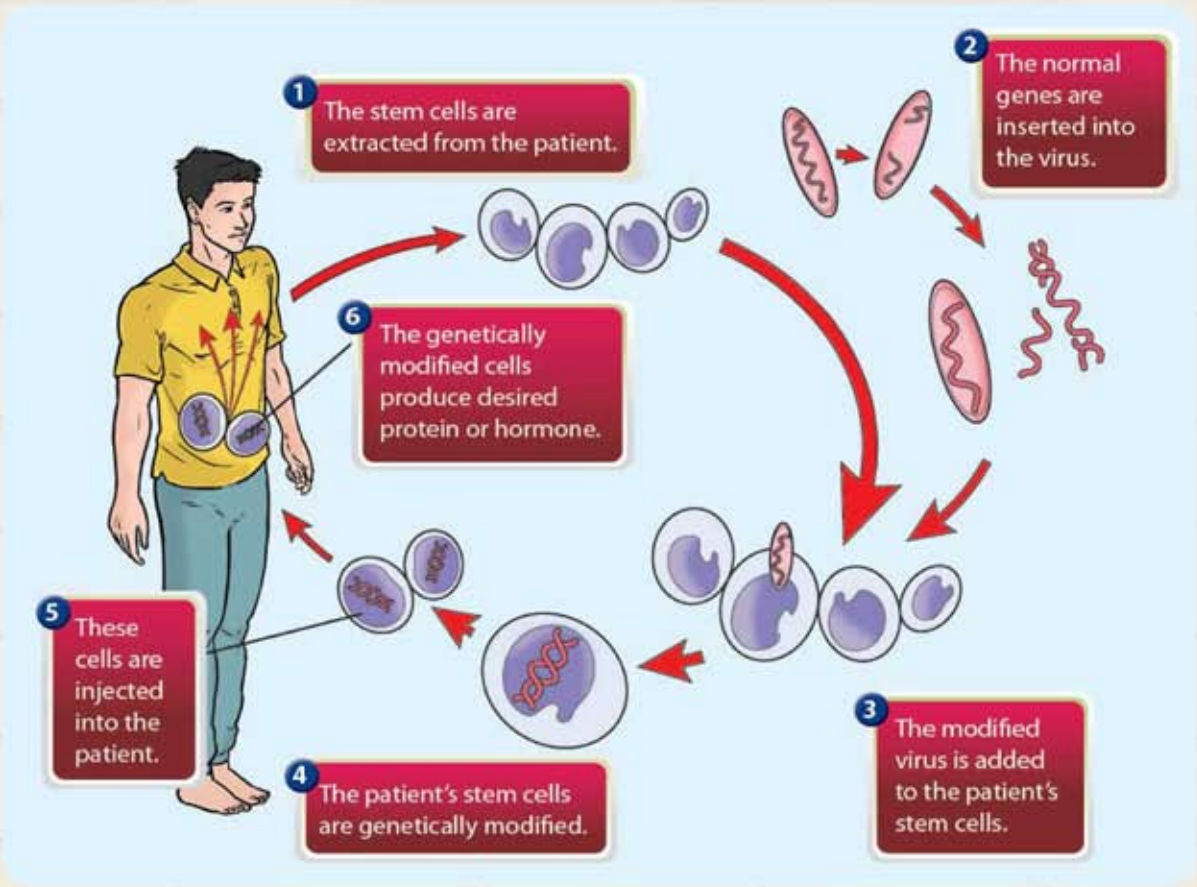


Figure 5.25 *The process of gene therapy*

Genetic Genealogy

Genetic genealogy is a genetic accumulation study to determine the family pedigree or hierarchy, ancestry and its history. DNA tests are used in the study.

Activity 5.4

Result Showcase

21st Century Skills

Aim: To gather information and prepare a presentation about genetic research.

Instructions:

1. Carry out this activity in groups.
2. Gather information about the application in genetic research such as the following:
   (a) forensic science
   (b) gene therapy
   (c) genetic genealogy
3. Gather the information above from various sources and present the outcome of your group discussion in class.

The Effect of Genetic Research on Human Lives

Genetic research is a very useful field in biology. The genetic research is a technique that is widely used to change the genes in medical and agricultural fields. There are a few advantages and disadvantages of genetic research that have emerged due to human behaviour. Let us carry out an activity to widen our knowledge and take into account the opinions of other friends about the advantages and disadvantages of genetic research in terms of economic, welfare, ethics, psychological and social.

Activity 5.5

Debate

21st Century Skills

Aim: To debate on the effects of genetic research.

Instructions:

1. Form two debate teams and invite a few teachers as adjudicators.
2. Debate the topic "Genetic research brings about more advantages than disadvantages" in terms of genetic screening based on the following aspects:
   (a) economy (insurance, job opportunities)
   (b) welfare (family institution)
   (c) ethics
   (d) psychology
   (e) social

5.3.4
5.3.5

FORMATIVE PRACTICE 5.3

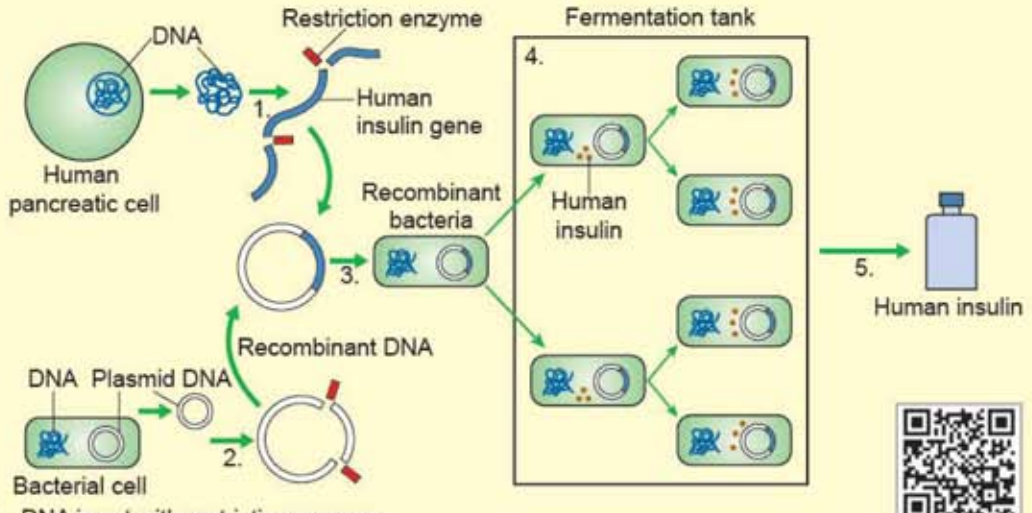
1. What is mutation?
2. List three factors that cause mutation.
3. List the advantages and disadvantages of genetic research.
4. What problems will arise if ethics and values are not practised in genetic research?

5.4 Genetic Engineering Technology

What is genetic engineering? Genetic engineering is the term used for genetic modification of an organism. Genetic engineering was first introduced around 1971-1973 and is known as genetic engineering science. Genetic engineering, is usually related to recombinant DNA, genetically modified organisms (GMO) and gene therapy.

Recombinant DNA Technology

Recombinant DNA technology is a technology that combines two different species to produce a new genetic characteristic. For example, DNA from a plant can be combined with a bacterial DNA, or a human DNA is combined with DNA from fungi, to create a hybrid DNA. A more detailed example is, the production of human insulin using bacteria. The production of this insulin can help people who suffer from diabetes mellitus.



1. DNA is cut with restriction enzyme
2. Plasmid DNA is cut with restriction enzyme
3. Recombinant DNA is introduced into a bacterial cell
4. Recombinant bacteria multiplying in fermentation tank and producing human insulin
5. Extraction and purification of human insulin

Recombinant DNA Technology
http://bukuteksskssm.my/Science/F4/Pg100.mp4

Figure 5.26 *The making of insulin through recombinant DNA technology*

Genetically Modified Organism (GMO)

Have you ever heard of the term GMO? GMO is the abbreviation for Genetically Modified Organism, that is an organism (plant, animal, bacteria or virus) which has been genetically modified for a particular purpose.

Photograph 5.8 *Example of genetically modified food*

This technology combines genes from two different species. This can be done by combining an animal gene with a plant gene or a bacterial gene. This will produce a genetically modified organism (GMO) with new characteristics that might not be possible to be produced through the traditional crossover process. The new organism has a few specific changes that are needed to increase commercial quality. A few plants that have been produced are plants that can resist pests or diseases. This application can be seen in paddy, maize and palm oil cultivation.

Bigger fruits, higher nutritional value and resistance to pests and diseases are the characteristics of the product desired in the agricultural field. One of the benefits of crops produced through genetic modification is a reduction in the use of pesticides. Therefore, it can reduce environmental pollution.

INFORMATION

Creation of an Insect Resistant Tomato Plant
http://bukutekskssm.my/Science/F4/Pg101.jpg

Brain Teaser

Is this a product of genetic engineering?

Activity 5.6

Multimedia Presentation

21st Century Skills

Aim: To search for information about genetic engineering such as recombinant DNA, gene therapy and genetically modified organism.

Instructions:

1. Carry out this activity in groups.
2. Gather information about recombinant DNA, gene therapy and genetically modified organism (GMO).
3. Do a multimedia presentation about the topics that were discussed.

The Effects of Genetic Engineering Technology in Life

Genetic engineering technology

Advantages

1. Identifies and determines hereditary diseases and consequently treat the disease.
2. Produces quality plants and livestock.
3. Produces plants and livestock that has high resistance towards diseases compared to the earlier generation.
4. Produces more plants that require shorter time to harvest.
5. Produces insulin and enzymes from bacteria that can improve human health.

Disadvantages

1. The product of genetic changes causes allergy and side effects to the consumers that suffer from allergy.
2. Genetic research produces new species that can cause the original species to become extinct.
3. Can cause side effects such as mutation to the consumers.
4. Genetic modification may be used unethically to produce biological weapons that can harm humans.
5. Produce organisms that have high resistance to pesticides.

Figure 5.27 *Advantages and disadvantages of genetic engineering technology*

Activity 5.7

Debate

21st Century Skills

Aim: To debate on the effects of genetic engineering technology in life.

Instructions:

1. Prepare the debate topic for your class. For example, the debate topic that can be considered is as follows:
   "Genetic engineering has more advantages than disadvantages"
2. Divide the class into two groups. One group is the proponent and the other is the opponent.
3. The debate can be carried out in the class or school hall.

Ethics in Genetic Engineering Technology

1. Genetic research needs to be carried out with high integrity so that it is not morally and religiously wrong.
2. Genetic engineering technology can help humans in terms of health such as insulin synthesis to help humans who suffer from diabetes mellitus.
3. Genetic engineering technology can help humans in solving the problems of food shortage and crop damage.
4. Ethics and values must be practised when carrying out genetic engineering experiments so that it does not touch on religious and moral sensitivities.
5. To prevent the misuse of genetic engineering technology, laws and regulations should be enforced to educate the researchers on the development of genetic engineering.

FORMATIVE PRACTICE 5.4

1. What is meant by genetic engineering?
2. Explain the meaning and give one example of recombinant DNA, gene therapy and GMO.
3. State three advantages and disadvantages of genetic engineering technology.

5.5 Variation

Photograph 5.9 *Variation among students*

Look at your friends and teachers around you. Do they look the same or different? Why?

The difference that exists among us is caused by variation. Variation is the differences in characteristics among individuals from the same species. Look at the example of variation in Photograph 5.9. Can you state the examples of variation that can be seen in this picture?

5.4.3
5.5.1

Continuous Variation and Discontinuous Variation

Continuous variation is the variation that shows differences that are not distinct or not clear between individuals in the same population. Examples of continuous variation in humans are height and body weight. Can you think of other examples of continuous variation that you can see among your friends and family members?

Continuous variation is quantitative. These characteristics can be measured and are represented by a normal distribution curve. Look at the normal distribution graph in Figure 5.28 below.

Continuous variation is determined by genes but can also be influenced by environmental factors. As an example, the skin colour of an individual is determined by genes that are inherited from his mother and father. However, the individual can have different skin colour when he stays at two different locations.

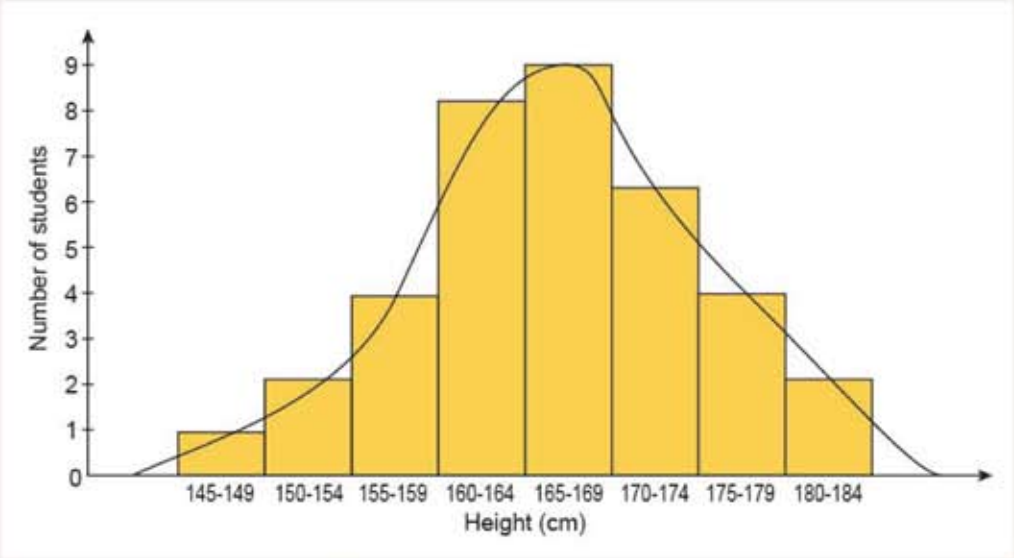


Figure 5.28 *Continuous variation*

Discontinuous variation is the variation that shows differences that are distinct or very clear between individuals of the same population. Examples of discontinuous variation in humans are the ability to roll the tongue, types of fingerprints, earlobes and blood groups. Can you think of other examples of discontinuous variation that you can see among your friends and family members?

The graph for discontinuous variation is in discrete shape. The bar chart is used to represent discontinuous variation. Discontinuous variation is qualitative. Discontinuous variation is determined by genetic factor only. Hence, the traits for discontinuous variation can be inherited from one generation to the next generation, and they are not influenced by environmental factors.

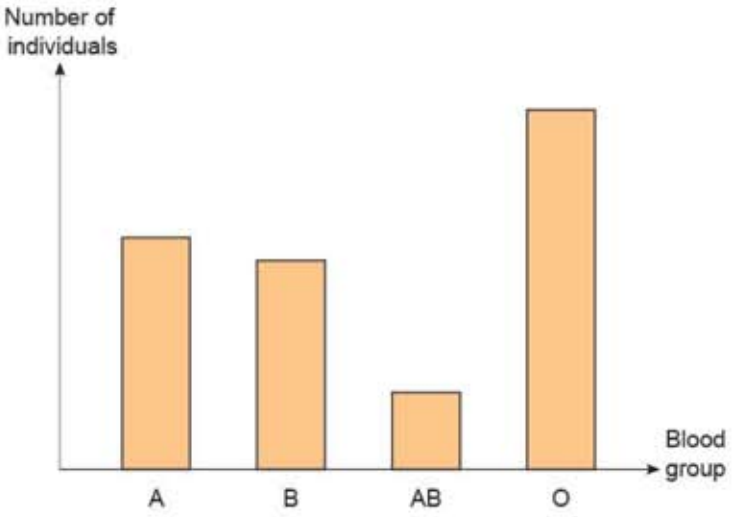


Figure 5.29 *Discontinuous variation*
(*Source: National Blood Centre*)

(a) Unable to roll the tongue

(b) Able to roll the tongue

Photograph 5.10 *An example of discontinuous variation*

Activity 5.8

Aim: To investigate the type of variation for height and body mass among the students.

Material: Graph paper

Apparatus: Measuring tape, weighing machine

Instructions:

1. Measure the height of every student in the class.
2. Record the height data in the table below according to the height range of the students.
3. Plot a histogram of the number of students against the height range.
4. Repeat steps 1 to 3 for body mass.

Result:

Height (cm)	130 – 134	135 – 139	140 – 144	145 – 149	150 – 154	155 – 159	160 – 164	165 – 169	170 – 174
Number of students									

Body mass (kg)	35 – 39	40 – 44	45 – 49	50 – 54	55 – 59	60 – 64	65 – 69	70 – 74	75 – 79
Number of students									

Questions:

1. What is the frequent height and body mass range?
2. What is the shape of the height and body mass histograms that you have plotted?
3. Is there any difference that is distinct between the height and body mass of students in the class?

Activity 5.9

Aim: To investigate the type of variation for the ability to roll the tongue among students.

Material: Graph paper

Instructions:

1. Gather information of those who are able and not able to roll their tongue in the class.
2. Record the data in the table below.
3. Plot a bar chart of number of students against their ability to roll their tongue.

Result:

Characteristic	Ability to roll the tongue	
Trait	Able	Unable
Number of students		

Questions:

1. What is the shape of the bar chart that you have plotted?
2. Is there any distinct difference between the ability to roll the tongue among the students in the class?

Factors that Cause Variation

Can you state the factors that cause variation? Let us do the following Activity 5.10 to gather the information.

Activity 5.10

Gallery Walk

21st Century Skills

Aim: To gather information about variation.

Instructions:

1. Carry out this activity in groups.
2. Gather information about:
   (a) factors that cause variation
   (b) the importance of variation
3. Record the information on a flip chart paper.
4. Put up your group's work on the classroom wall.
5. A member from each group will present to other groups.

Factors that cause variation

Genetic factor

- Crossing over between homologous chromosomes during meiosis enables the exchange of genetic materials and produces a new genetic combination.
- Independent assortment of chromosomes produces gametes that have different genetic information.
- Random fertilisation between male and female gametes produces zygotes with different genotype combination.
- Chromosome and gene mutations produce new phenotypes due to changes in genetic information.

Environmental factor

Environmental factors such as pH, sunlight, temperature, water, climate and nutrition can cause changes in the characteristics of organisms.

For example,

- a person will have dark skin colour if he is often exposed to sunlight.
- eating excessively will make a person fat.
- the *Hydrangea* sp. flower is blue if planted in acidic soil and pink in alkaline or neutral soil.

Figure 5.30 *Factors that cause variation*

5.5.1

Importance of Variation

Variation in organisms enables the organisms to adapt themselves to their environment. Individuals with different characteristics from the majority group are able to withstand, adapt and survive with the changes in the environment. If all individuals are the same, they will become extinct when a drastic change happens in the environment.

Variation enables us to easily differentiate and recognise each individual in the same species.

Variation allows natural selection, that is, an organism with suitable characteristics will continue to live, whereas an organism with less suitable characteristics will become extinct. The evolution of organism occurs through natural selection.

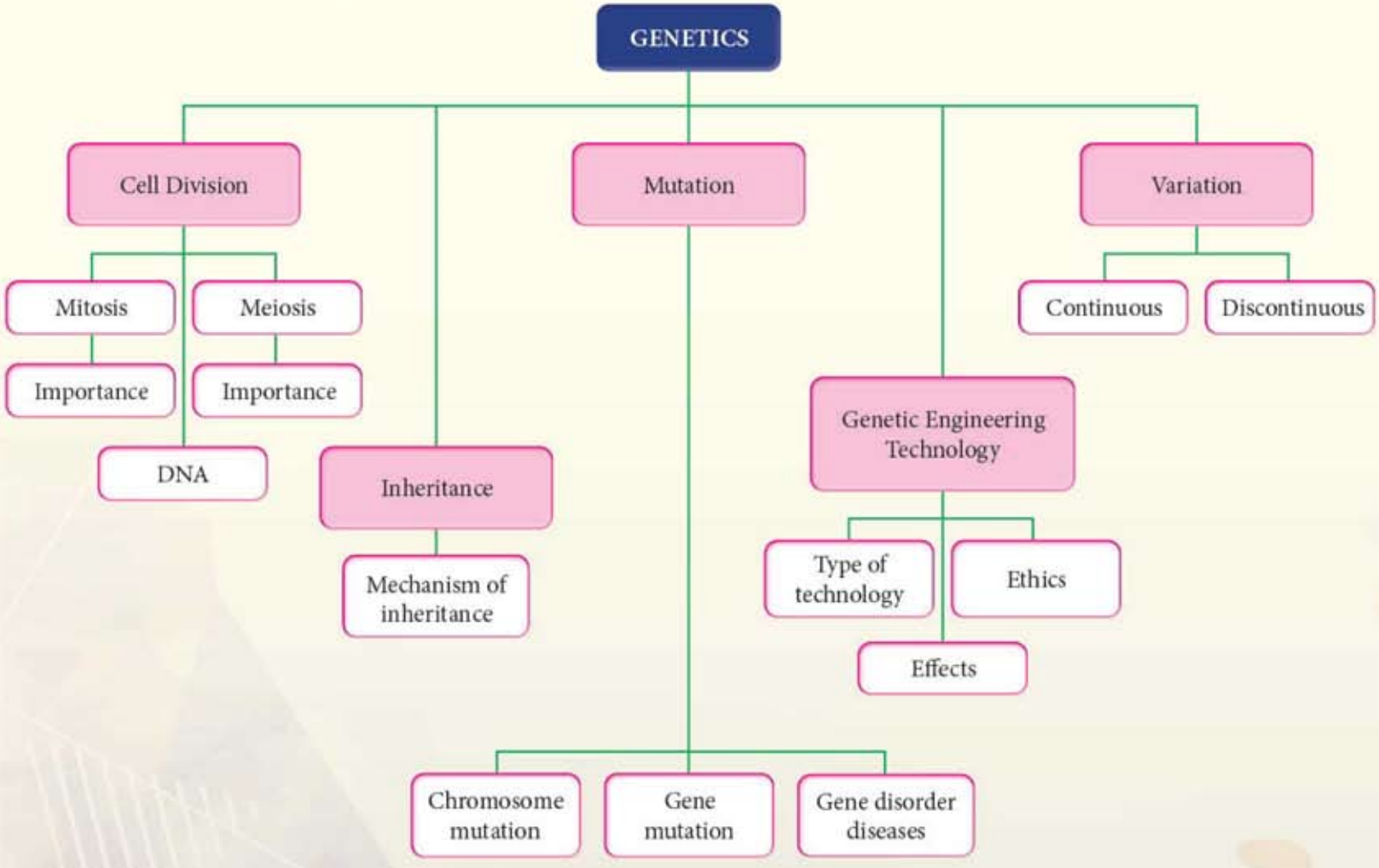
Variation helps organisms to camouflage in order to protect themselves from predators.

Variations in animals and plants can increase their value. For example, as a result of genetic engineering and selective breeding, animals and plants with new genetic characteristics can be produced according to the characteristics desired. This can increase the quality and quantity of the product.

FORMATIVE PRACTICE 5.5

1. What is meant by variation?
2. (a) Name two types of variations.
   (b) Compare and contrast both types of variations that you stated in question **2**(a).
3. State two genetic factors that cause variation.
4. How does environmental factor causes variation? Explain it by providing suitable examples.
5. State three importance of variation.

Summary


GENETICS
Cell Division
Mutation
Variation
Mitosis
Meiosis
Importance
Importance
DNA
Inheritance
Mechanism of inheritance
Genetic Engineering Technology
Type of technology
Ethics
Effects
Continuous
Discontinuous
Chromosome mutation
Gene mutation
Gene disorder diseases

Self-reflection

After studying this chapter, you are able to:

5.1 Cell Division

- ☐ Explain gene, deoxyribonucleic acid (DNA) and chromosomes in the nucleus.
- ☐ Compare and contrast mitosis and meiosis.
- ☐ Justify the importance of mitosis and meiosis.

5.2 Inheritance

- ☐ Explain inheritance in humans.
- ☐ Communicate the inheritance mechanisms.

5.3 Mutation

- ☐ Describe the definition of mutation and types of mutations.
- ☐ Explain with examples the factors that cause gene mutation and chromosome mutation.
- ☐ Explain with examples gene disorder diseases with their characteristics and their screening method.
- ☐ Discuss genetic research application to increase living quality.
- ☐ Debate the effects of genetics research on human life.

5.4 Genetic Engineering Technology

- ☐ Justify genetic engineering technology.
- ☐ Debate the effects of genetic engineering technology in life.
- ☐ Justify ethics in genetic engineering technology.

5.5 Variation

- ☐ Communicate continuous variation and discontinuous variation.

Summative Practice 5

QUIZ

Objective Questions
http://bukutekskssm.my/Science/F4/Q5

1. (a) Figure 1 shows the structure of a chromosome.

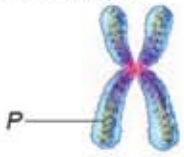


Figure 1

(i) Name the structure marked *P*.

(ii) State three basic components that form the structures that you named in question **1**(a)(i).

(b) How many chromosomes can be found in the human body cell?

(c) Explain the difference between autosome and sex chromosome.

2. Figure 2 shows a phase in the cell division process.

Figure 2

(a) State the phase shown in Figure 2.

(b) At this phase, explain the behaviour of chromosomes.

(c) Name the process that occurs at this phase. Explain its impact on organisms if this process does not occur.

(d) State the animal cell that carries out the process of cell division as in Figure 2 above.

3. Figure 3 shows two stages in a cell that undergoes mitosis.

Figure 3

(a) Name stage *P*.

(b) State the behaviour of chromosomes during stage *Q*.

(c) Name an organ in humans and an organ in plants that undergo mitosis.

Mind Challenge

4. Figure 4 shows the karyotype that is analysed after Mrs K undergoes amniocentesis.

(a) What is the probability that causes Mrs K to undergo this procedure?

(b) (i) What is the name of the disease that will be suffered by the foetus in Mrs K's womb?

(ii) What is the sex of the foetus?

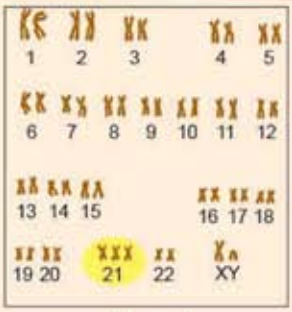


Figure 4