DEPARTMENT OF EDUCATION

GRADE 12

BIOLOGY

MODULE 3

GENETICS

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GRADE 12

BIOLOGY

MODULE 3

GENETICS

IN THIS MODULE YOU WILL LEARN ABOUT:

12.3 1:	**GENES AND CHROMOSOMES**
12.3.2:	**INHERITANCE**
12.3.3:	**VARIATION**
12.3.4:	**BIOTECHNOLOGICAL TECHNIQUES**

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DIANA TEIT AKIS
PRINCIPAL

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SECRETARY'S MESSAGE

Achieving a better future by individual students and their families, communities or the nation as a whole, depends on the kind of curriculum and the way it is delivered.

This course is a part of the new Flexible, Open and Distance Education curriculum. The learning outcomes are student-centred and allows for them to be demonstrated and assessed.

It maintains the rationale, goals, aims and principles of the national curriculum and identifies the knowledge, skills, attitudes and values that students should achieve.

This is a provision by Flexible, Open and Distance Education as an alternative pathway of formal education.

The course promotes Papua New Guinea values and beliefs which are found in our Constitution, Government Policies and Reports. It is developed in line with the National Education Plan (2005 - 2014) and addresses an increase in the number of school leavers affected by the lack of access into secondary and higher educational institutions.

Flexible, Open and Distance Education curriculum is guided by the Department of Education's Mission which is fivefold:

- To facilitate and promote the integral development of every individual
- To develop and encourage an education system satisfies the requirements of Papua New Guinea and its people
- To establish, preserve and improve standards of education throughout Papua New Guinea
- To make the benefits of such education available as widely as possible to all of the people
- To make the education accessible to the poor and physically, mentally and socially handicapped as well as to those who are educationally disadvantaged.

The college is enhanced to provide alternative and comparable pathways for students and adults to complete their education through a one system, many pathways and same outcomes.

It is our vision that Papua New Guineans' harness all appropriate and affordable technologies to pursue this program.

I commend all those teachers, curriculum writers, university lecturers and many others who have contributed in developing this course.

UKE KOMBRA, PhD
Secretary for Education

MODULE 12.3 GENETICS

Living organisms vary in many ways. For example, all humans have the same general shape and the same set of body organs. However, some features such as height, weight, eye and hair colour, shape of nose, language, knowledge, and skills differ from one person to the next. Some of these features that vary from person to person are inherited from parents. The study of inherited characteristics and the way they are passed on from one generation to another is called **Genetics**.

The scientific study of Genetics did not begin until the late 19th century. In experiments with garden peas, Austrian monk Gregor Mendel described the patterns of inheritance, observing that traits were inherited as separate units. These units are now known as **genes.** Gregor Mendel was the first scientist to study genetics and he is commonly known as the father of genetics.

Gregor Mendel

Mendel's work shows that heredity is due to the transmission of hereditary factors (now called genes) from one generation to the next during the process of reproduction. The genes always exist in pairs. They determine a particular characteristic in which one is dominant over another. In the study of genetics, Mendel used Punnett square to find possible result of various crosses. A Punnett square is used to find the probable results of crossing the traits of one organism with another.

The modern science of Genetics influences many aspects of daily life, from the food we eat to how we identify criminals or treat diseases. In agriculture, genetic advances enable scientists to change a plant or animal to make it more useful. For instance, some food crops, such as oranges, potatoes, wheat, and rice, have been genetically changed to withstand insect pests. The genetic makeup of cows has been modified to increase their milk production.

Genetic technologies have also helped convict criminals. DNA recovered from semen, blood, skin cells, or hair found at a crime scene can be analysed in a laboratory and compared with the DNA of a suspect. A DNA match can be used in a courtroom as evidence connecting a person to a crime.

To understand the content of this study module, student activities have been prepared for you. You must complete all these exercises, to check how well you have understood the module. These activities reinforce what you have learned. The module's summary notes are included towards the end. Answers to the student learning activities are given at the end of the module.

Learning Outcomes

After going through this module, you are expected to:

- state and explain the meaning of genetics, inheritance, trait, genotype, phenotype, codominance, gene, allele, chromosome, DNA, nucleotide, transcription, translation, variation, mutation, and biotechnology.
- distinguish between homozygous and heterozygous genotypes in monohybrid cross.
- solve problems involving monohybrid and dihybrid crosses using Punnett squares.
- explain the relationship between dominant and recessive alleles and phenotypic ratios using examples.
- describe the patterns of inheritance and explain how a monohybrid cross and dihybrid cross is performed and their use as a genetic tool.
- use Punnett square to predict the probability of genotypes of different crosses and derive the common ratios in genetic crosses.
- explain the laws of segregation and independent assortment.
- explain how incomplete dominance and codominance occur.
- describe the structure of DNA and RNA and use the significance of complementary base pairing in the conservation of the base sequence of DNA.
- describe the replication of DNA.
- understand some basic techniques used in genetic engineering.
- explain the advantages and disadvantages of cloning.

Time Frame

Suggested allotment time: **12 weeks**

If you set an average of 3 hours per day, you should be able to complete the module comfortably by the end of the assigned week. Try to do all the learning activities and compare your answers with the ones provided at the end of the module. If you do not get a particular exercise right in the first attempt, you should not get discouraged but instead, go back and attempt it again. If you still do not get it right after several attempts then you should seek help from your friend or even your tutor.

DO NOT LEAVE ANY QUESTION UNANSWERED

Terminology

Allele	One of the pair of genes responsible for contrasting traits.
Centromere	The point of attachment of two chromatids. They are spindles attached to the centromere during cell division.
Chromosome	A structure within a cell that contains a cell's genetic information. (A long thread-like structure found within the nucleus of cells).
Clone	Asexually reproduced organisms resulting from the same parent.
Codominance	A pattern of inheritance in which both alleles in a heterozygote are fully expressed.
Codon	The sequence of three nitrogenous bases in mRNA or DNA.
Continuous variation	A feature that is controlled by many genes. For example; height in the population.
Discontinuous variation	A feature that is controlled by a single gene. For example; eye colour.
Dominant allele	The expressed form of a trait that usually masks the recessive allele.
Double helix	The twisted ladder shape of the DNA molecule formed by two strands of nucleotides.
Gene	**A** unit of hereditary information that controls traits of a particular organism.
Genetics	The scientific study of heredity.
Geneticists	The scientists who study heredity.
Genome	The base sequence of the entire DNA in an organism.
Gene cloning	A process using genetic engineering to make copies of genes.

Genetic engineering	The use of biochemical techniques to identify, study, and modify genes.
Gene mutation	The error within individual genes in a chromosome that occur during DNA replication.
Genotype	An organism genetic makeup.
Gene therapy	A medical treatment that attempts to change a genome.
Homozygous	Having two identical alleles or genes for a given trait.
Heterozygous	Having two different alleles or genes for a given trait.
Inheritance	The transmission of genetic information from one generation to the next.
Messenger RNA	A type of RNA that carries the genetic instructions for protein production from the DNA to the ribosome.
Mutation	A sudden change to genetic material that makes an organism notably different from its parents.
Meiosis	A cell division in which four daughter cells with haploid number of chromosomes are produced.
Mitosis	A cell division in which two identical daughter cells with diploid number of chromosomes are produced.
Phenotype	The outward expression of a trait of an organism.
Recessive allele	The form of a trait that is typically masked by the dominant allele.
Recombination	The process by which new combinations of genes are passed on to offspring.
Recombinant DNA	DNA containing fragments derived from different organisms.
Replication	The copying of DNA that may occur in cells in the interphase.
Tissue culture	The process of growing an entire plant from individual cells or from small pieces of leaf, stem or root.
Trait	Any characteristic that can be passed on from parents to offspring.

Transcription	The process of transferring information from a strand of DNA to a strand of mRNA
Translation	The information of an amino acid chain form the information provided by mRNA.
Transgenic organism	A genetically engineered organism that has recombinant DNA from a species added to its genome.
Transfer RNA (tRNA)	A form of RNA that carries amino acids to the ribosome during protein synthesis.
Variation	A feature or characteristic that is different within a species. Variation in sexually reproducing organisms is greater than in asexually reproducing organisms.

12.3.1 Genes and Chromosomes

Most of the cells' genetic information is kept in distinct structures called **chromosomes**. The nucleic acid in chromosomes carries the genetic information. All organisms have a distinct number of chromosomes. Human body cells have **46 chromosomes**. Chromosomes contain the genetic **blueprint** that controls all cellular activity, such as growth and cell division. The genes are sections of a chromosome that contains a code for a trait. Most organisms have two copies of every genes and chromosomes. One from each parent.

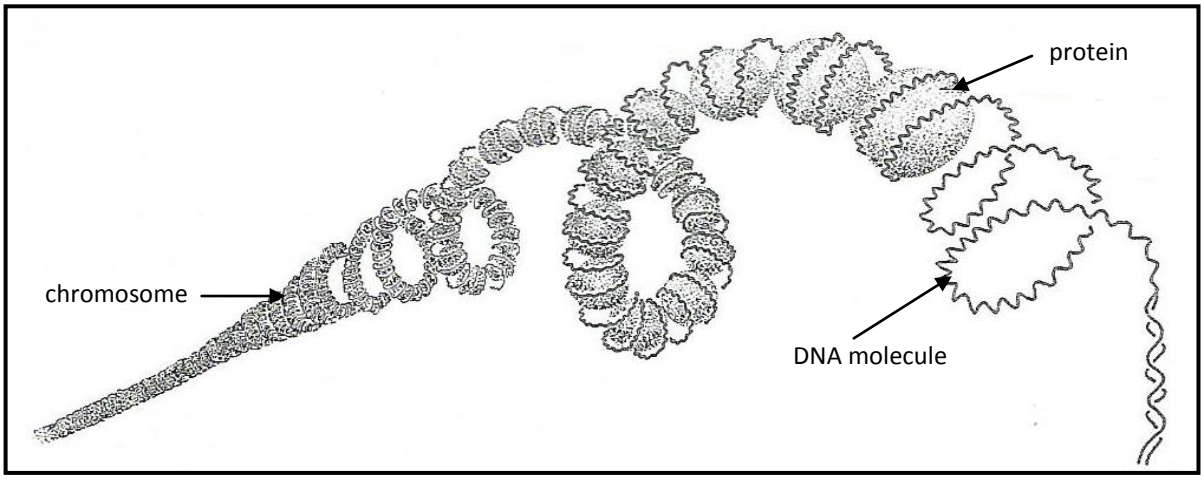
Structure and Function of Chromosomes

A **chromosome** is a long thread-like structure found within the nucleus of all cells. It is a molecule of DNA that contains genes which are the units of heredity. The structure basically consists of proteins and nucleic acid. Proteins are made of amino acids. The nucleic acids are made of phosphate groups, sugar, and nitrogenous bases. Chromosomes are present in the nucleus of cells all the time. They can only be seen when the cell is in the process of dividing. Because at that time they get shorter and thicker. All organisms have a fixed number of chromosomes.

Chromosome numbers

When a cell has two sets of chromosomes, it is referred to as the **diploid number** of chromosomes, one set from each parent. When a cell has half the total number of chromosomes it is called the **haploid number**.

In humans, the haploid number of chromosomes is 23 and the diploid number is 46. For example, dogs have 39 pairs of chromosomes and a diploid number of 78, while tomato plants have 12 pairs of chromosomes and a diploid number of 24. Sex cells (eggs or sperm) contain only half the number of chromosomes. Human sex cells contain haploid number of chromosomes. A human zygote contains diploid number of chromosomes.



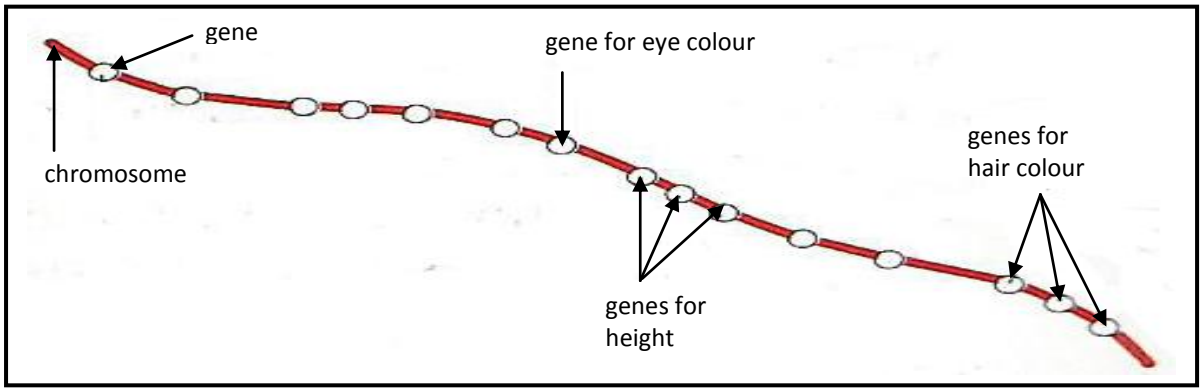
Simplified model of a chromosome structure

Function of chromosomes
A significant function of chromosomes is to build up an exact copy of itself. When pairs of identical chromosome separate during mitosis, each cell receives a full set of genes.

Chromosome and genes
Chromosomes are molecules of deoxyribonucleic acid or DNA that contain genes. A **gene** is a unit of inheritance that contains genetic information. Gregor Mendel refers to genes as **hereditary factors**.

A gene is made up of chemicals called **deoxyribonucleic acid**. The genes are arranged one after the other along the length of every chromosome. Most organisms have two copies of every gene and chromosome, one from each parent.

Function of genes
The genes control the development of inherited characteristics in organisms.
For example, there are genes which control eye, hair, and skin colours.



Relationship between chromosomes and genes

A typical animal or plant cell nucleus contains thousands of genes. Different organisms have different number of genes on their chromosomes.

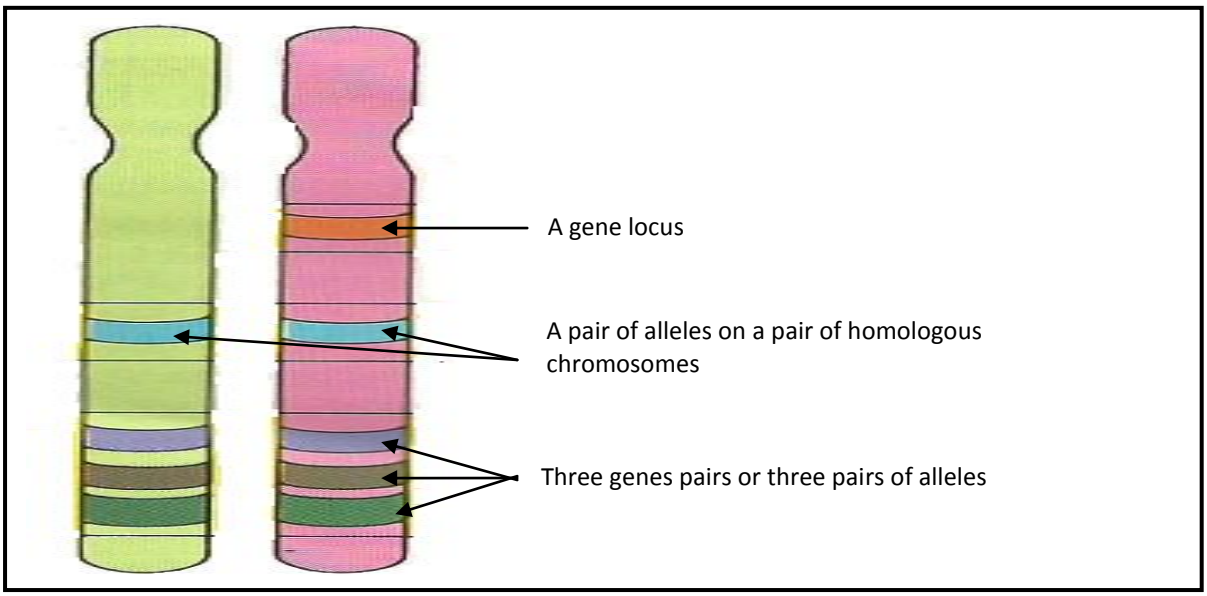
Through the Human Genome Project, scientists have identified an estimated 20 000 to 25 000 genes within the human cells. All the genes of an organism are known collectively as **genome**.

A gene is a unit of inheritance and contains the genetic information for the production of one protein.

Homologous chromosome

Chromosomes vary in size and shape and occur in matched pairs called **homologous**. The number of homologous chromosomes in a cell depends upon the organism. For example, most cells in the human body contain 46 or 23 pairs of chromosomes.

An example of pair of homologous chromosome is given below.



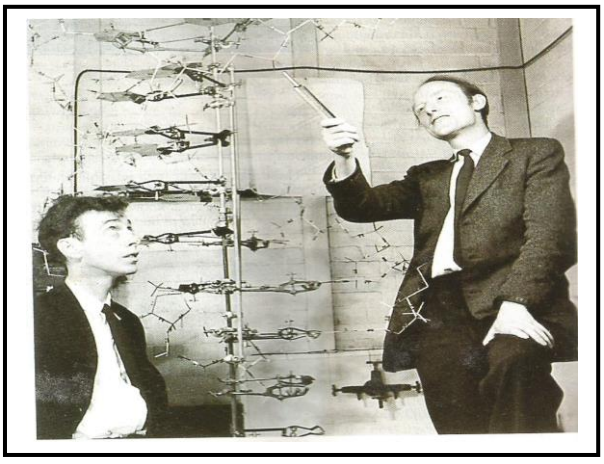
Pairs of homologous chromosomes

Structure and function of deoxyribonucleic acid – DNA

The DNA structure was first identified in 1953 by James Watson and Francis Crick.

A DNA is a molecule consisting of a long chain of nucleotides in the shape of a double helix and found in the nucleus of cells inside the chromosomes.

The DNA part of the chromosome controls the inherited characters. The sections of the DNA molecule constitute the genes. The DNA carries genetic code.



James Watson and Francis Crick

The term **genetic code** refers to all the genetic information we inherit from our parents or pass it onto our offspring.

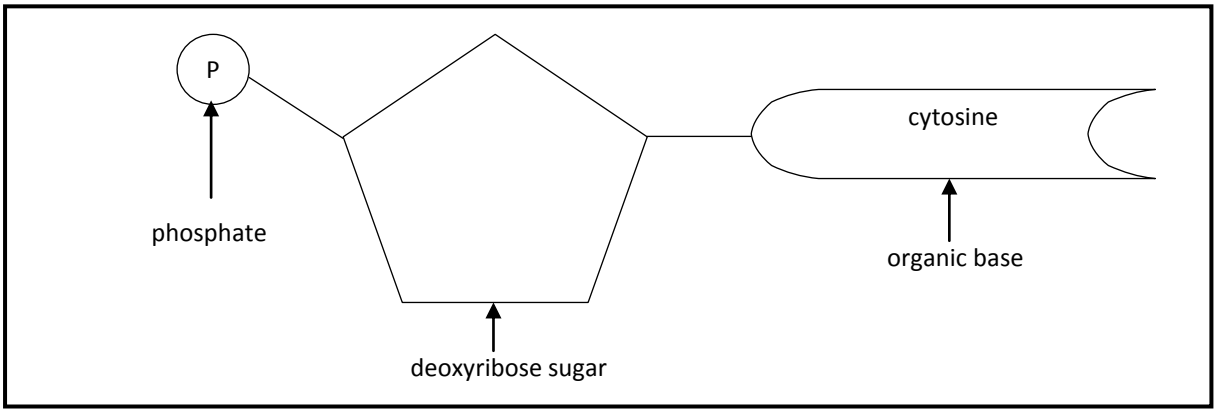
What is a nucleotide?

A molecule of DNA consists of two long strands composed of a large number of repeated chemical compounds called **nucleotides**.

Each nucleotide consists of a 5-carbon sugar molecule called **deoxyribose** that bonds to a phosphate group ($-PO_3$) and to a nitrogen-containing compound, known as a **base**.
DNA uses four bases in its structure:

i. adenine (A) ii. guanine (G)
iii. cytosine (C) iv. thymine (T)

The order of the bases in a DNA molecule determines the amino acid sequence of a protein.
An example of a single nucleotide and its main parts are shown below.

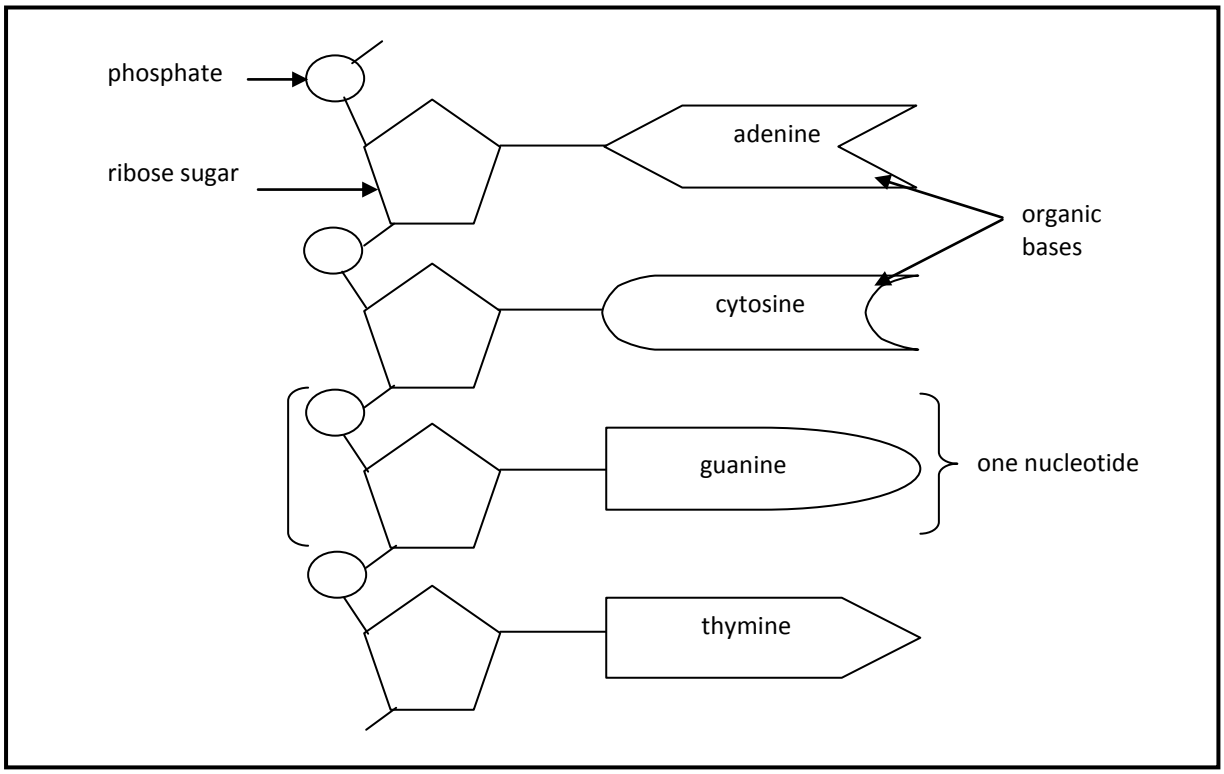


Parts of a single nucleotide

The deoxyribose sugar molecule occupies the center position in the nucleotide, the phosphate group on one side, and one of the four bases on the other side. The phosphate group of each nucleotide is linked to the deoxyribose of the adjacent nucleotide in the chain.

A single nucleotide consists of a 5-carbon sugar called deoxyribose, a phosphate group and an organic base (nitrogen-containing compound).

The phosphate and sugar molecules are the same all the way down the chain, but bases may be any one of the four. The adenine, guanine, cytosine, and thymine.



Part of a DNA molecule with four nucleotides.

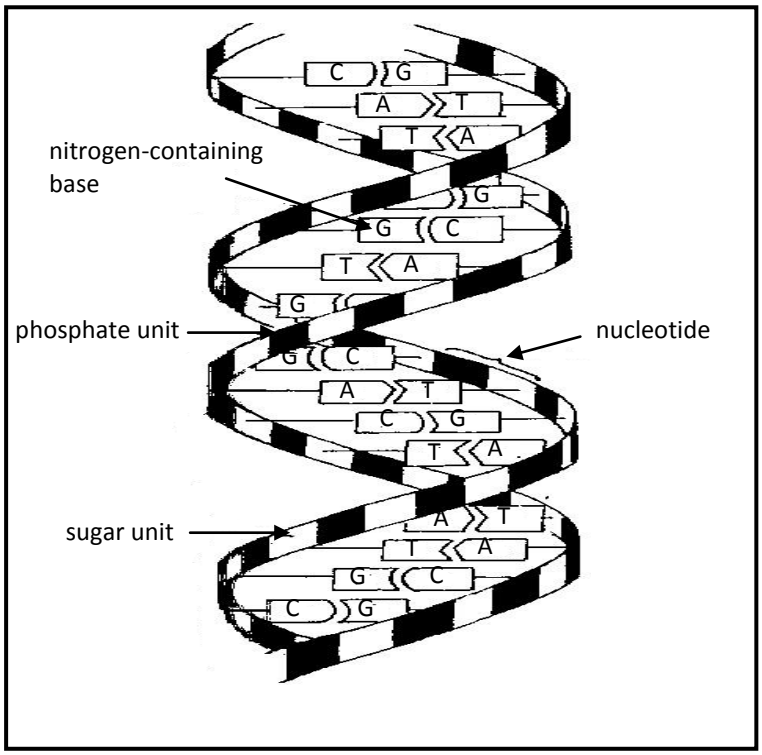
In the cells of most organisms, the nucleotides are linked together forming a chain that are arranged like a twisted ladder called a **double helix**.

Alternating phosphate and sugar molecules form each side of this ladder. Bases from one DNA strand join with bases from another strand to form the rungs of the ladder, holding the double helix together.

The pairing of bases in the DNA double helix is highly specific. The adenine always joins with thymine, and guanine always links to cytosine.

These base combinations are known as **complementary base** pairing, and play an important role in DNA's function by aiding in the replication and storage of genetic information. A DNA molecule is made up of many nucleotides.

The structural diagram of a DNA molecule.



Model of the double helix of DNA

What are nitrogenous bases?

These are organic substances containing nitrogen that make up the genetic code in DNA and RNA molecules. The DNA and RNA each have four bases, three of which are common to both. These are cytosine, guanine, and adenine. The fourth in DNA is thymine whereas for RNA is **uracil**.

These bases are grouped into two chemical groups called **purines** and **pyrimidines**. The purines are adenine and guanine, whereas pyrimidines are thymine and cytosine.

Functions of DNA

The DNA has two important functions. They are DNA replication and protein synthesis.

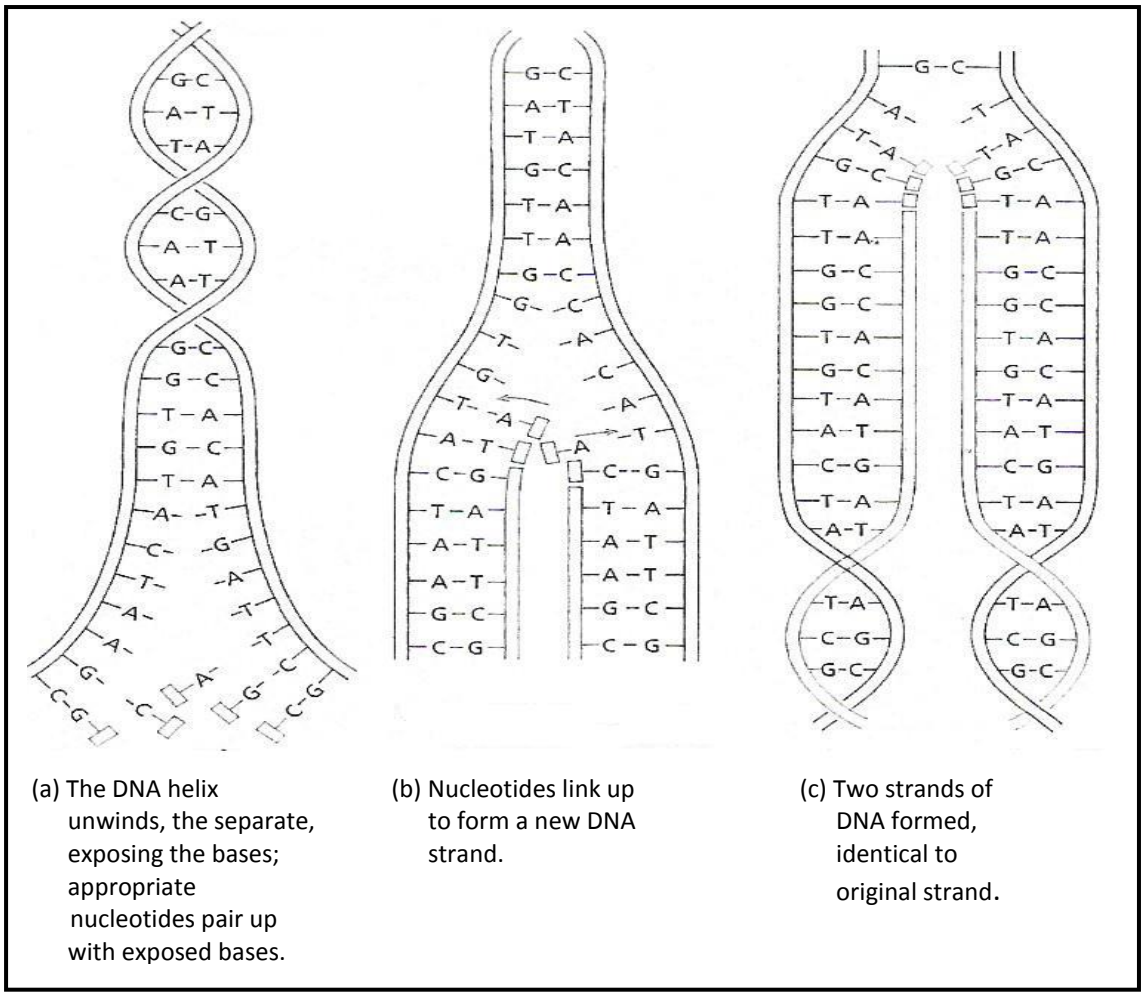
1. **DNA replication**
   In order for inherited traits to be transmitted from a parent to an offspring, the genetic information encoded in DNA must be copied during cell division. The accuracy of DNA replication depends upon the pairing of complementary of bases.

Steps in DNA replication

(i) The DNA double helix unwinds or unzips and pairs joining the pairs break, separating the DNA molecule into two separate strands.

(ii) The unpaired bases of each DNA strand attach to free floating bases within the cell. The unpaired bases pair only with specific, complementary bases.
For example; an adenine base will pair only with a thymine base and a cytosine base will pair only with a guanine base.

(iii) Once all of the bases of a DNA strand pair to complementary bases, they link to each other, forming a new DNA double-helix molecule. Thus the original DNA molecule replicates into two new DNA molecules.



(a) The DNA helix unwinds, the separate, exposing the bases; appropriate nucleotides pair up with exposed bases.

(b) Nucleotides link up to form a new DNA strand.

(c) Two strands of DNA formed, identical to original strand.

The DNA replication

Significance of replication

The significance of replication is that identical copies of genes can be made.

It is now time for you to complete Learning Activity 1.on the next page. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Assignment 1 (which you will send in for assessment)

Learning Activity 1

40 minutes

A. Answer the following questions on the spaces provided.

1. What are chromosomes? Where are they located?

   _____
   _____
   _____

2. What are genes made of? Where in the cell will you find the genes?

   _____
   _____
   _____

3. State the function of the genes.

   _____
   _____
   _____

4. In what part of the eukaryote cell is the DNA located?

   _____

5. Name the four nitrogen-containing bases which make up a DNA molecule?

   a. _____ b. _____

   c. _____ d. _____

6. What chemical substances make up the structure of DNA?

   _____
   _____
   _____

7. List the three components of nucleotides.

   i. _____

   ii. _____

   iii. _____

8. Why is the DNA molecule called a double helix?

_____

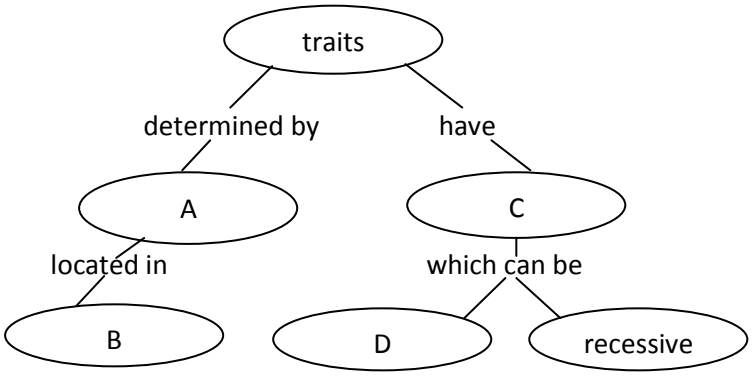
_____

_____

9. Name the scientists who modelled the DNA molecule.

_____

B. Complete the concept map below by adding the following terms; alleles, genes, chromosomes, dominant.



A. _____ B. _____

C. _____ D. _____

C. Fill in the missing word.

DNA is made of _____ that consist of _____, phosphate, and _____ bases. The _____ include adenine, _____, cytosine, and _____. _____ is shaped like a double _____ and is the main component in _____.

Thank you for completing your Learning Activity 1. Check your work. Answers are at the end of this unit.

What is RNA?

RNA or ribonucleic acid is a single-stranded nucleic acid made during the transcription process. The RNA usually assists protein synthesis.

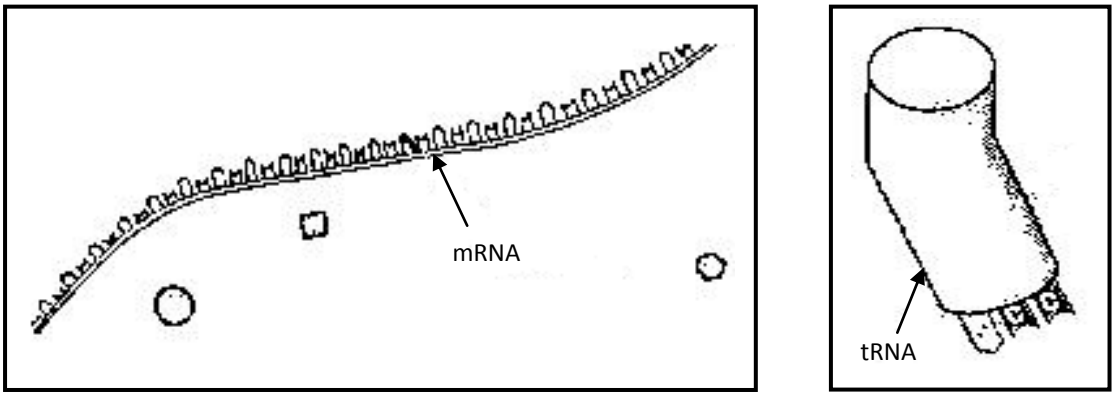
There are three types of RNA

1. **Ribosomal RNA (rRNA)**
   The rRNA is the site of protein synthesis found in the cell's ribosomes.

2. **Messenger RNA (mRNA)**
   It carries genetic instructions for protein production from the DNA to the ribosome.

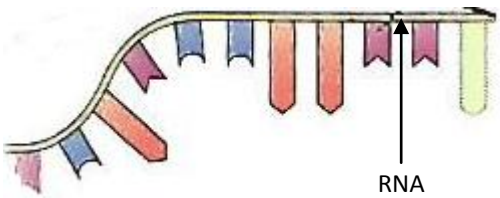
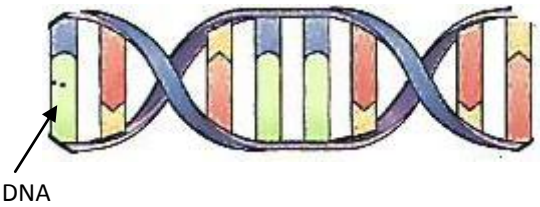
3. **Transfer RNA (tRNA)**
   Carries specific **amino acids** to the ribosomes to receive instructions from the mRNA on how to join together to make **proteins.**

The structure of mRNA and tRNA



Structure of a mRNA and tRNA

The structural differences between DNA and RNA

RNA	DNA
single-stranded 	double-stranded 
Base pairs: C-G, A-U (Cytosine-Guanine, Adenine-Uracil)	Base pairs: C-G, A-T (Cytosine-guanine, Adenine-Thymine)
Ribose sugar group	Deoxyribose sugar group
RNA molecules are generally shorter	DNA molecules are generally longer

Differences between DNA and RNA

It is now time for you to complete Learning Activity 2. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Assignment 1 (which you will send in for assessment)

Learning Activity 2

30 minutes

Answer the following questions on the spaces provided.

1. What is RNA?

   _____

2. Draw a structural diagram of RNA molecule.

3. What is the function of the RNA polymerase?

   _____

   _____

4. What role do mRNA and tRNA play in protein manufacture?

   _____

   _____

   _____

5. Make comparison between the structure of DNA and RNA.

RNA	DNA

Thank you for completing your Learning Activity 2. Check your work. Answers are at the end of this module.

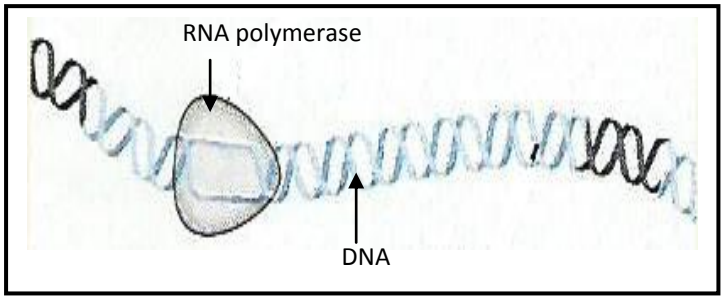
2. Protein synthesis

DNA replication ensures that the genetic instructions encoded in DNA can be used continuously through generations to produce the proteins that build and operate the cells of an organism. The process of drawing genetic instructions to create proteins, known as protein synthesis, has two important stages: transcription and translation.

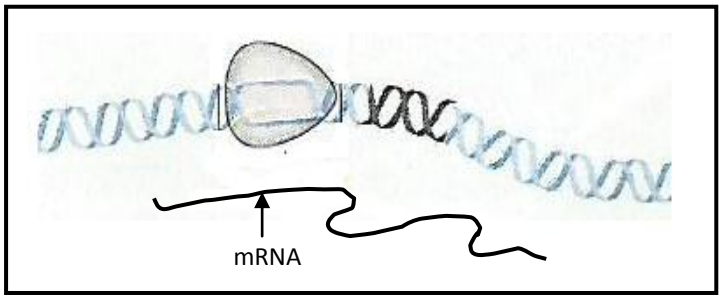
Stage 1 Transcription

In transcription genetic information from a strand of DNA is transferred or copied into a strand of a messenger RNA (mRNA). In this stage the amino acids are arranged in correct position according to the DNA base sequence.

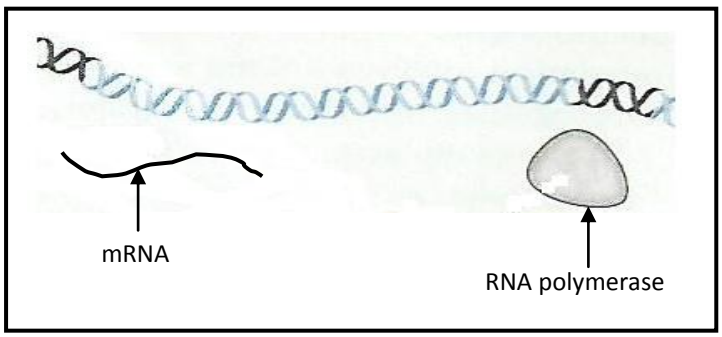
Firstly, mRNA is attached to existing ribosomes. Then the tRNA already attached to certain amino acids in the cytoplasm move into the ribosomes, bringing in amino acids to add to the polypeptide (protein) chain under construction.



1. Transcription begins.
The enzyme RNA polymerase separates or "unzips" a section of DNA.



2. mRNA synthesis begins.
RNA polymerase binds unattached RNA bases to their complementary bases on the DNA strand and links the RNA nucleotides to form a molecule of mRNA.



3. Transcription ends.
After a section of DNA is transcripted, the next section is exposed. The process repeats until DNA signals mRNA synthesis to end.

The three main stages of transcription process

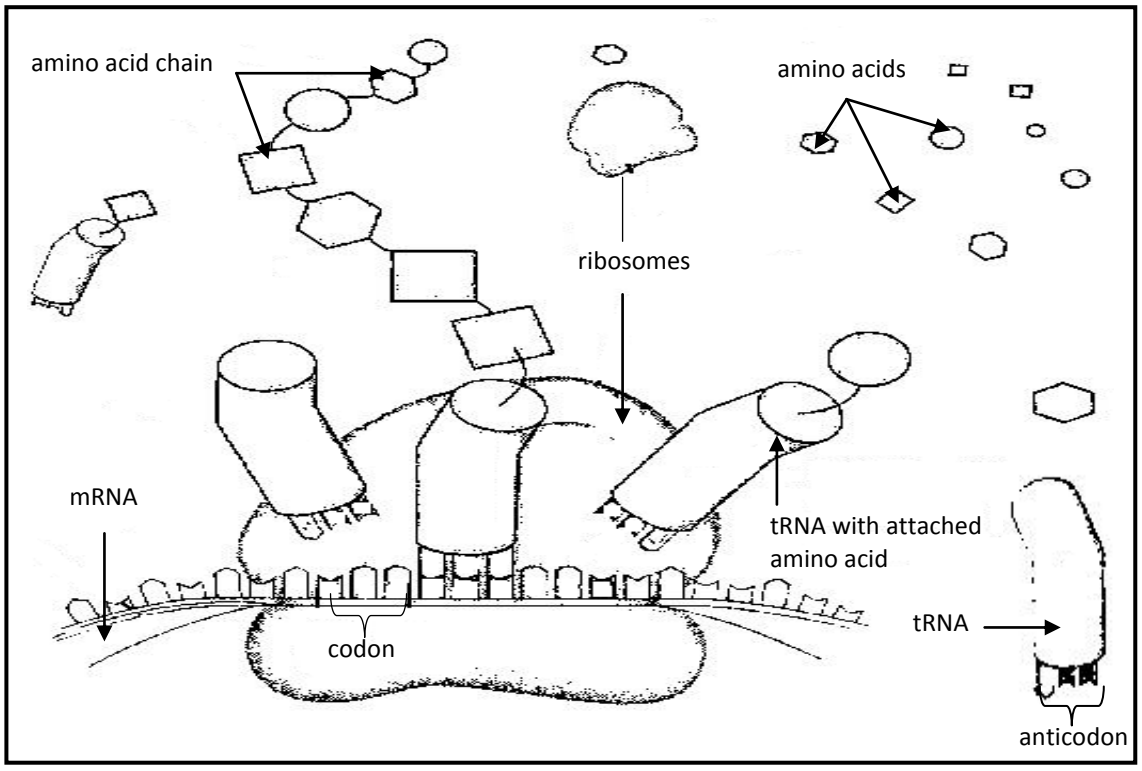
In order for the production of proteins to occur, first the DNA double helix must unzip and expose the nitrogenous bases.

Stage 2 Translation

Translation is the process where genetic information carried by mRNA is translated to form proteins. It involves linking amino acids together into their correct sequences.

Once transcription is complete and the genetic code (the order of nucleotide sequence in DNA) has been copied onto mRNA, the genetic code must be changed into the language of proteins.

That is, the information coded in the four bases found in mRNA must be translated into genetic information by the 20 amino acids used in the formation of proteins.



The linking of amino acids

There are many different types of tRNA found in the cytoplasm of the cell. Each type binds with one of the 20 amino acids used in protein formation. One end of a tRNA binds with a specific amino acid. The other end carries three bases, known as an **anticodon.**

The tRNA with an amino acid attached travels to the ribosome where the mRNA is located. The anticodon of the tRNA undergoes complementary base pairing with a series of three bases on the mRNA, known as the **codon**. The mRNA codon codes for the type of amino acid carried by the tRNA. Study the diagram above.

A codon is a three-base section of the mRNA. Most codons carry a code for a specific amino acid. An anticodon is a sequence of three bases found on tRNA. Each tRNA carries only one anticodon.

What are proteins?

Proteins are organic compounds in living cells. They are very complex and exist in many different ways. All life forms are generated and controlled by proteins. A protein molecule consists of four basic elements: carbon, hydrogen, oxygen, and nitrogen. Each protein molecule is made from long chains of amino acids or polypeptide. A type of protein produced is determined by the type and sequence of the linked amino acids.

What are amino acids?

Amino acids are the basic building blocks of protein molecules. Long chains of amino acids are called **polypeptides**.

Proteins can be single chain of polypeptide or made up of several chains of polypeptides linked together. There are 20 commonly, known as **amino acids**.

The 20 amino acids

Alanine (Ala), Arginine (Arg), Asparagine (Asn), Asparatic Acid (Asp), Cysteine (Cys), Glutamic Acid (Gul), Gultamine (Gln), Glycine (Gly), Histidine (His), Leucine (Leu), Lysine (Lys), Methionine (Met), Phenylalanine (Phe), Proline (Pro), Serine (Ser), Threonine (Thr), Tryptophan (Trp), Tyrosine (Tyr), Valine (Val) STOP.

Each group of the three bases stands for one amino acid. For example, cytosine-guanine-adenine (CGA) specifies the amino acid alanine and the base triplet cytosine-adenine-thymine (CAT) specifies the amino acid valine.

A gene is a sequence of triplets of the four bases, which are specific to an entire protein. **Insulin** is a small protein with only 51 amino acids. A sequence of 153 (that is 3 x 51) bases in the DNA makes up the genes that produce insulin in the pancreas. Most proteins are much larger and most genes contain a thousand or more bases.

Example

DNA molecule:	TAC	TAG	CCG	CGA	TTT	ACA	ATT
DNA complementary:	ATG	ATC	GGC	GCT	AAA	TGT	TAA
mRNA molecule:	AUG	AUC	GGC	GCU	AAA	UGU	UAA
tRNA molecule:	UAC	UAG	CCG	CGA	UUU	ACA	AUU
Amino acid:	met	iso	gly	ala	lys	cys	stop

Study the table on the next page about specification of amino acids by each group of three bases.

	U	C	A	G	
U	UUU, UUC: Phenylalanine UUA, UUG: Leucine	UCU, UCC, UCA, UCG: Serine	UAU, UAC: Tyrosine **UAA, UAG: Termination**	UGU, UGC: Cysteine **UGA: Termination** UGG: Tryptophan	U C A G
C	CUU, CUC, CUA, CUG: Leucine	CCU, CCC, CCA, CCG: Proline	CAU, CAC: Histidine CAA, CAG: Glutamine	CGU, CGC, CGA, CGG: Arginine	U C A G
A	AUU, AUC, AUA: Isoleucin **AUG: Methionine**	ACU, ACC, ACA, ACG: Threonine	AAU, AAC: Asparagine AAA, AAG: Lysine	AGU, AGC: Serine AGA, AGG: Arginine	U C A G
G	GUU, GUC, GUA, GUG: Valine	GCU, GCC, GCA, GCG: Alanine	GAU, GAC: Aspartic GAA, GAG: Glutamic	GGU, GGC, GGA, GGG: Glycin	U C A G

The group of three bases stands for one amino acid

It is now time for you to complete Practical Activity 3 in your Assessment Book 3 before going on to the next topic.

Cell Divisions

Organisms will not grow or function properly if the genetic information encoded in DNA was not passed from cell to cell. DNA is packaged into structures called **chromosomes** within a cell. Every chromosome in a cell contains many genes, and each gene is located at a particular site on the chromosome. Chromosomes vary in size and shape and usually occur in matched pairs called **homologous**. The number of homologous chromosomes in a cell depends upon the organism. For example, most cells in the human body contain twenty three (23) pairs of chromosomes.

Within all organisms, cells divide to produce new cells, each of which requires the genetic information found in DNA. Each new cell needs a complete copy of an organism's genetic information to function properly.

Organisms use two types of cell division to ensure that DNA is passed down from cell to cell during reproduction. Simple one-celled organisms and other organisms reproduce asexually in a cell division process called **mitosis**. During mitosis a cell doubles its DNA before dividing into two cells and distributing the DNA evenly to each resulting cell.

The organisms that reproduce sexually use a different type of cell division. These organisms produce special cells called **gametes**, or egg and sperm. In the cell division known as **meiosis**, the chromosomes in a gamete cell are reduced by half. During sexual reproduction, an egg and sperm unite to form a zygote, in which the full number of chromosomes is restored.

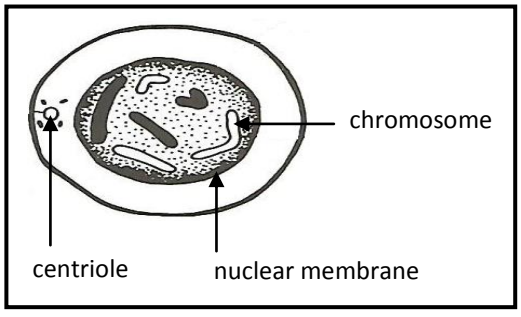
Mitosis

The mitosis cell division is a continuous process, but to make it easier for you to understand it is divided into several stages or phases. This cell division occurs in asexual reproduction.

The main stages of cell division in mitosis

Interphase - Original cell

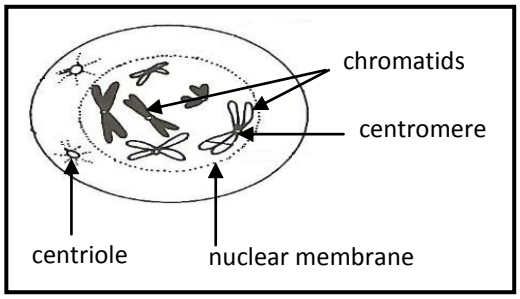
At interphase, the strand of DNA that make up the chromosome inside the nucleus replicate themselves. At this stage the chromosomes cannot be stained and therefore biologist cannot see them.



Interphase

Prophase

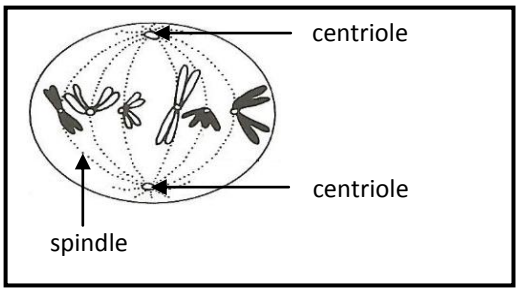
At this stage, the copied chromosomes become shorter and thicker and appear in the nucleus. The chromatid pairs of the condensed chromosomes become visible. They can now be stained. Each pair of chromatids is joined at a point called the **centromere**. At the end of the prophase the nuclear membrane disappears.



Prophase

Metaphase

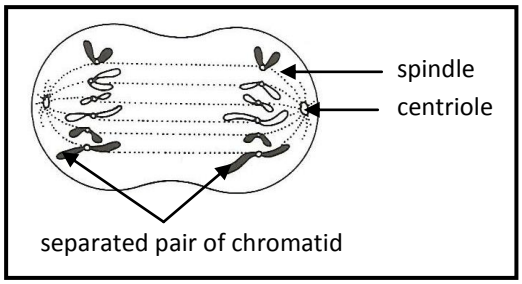
At this stage, the chromatid pairs are pulled to the centre of the cell and the centromere attach them to the spindle fibres. At the end of metaphase, each chromatid is lined up an equal distance from the end of the cell.



Metaphase

Anaphase

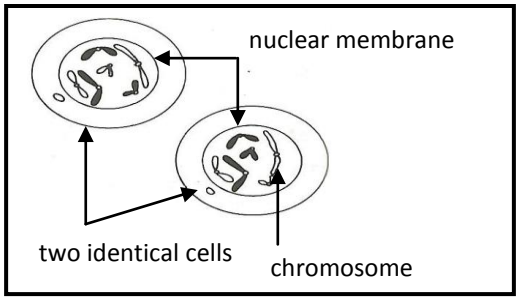
At the anaphase stage, the chromatid pairs are separated as the centromere splits into two. One of each pair moves towards the opposite end of the cell. The separated chromatids are now chromosomes. Each end of the cell has the same number and type of chromosomes.



Anaphase

Telophase

This is the last stage of mitosis. The nuclear membrane forms around the chromosomes in each cell. The cell splits, forming two identical cells each with the same number of chromosomes. The cytoplasm and two new daughter cells with identical genetic information are formed.



Telophase

In mitosis two identical daughter cells are produced.

Meiosis

Meiosis is a very specialised and complex type of cell division. It is the division of the nucleus in a living cell which leads to the production of gametes for sexual reproduction. It ensures that a parent passes its gene through sex cells to its offspring. Also in meiosis the number of chromosomes in the daughter cell is reduced by half in the parent cell.

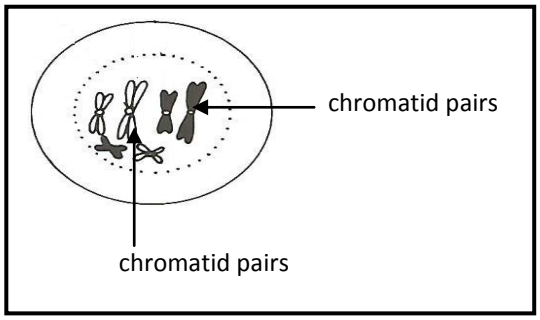
There are two stages of cell division in meiosis. Each division is different in many important ways. The most significant difference is that the resulting daughter cells are not genetically identical copies of their parent cell.

Division 1

In the first division the chromosomes replicate themselves without separating.

Prophase I

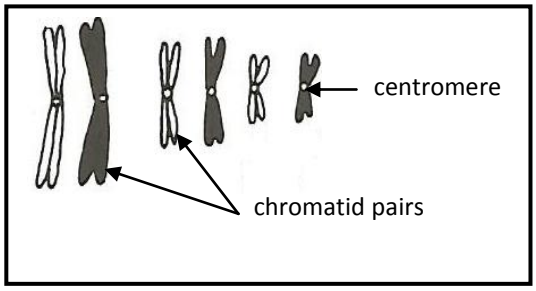
In prophase I, the chromosomes if stained appear as chromatid pairs joined at the centromere.



Prophase I

Metaphase I

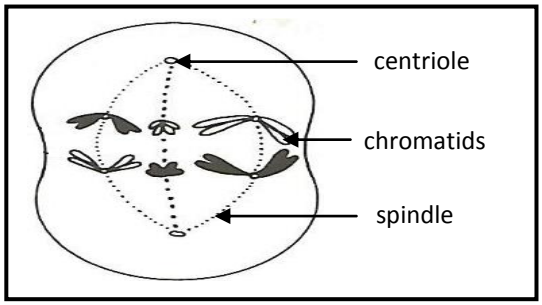
Metaphase I begins with the chromosomes of the same length and appearance pairing up with each other. They intertwine and attach themselves to the centre of the spindle fibres.



Metaphase I

Anaphase I

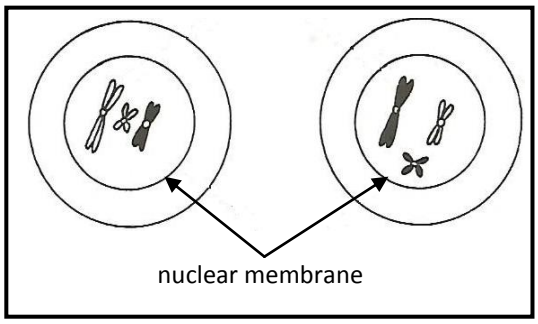
In anaphase I, unlike in mitosis, the pairs remain unseparated. Instead, one intact chromatid pair moves to one pole of the cell and the other pair moves to the other pole of the cell.



Anaphase I

Telophase I

In telophase I, the chromosomes become bound by a nuclear membrane and two new cells are formed.



Telophase I

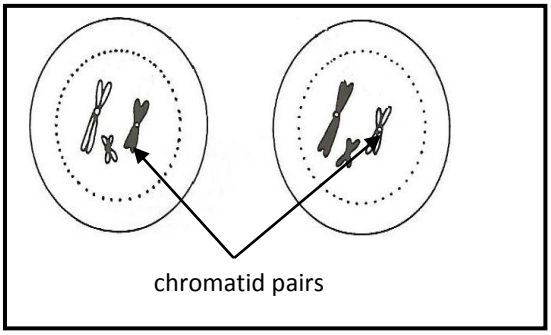
The first stage of meiosis produces two daughter cells. Each daughter cell contains only one chromosome of each pair that was in the parent cell. The total number of chromosomes present in each daughter cell is one half of the number of chromosomes in the parent cell.

Division II

In the second division the chromosomes separate without replicating themselves.

Prophase II

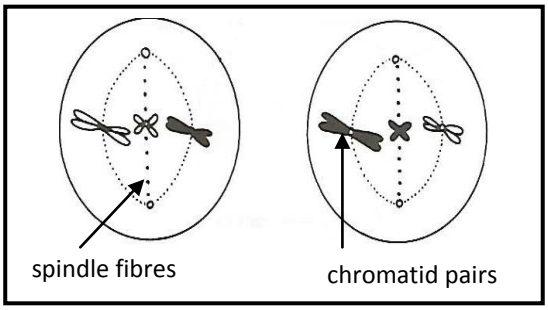
In prophase II, the chromosomes already exist as chromatid pairs. There is no duplication.



Prophase II

Metaphase II

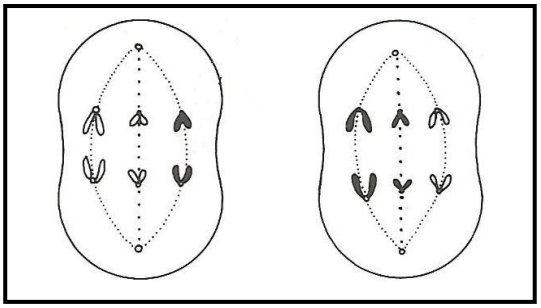
In metaphase II, the chromatid pairs line up along the spindle fibres.



Metaphase II

Anaphase II

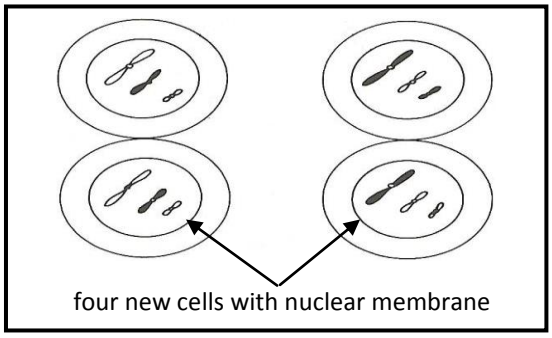
In anaphase II, the chromatid pairs separate and one of each pair move to opposite poles of the cell.



Anaphase II

Telophase II

In telophase II, the nuclear membrane reforms, forming cells each with only half the number of chromosomes of the original cell. At the end of meiosis, four new cells are formed.



Telophase II

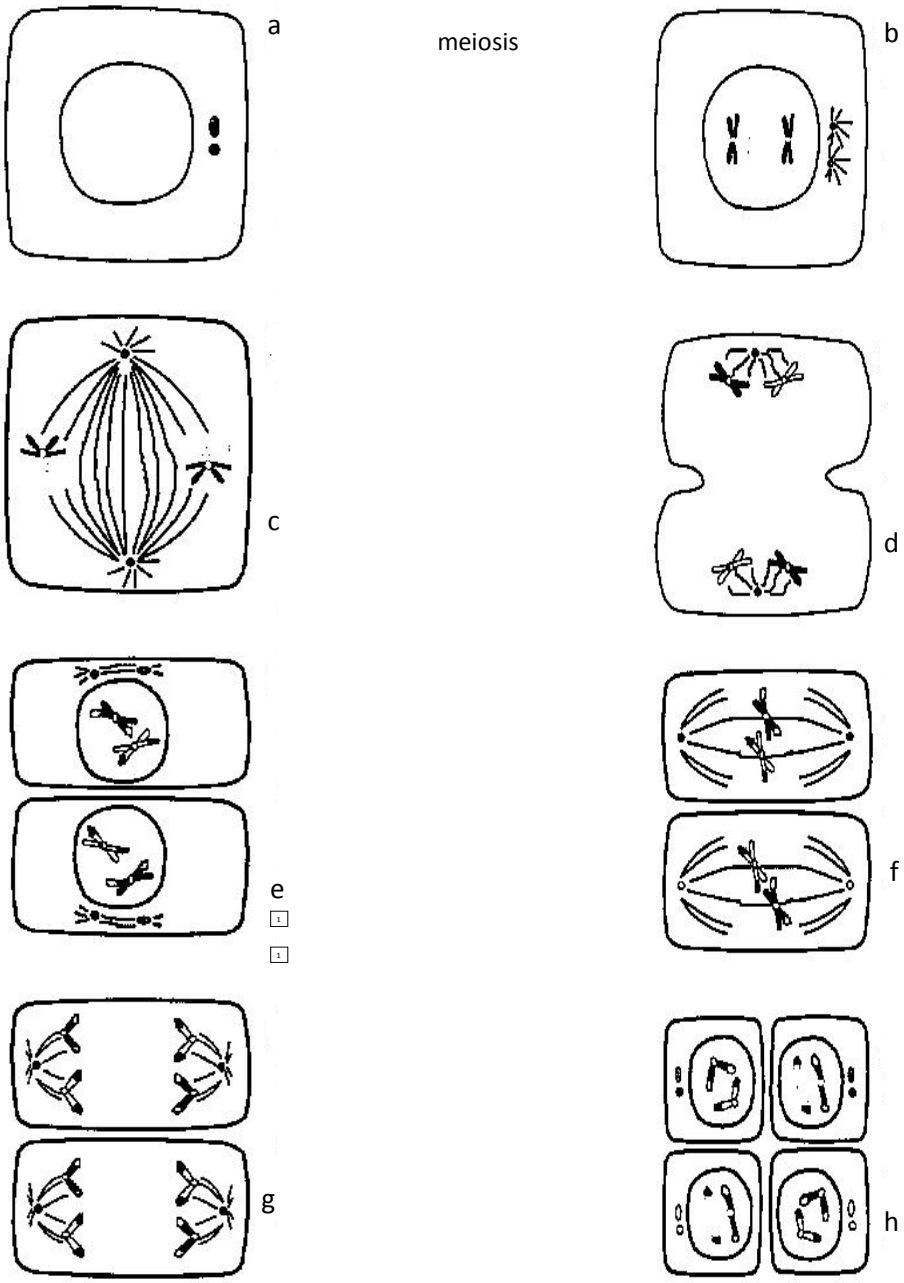
It is now time for you to complete Learning Activity 3 on the next page. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Assignment 1 (which you will send in for assessment)

Learning Activity 3

40 minutes

A. For question 1 refer to the cell division diagrams given below.

1. i. Name the stages in their correct order.



a. _____ b. _____

c. _____ d. _____

e. _____ f. _____

g. _____ h. _____

ii. How many chromosomes does the parent cell contain? _____.

iii. How many chromosomes does each of the gametes contain? _____.

iv. What is the total number of chromosomes in the four daughter cells? ____.

2. Define the following and state their function.

i. mitosis

_____
_____
_____
_____

ii. meiosis

_____
_____
_____
_____

3. State two differences between mitosis and meiosis.

_____
_____
_____
_____
_____

B. Write the word or phrase that best completes each statement.

i. During interphase, the DNA in the nucleus is present in the form of thin strands called _____.

ii. Chromatids line up at the centre of the cell during _____.

Thank you for completing your Learning Activity 3. Check your work. Answers are at the end of this module.

12.3.2: Inheritance

In Grade, 11, you studied sexual reproduction in plants and animals. You have learnt that sexual reproduction involves the fusion (joining) of two gametes. One from the male organism (pollen, sperm) and the other from the female organism (ovule, ovum), to form a zygote. The organism developing from the zygote closely resembles the parents, but also differs in some characteristics from either parent.

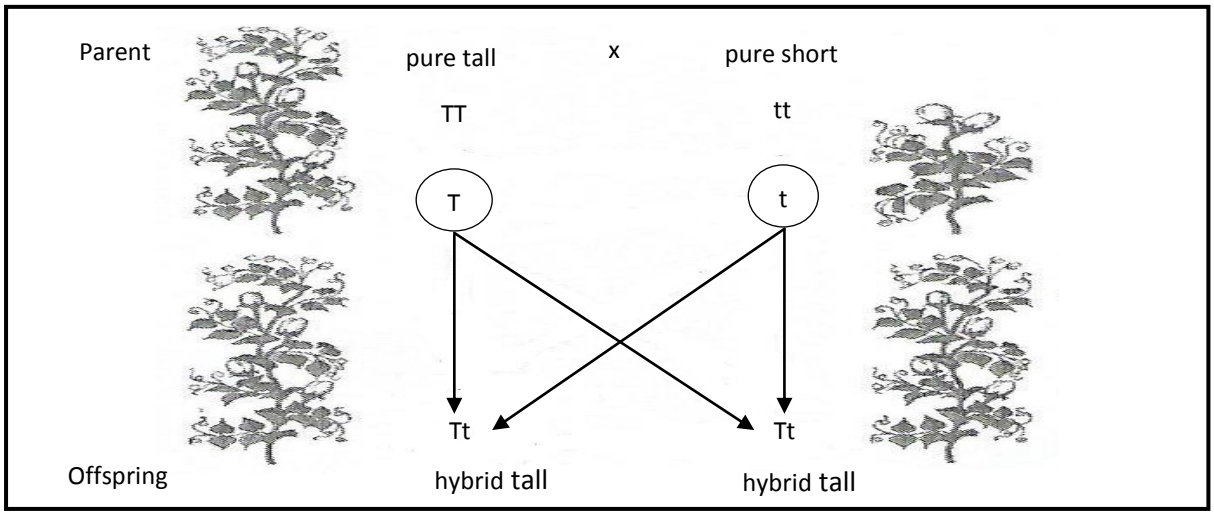
An organism's characteristics are determined by the genes of the chromosomes of male and female parent. The transmission of these characteristics from parents to offspring or from one generation to another is called **inheritance**. Gregor Mendel was the first scientist to study inheritance. His experiments showed that heredity is due to the transmission of hereditary factors called **genes** passed from one generation to the next during the process of reproduction.

Mendel's factors are also referred to as **alleles**. An **allele** is a distinct form of a gene. If an organism has two different alleles for a trait, only one is expressed or visible. A **dominant allele** is a form of a gene that is fully expressed when two different alleles are present. A **recessive allele** is a form of a gene that is not fully expressed when paired with a dominant allele.

Mendelian experiments

Mendel began his genetic experiments by observing the results of self-pollination in pea plants. From the observation, he realised that generation after generation the results in the offspring produced were still the same. For example, tall plants always produce tall plants. The traits or characteristics of the parents are always passed on to their offspring.

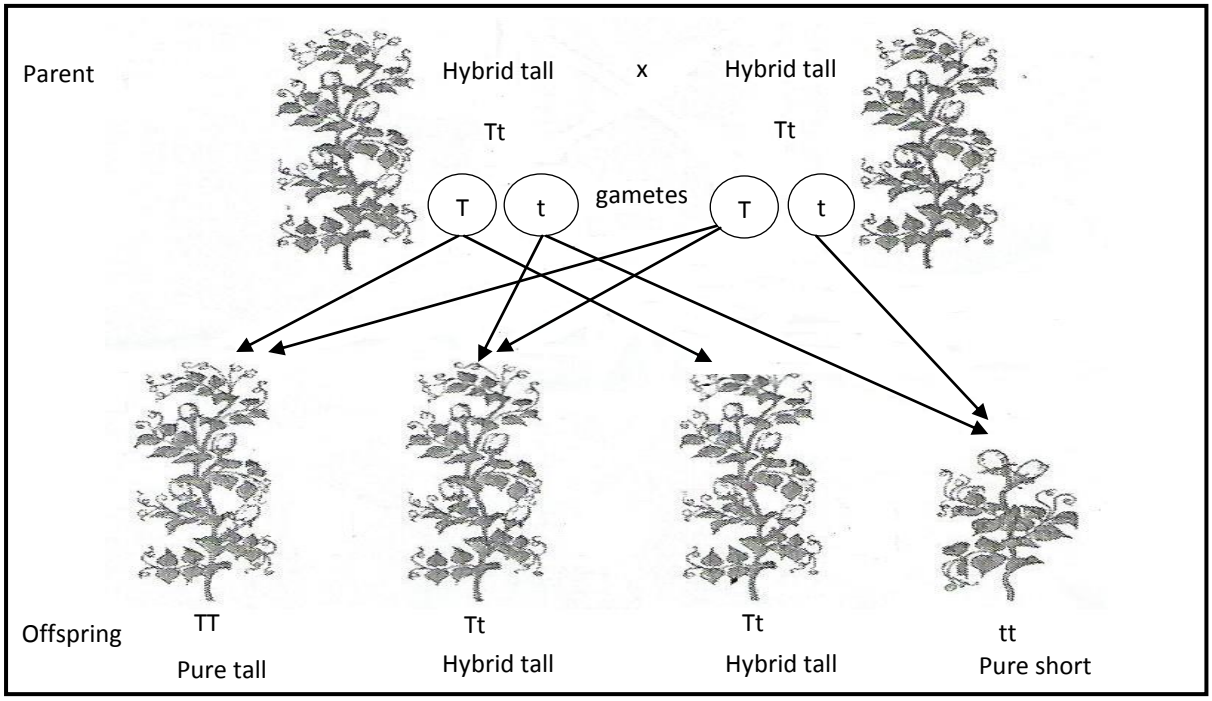
Mendel crossed two plants with contrasting traits, a tall plant with a short plant by transferring pollen from the tall to the pistil (female reproductive part) of the short plant. The offspring resulted from the cross were all tall. They were just like the plant from which he had taken the pollen.



Crossing two plants with contrasting traits

Next he used a short plant for pollen and a tall plant for seed production. However, all the results were still the same, the offspring were all tall.

He repeated the crosses until he tested seven different traits. Then he discovered that in all the seven crosses, one of the traits present in a parent plant was absent in the next generation.



Crossing two hybrid tall plants

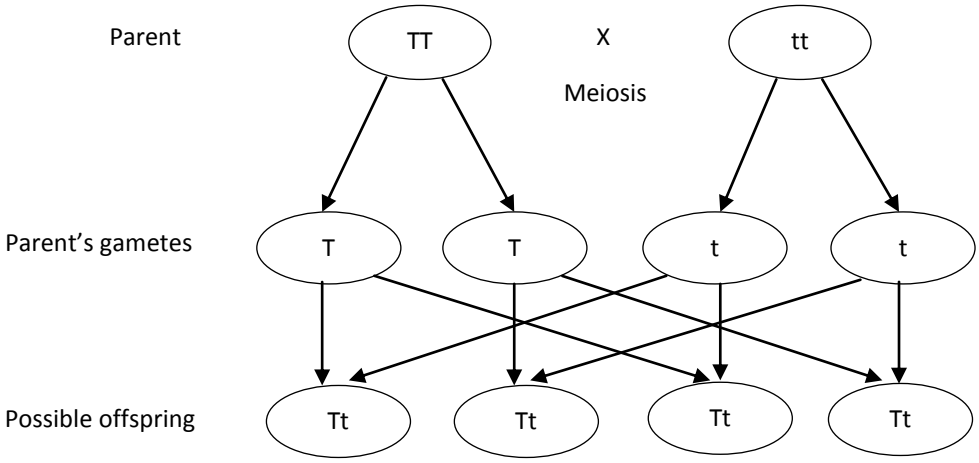
During the genetic experiments, Mendel used symbols such as T, Tt and t to represent the different types of plants he studied. For example; a capital T for true-breeding dominant, small t for true-breeding recessive and a capital and small Tt for non-true breeding, hybrid. The letters actually represent the genes responsible for producing the different characteristics.

Purebred and hybrid organisms
A plant or any organism that receives the same genetic trait from both of its parents is called a purebred. The TT for tall and tt for short in the diagram above are typical examples of purebred organisms. An organism that receives different forms of a genetic trait from each parent is called a hybrid. The Tts are examples of hybrid organisms.

Patterns of inheritance
Certain patterns of inheritance were evident long before scientists discovered the molecular structure of DNA and chromosomes. Throughout history, people have recognised that certain traits, whether in humans, animals, or agricultural crops, could be passed from generation to generation.

The inheritance patterns can be represented in several ways as follows.

1. **Flow chart**



Flow chart showing a genetic cross

2. **Punnett square**

Punnett squares are special charts that can show the probability of each resulting genotype. Study examples A and B below.

A. Results of crossing TT and tt

Female → Genes Male ↓	t	t
T	Tt	Tt
T	Tt	Tt

B. Results of crossing Tt and Tt

Female → Genes Male ↓	T	t
T	TT	Tt
t	Tt	tt

The TTs seen in the flow chart and Punnett squares are described as **homozygous dominant** because there are two of the same dominant alleles together. The Tts are described as **heterozygous** because it has two different alleles for the same characteristic.

Monohybrid Cross and Dihybrid cross

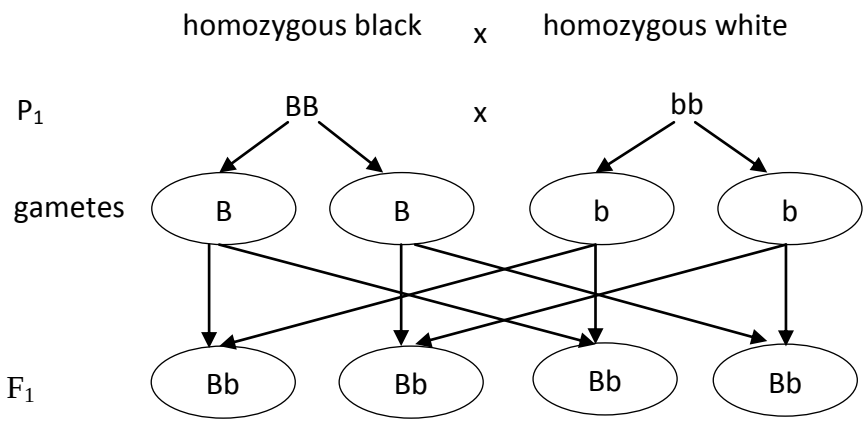
What is a monohybrid cross?

The inheritance of **one characteristic** (trait) is known as **monohybrid cross**. The parents involved differ in one pair of characteristics or trait.

An example is a cross between a cat with black fur and a cat with white. The only characteristics that is concerned here is the colour of the fur.

For instance, if there was a cross between a homozygous black dominant (BB) cat and a homozygous white recessive (bb) one. All the F_1 offspring will be heterozygous black (Bb).

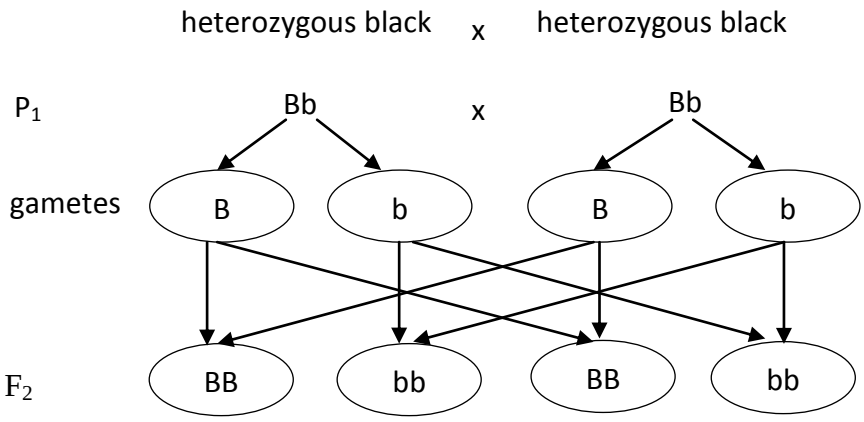
Study the diagram of monohybrid cross given below.



Flow chart showing a monohybrid cross

Results
Genotype: 100% Bb (All Bb)
Phenotype: 100% black (All heterozygous black)

If there is a cross between the heterozygous black cats of the F_1 generation, all the offspring produced will be homozygous black dominant and homozygous white recessive. Study the crosses shown below.



Flow chart showing a monohybrid crosses of F_1 generation

Results:
Genotype: 2BB : 2bb
Phenotype: 2 homozygous black dominant : 2 homozygous white recessive.

The above results show that 50 percentage of the offspring produced homozygous black dominant and another 50 percentage is homozygous white recessive.

What is a dihybrid cross?
The inheritance of **two characteristics** is known as a **dihybrid cross**.

For example, if a pure black rat with curly fur is crossed with a pure white rat with straight fur. Black fur is dominant to white and straight is dominant to curly.

For the fur colour, black (B) is dominant and white (b) is recessive. For the fur, straight is dominant and curly is recessive. B is the gene for black, b is the gene for white. S is the gene for straight, s is the gene for curly.

parent black, curly **BBss** x white, straight **bbSS**

gametes → / ↓	**Bs**	**Bs**	**Bs**	**Bs**
bS	BbSs	BbSs	BbSs	BbSs
bS	BbSs	BbSs	BbSs	BbSs
bS	BbSs	BbSs	BbSs	BbSs
bS	BbSs	BbSs	BbSs	BbSs

Dihybrid cross between black, curly fur rats with white, straight fur rat

Results
Possible genotypes in the F_1 generation: All BbSs (100% BbSs)
Possible Phenotype in the F_1 generation: 100% black and straight.
F_1 generation: All offspring are black with a straight fur.

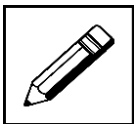
parents from F_1 generation **BbSs** x **BbSs**

gametes → / ↓	**BS**	**Bs**	**bS**	**bs**
BS	BBSS	BBSs	BbSS	BbSs
Bs	BBSs	BBss	BbSs	Bbss
bS	BbSS	BbSs	bbSS	bbSs
bs	BbSs	Bbss	bbSs	bbss

Dihybrid crosses between heterozygous black rats with straight fur rats

Results
There are nine possible genotypes or gene combinations in the F_2 generation.
Genotype ratios: 1BBSS: 2BBSs: 2BbSS: 4BbSs: 1BBss: 2Bbss: 1bbSS: 2bbSs: 1bbss
Phenotype ratio: 9 black/straight : 3black/curly : 3white/straight : 1white/curly

It is now time for you to complete Learning Activity 4 on the next page. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Assignment 1 (which you will send in for assessment)



Learning Activity 4

40 minutes

Write the answer for each question on the spaces provided.

1. Define

   i. genetic

   _____
   _____
   _____

   ii. inheritance

   _____
   _____
   _____

2. What is the difference between

   a. purebreed and hybrid?

   _____
   _____
   _____

   b. monohybrid and dihybrid crosses?

   _____
   _____
   _____

3. What would be the ratio of genotypes and phenotypes of the F_1 generation if a pure breeding black rabbit is crossed with a pure breeding white rabbit? Black is dominant to white. Let pure black rabbit be represented by BB and pure white rabbit be represented by bb. Show your working out for the ratio of genotypes and phenotypes using a Punnett square.

4. What are the genotype and phenotype ratios of the F_1 if a heterozygous black rabbits are crossed? Show your working out using a Punnett square.

5. a. In pea plants, round seed is dominant over wrinkled seed shape. Green seed colour is dominant over white seed coat colour. Use a Punnett square to show a cross between a purebred pea plant with round seeds and grey seed coats and a purebred plant with wrinkled seeds and white coats.

Round seed dominant represented by RR. Wrinkled seed shape represented by rr. Green seed coat colour dominant represented by WW. Yellow seed coat colour recessive represented by ww. What traits are seen in F_1 generation? Show your working out using a Punnett square.

b. Use a Punnett square to find the possible genotype and phenotype ratios if F_1 generations are crossed?

Thank you for completing your Learning Activity 4. Check your work. Answers are at the end of this module.

Dominant and Recessive genes

Genes normally exist in pairs, one of which is dominant and the other is recessive. If both dominant and recessive genes are present, only the dominant gene is shown or expressed. In other words the trait of the dominant gene is visible.

A distinct form of a gene is called an **allele.** A **dominant allele** is a gene that is fully expressed. A **recessive allele** is a form of a gene that is not fully expressed when paired with a dominant allele.

What is a dominant gene?

A dominant gene is one of the stronger pair of genes. It is the gene that overrides the weak or recessive gene and always expresses its characteristics. A dominant gene is always represented by a capital letter.

For example, if B or b is the genes for coat colour in a mouse, and black is dominant, the mouse genotype will be either BB or Bb. Because the B (black) is dominant, it will be shown. The genotype and phenotype can also be expressed number ratio and percentage.

	pure black mouse		pure white mouse
parent	**BB**	x	Bb

gametes → / ↓	**B**	B
B	**BB**	**B**B
b	**B**b	Bb

Cross showing the dominant gene in bold letters

Results

Genotype ratios: 2BB: 2Bb

Phenotype ratios: 4 black cats

Ratios: 2 : 2

What is a recessive gene?

A recessive gene is one of the pair of gene that is weak. The characteristics of recessive genes are not often expressed. A recessive gene is usually represented by a small letter of the same type as the dominant gene.

Examples, Aa, Bb, Ww, Yy can represent any gene whose characteristics cannot be seen or expressed.

For example, crossing a homozygous dominant black mouse with a homozygous recessive white mouse will produce a pure white mouse.

	pure black mouse		pure white mouse
parent	BB	x	**bb**

gametes → ↓	B	**b**
B	BB	B**b**
b	B**b**	**bb**

Cross showing recessive genes in bold letters

Results
Genotype ratio: BB: Bb: bb
Phenotype ratio: 3black: 1white.
Ratio: 1: 2: 1.

When both genes are dominant, they are said to be **homozygous dominant**. For example, BB. If both genes are recessive, they are said to be **homozygous recessive**. For example, bb. If the genes are made up of a dominant gene and a recessive gene, then they are said to be **heterozygous**. For example, Bb. **Homo** = same and **hetero** = different.

A dominant allele is fully expressed while a recessive allele is not fully expressed.

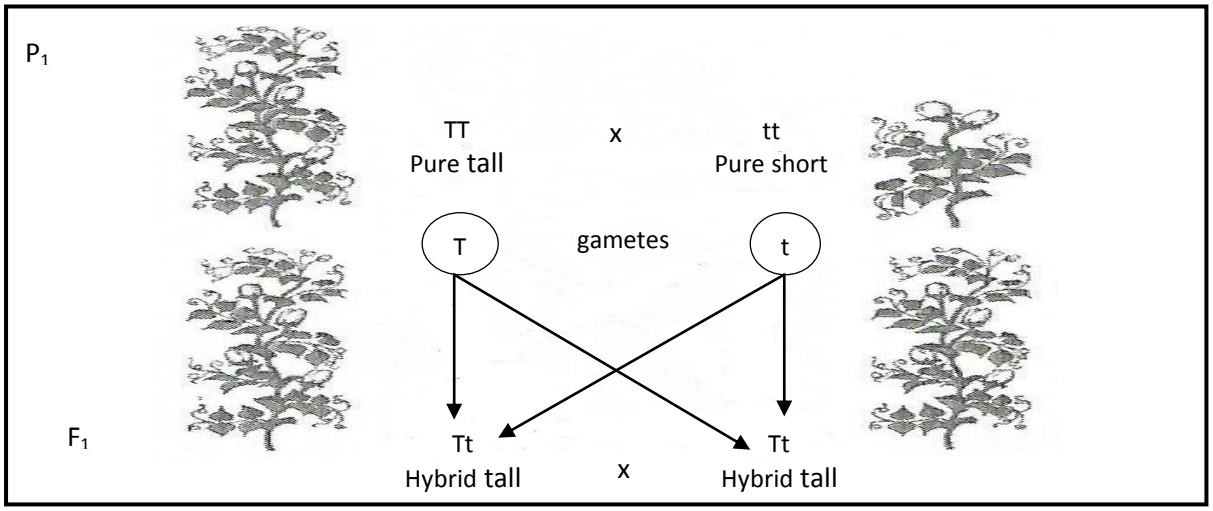
Mendel's phenotypic and genotypic ratios
A **genotype** is the genetic makeup of an organism. It is the actual pair of genes that decide a trait of an organism. The genes often occur in pairs and various combinations are possible. For examples, BB, bb, and Bb are paired symbols that show the genotype of an organism.

A **phenotype** is the characteristic that is actually seen such as black hair, brown eyes, or the red colour of a flower. It is the outward expression of an organism's trait. The phenotype of an organism depends on whether the alleles are dominant or recessive. Usually the phenotype of the dominant allele will be shown or expressed. If the genotypes are homozygous recessive, the phenotype shown will be of the recessive gene.

The generation of organisms which resulted from the first cross is called **F_1 generation**. The results from F_1 generation always show the dominant characteristics. The plants produced from crossing the members of F_1 generation are called **F_2 generation**. The F_2 generation usually show three quarters (¾) of dominant characters and one quarter (¼) of recessive characters. The possible genotypes and phenotypes of offspring in F_1 and F_2 generations are often expressed in ratio forms.

F_1 means 1 filial which describes the first generation that result from crossing two parental lines. F_2 means 2 filial generations.

Example 1. A pure tall plant is crossed with a pure short plant. Find all the possible genotypic and phenotypic ratios in the F_1 generation of this cross.



F_1 generation from a cross between a pure tall and pure short plant

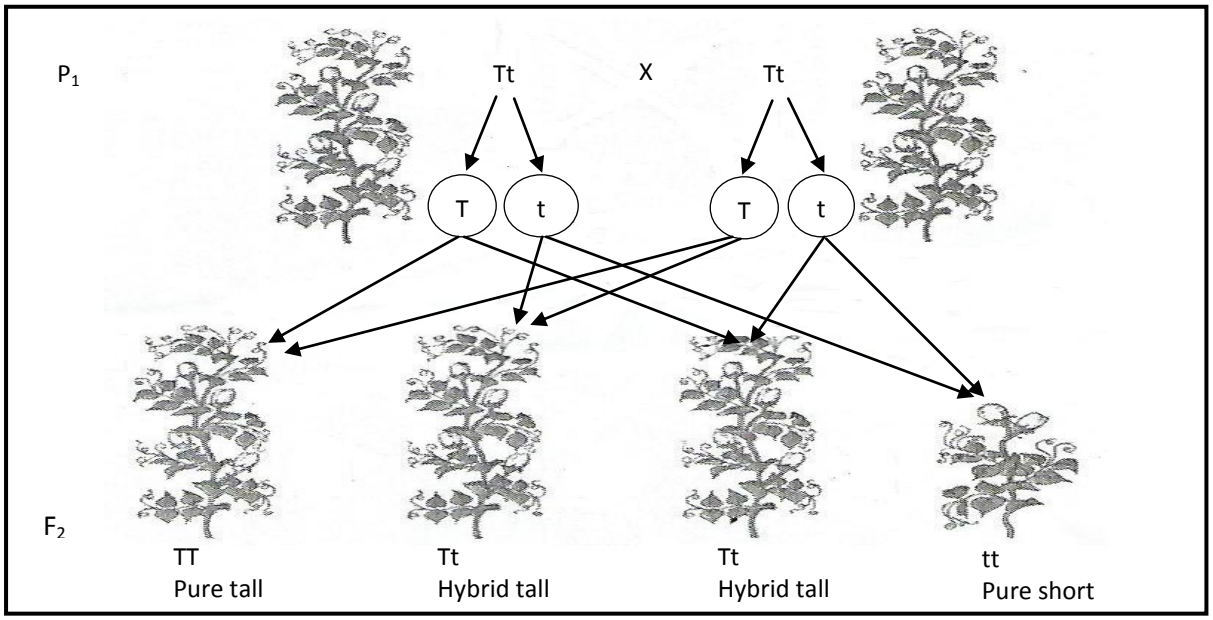
Results

Genotypic ratios: All Tt.

Phenotypic ratios: All heterozygous black plants.

Ratios: 100

Example 2. When crossing the F_1 generations, what will be the possible genotypic and phenotypic ratios?



F_2 generation from crossing the F_1 generation

Results

Genotypic ratios: 1TT: 2Tt: 1tt or 50% Tt: 25% tt.

Phenotypic ratios: 3Black: 1White (3 heterozygous black: 1 homozygous white).

The F_2 generations usually show three quarters (¾) of dominant characters and one quarter (¼) of recessive characters.

The rules of genetics

The rules of genetics were first discovered by Austrian monk, Gregor Mendel after studying the colour, height, seeds, and other characters of the pea plant.

From the results of his experiments, he developed the following rules:

- An organism's characteristics are passed down from one generation to the other.
- Genes exist in pairs (alleles), one of that may be dominant.
- In a gamete (sperm, ova, pollen, or ovum) only one of the two alleles is present. If the dominant and recessive alleles are present together, the dominant one will show.

It is now time for you to complete Learning Activity 5. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Assignment 1 (which you will send in for assessment)

Learning Activity 5

20 minutes

Answer the following questions on the spaces provided.

1. Explain the difference between:

   a. gene and allele.

   _____
   _____
   _____

   b. dominant genes and recessive genes.

   _____
   _____
   _____

   c. homozygous and heterozygous.

   _____
   _____
   _____

2. What is a pure breed organism?

   _____
   _____
   _____

3. Define the following terms, using examples to illustrate your answers.

   i. Genotype

   _____

   _____

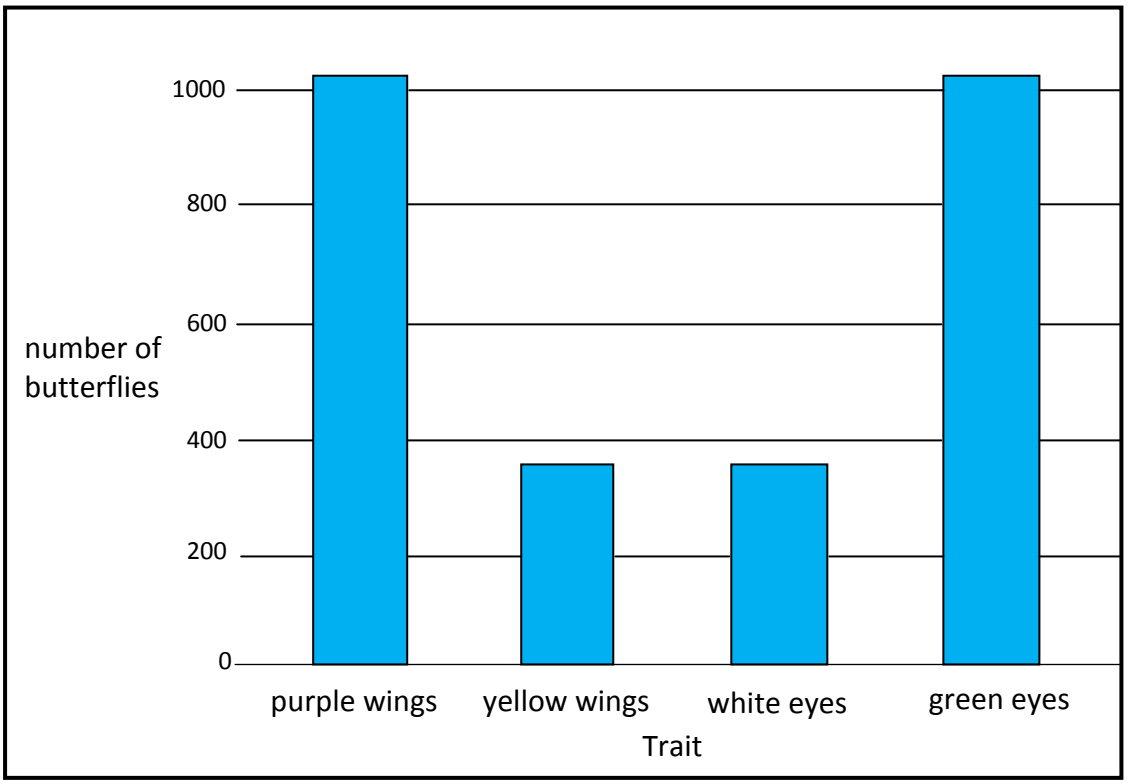
   ii. Phenotype

   _____

   _____

4. The gene for red hair is recessive to the gene for black hair. What colour hair will a person have if he inherits a gene for a red hair from his mother and a gene for black hair from his father? Work this out using a Punnett square. Use capital B for black hair colour and small letter b for red hair colour.

   Refer to the graph below to answer question 5.



5. The graph shows the traits of 1355 butterflies.

   a. Which traits are dominant? Explain your answer.

   _____

   _____

   _____

b. Which traits are recessive? Explain your answer.

_____
_____
_____
_____
_____

6. Use the words 'homozygous,' 'heterozygous', 'dominant' and 'recessive' (where suitable) to describe the following gene combinations:

i. Aa

_____
_____

ii. AA

_____
_____

iii. aa

_____
_____

Thank you for completing your Learning Activity.5. Check your work. Answers are at the end of this module.

_____

Mendel's Hypothesis

The Mendel hypothesises were developed after observing the results in F_2 generations of offspring.

1. **First Hypothesis**
   Inherited characteristics are controlled by genes, which occur in pairs.

2. **Second Hypothesis**
   One gene in a pair may mask the other or prevent it from having an effect.

3. **Third Hypothesis**
   The third hypothesis is now called the **law of segregation** or separation.

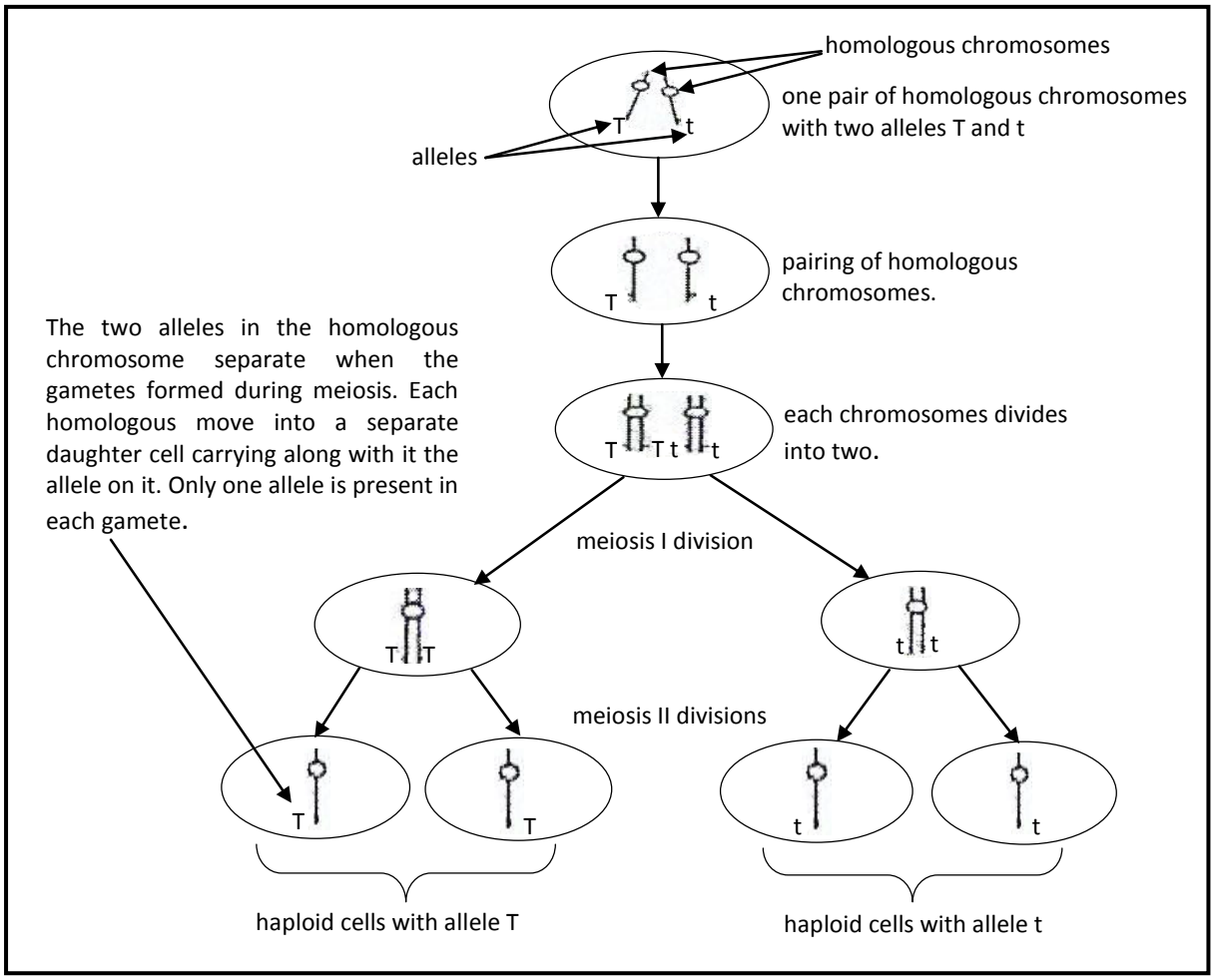
Mendel's Laws of Segregation and Independent Assortment

The two basic rules of inheritance are referred to as the Mendel's laws.

1. **Law of Segregation**
   The **Law of Segregation** states that a pair of genes is segregated or separated during the formation of gametes in meiosis. Each gamete receives only one of each gene pair.

Example 1:

Meiosis in a F_1 hybrid male

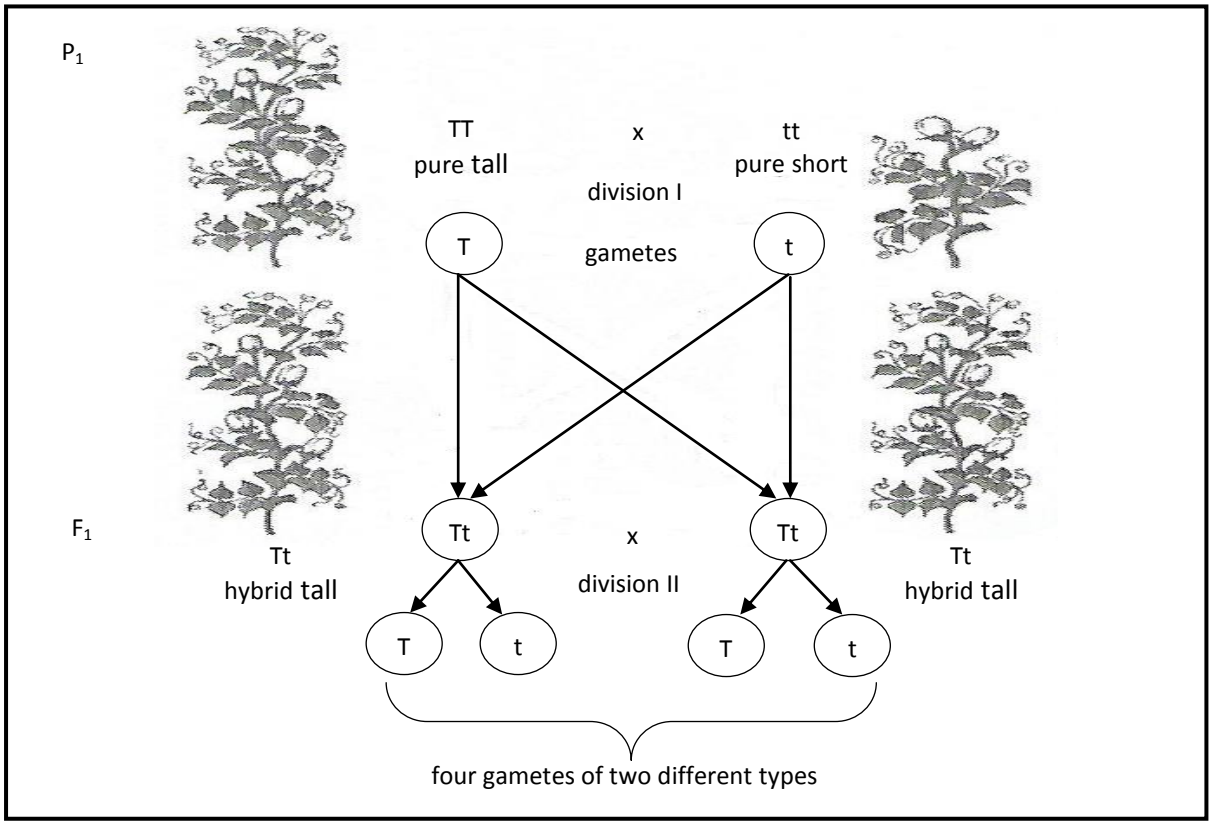


During meiosis a chromosome from one parent goes into one daughter cell. The corresponding chromosome (homologous chromosome) from the other parent goes into the other daughter cell. Each daughter cell divides again. A total of four gametes resulted.

In the first division of meiosis the chromosome carrying the gene for tallness (T) goes into one daughter cell. The homologous chromosome carrying the gene for shortness (t) goes into the other daughter cell. In the second division, four gametes of two different types are produced.

Example 2:

Meiosis in a cell of homozygous parents.



A cross showing the segregation of genes from homogenous parent cells

Mendelian Principle of Segregation
The diploid organisms inherit a pair of genes for each trait. Two genes segregate from each other at meiosis. Each gamete formed after meiosis has an equal chance of receiving one of the other genes, but not both.

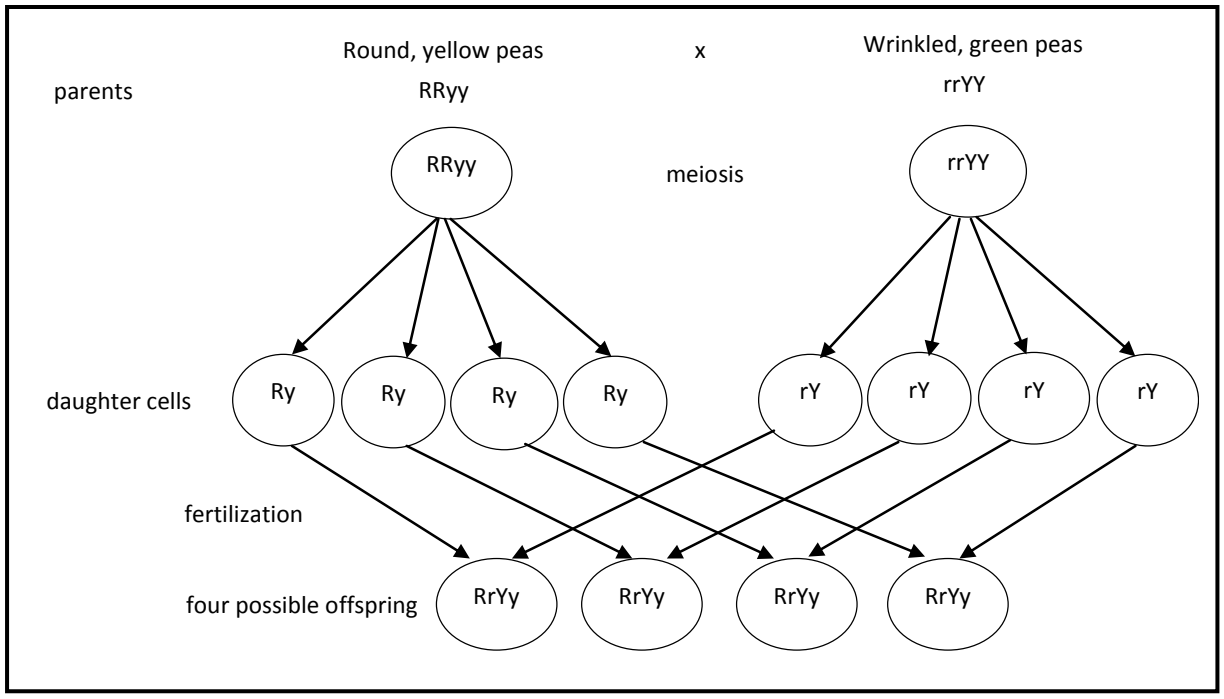
2. **Law of Independent assortment**
Mendel also studied the inheritance of two traits. He crossed pea plants that had yellow, round peas (RRyy) with plants that had green, wrinkled peas (rrYY). The results in the F_1 generation shows that all the peas were round and yellow (RrYy).

The F_1 plants were allowed to self-fertilise. All possible combinations of the pea colours and shapes appeared in the F_2 generation. From this finding, Mendel concluded that traits are inherited independently. This idea is now called the **Law of Independent Assortment**.

Law of Independent Assortment states that gene pairs segregate (separate) into gametes randomly and independently of each other. It means that one trait does not have any connection with another trait.

Example 1:

A cross between pure round yellow pea (RRyy) and a pure wrinkled green pea (rrYY). Round is dominant to wrinkle and yellow is dominant to green.



A monohybrid cross showing the independent assortment of genes.

When using a Punnett square. The independent assortment of the genes can also be shown using a Punnett square.

	Round, yellow peas (RRyy)	x	Wrinkled, green peas (rrYY)
parents	RRyy	x	rrYY

gametes	Ry	Ry	Ry	Ry
rY	RrYy	RrYy	RrYy	RrYy
rY	RrYy	RrYy	RrYy	RrYy
rY	RrYy	RrYy	RrYy	RrYy
rY	RrYy	RrYy	RrYy	RrYy

Punnett square showing independent assortment of genes

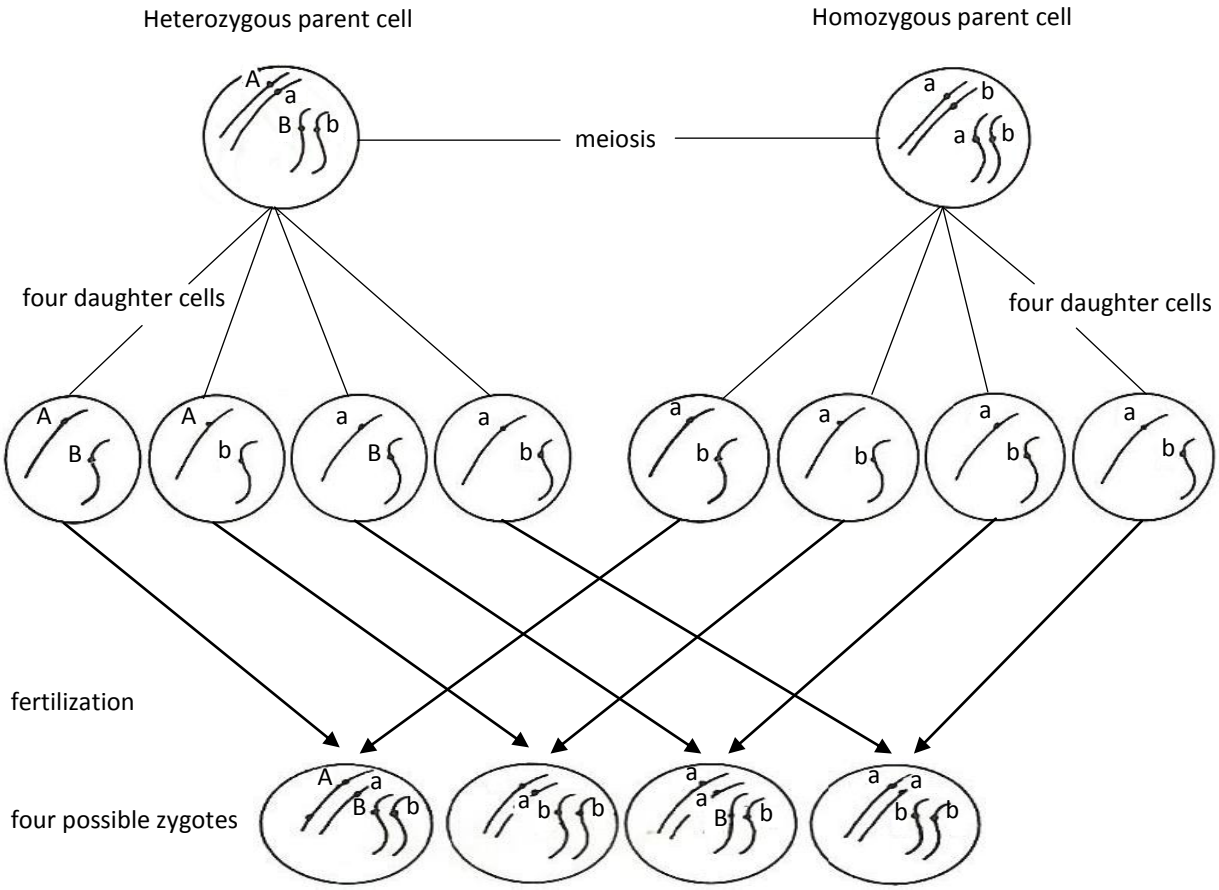
Result

Possible gametes (genotypes): All RrYy

All the F_1 generation peas are round and yellow.

Example 2:

A cross between heterozygous parent and homozygous parent.



A dihybrid cross showing the independent assortment of genes.

Mendelian Principle of Independent Assortment
Each gene pair tends to assort (fit) into gametes independently of other gene pairs that are located on non-homologous chromosomes.

It is now time for you to complete Learning Activity 6 on the next page. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Assignment 1 (which you will send in for assessment)

Learning Activity 6

30 minutes

Answer the following questions on the spaces provided.

1. State Mendel's law of

   a. segregation.

   _____
   _____

   b. independent assortment.

   _____
   _____

2. Explain the principles of

   a. segregation.

   _____
   _____

   b. independent assortment.

   _____
   _____

3. State three (3) of Mendel's hypotheses developed after observing results in F_2 generations of offspring.

   i. _____
   _____

   ii. _____
   _____

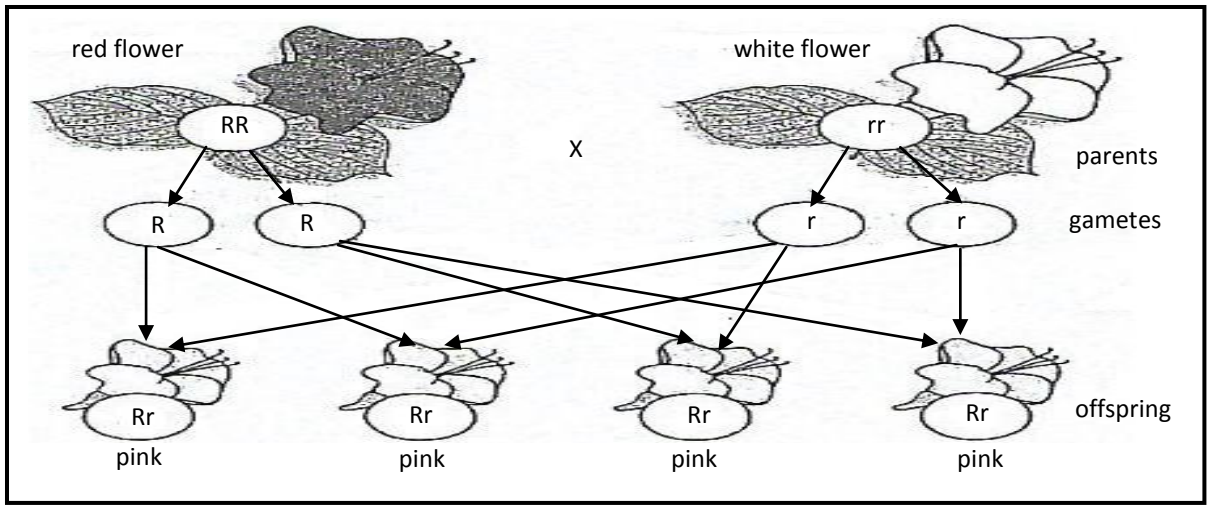
   iii. _____
   _____

Thank you for completing your Learning Activity 6. Check your work. Answers are at the end of this module.

Incomplete dominance

Incomplete dominance is the inheritance of a dominant and a recessive allele which results in a mixing of traits to produce intermediate characteristics.

For example, red and white roses plants may have red, white, or pink flowers. Plants with red flowers have two copies of the dominant allele *R* for red flower color (*RR*). Plants with white flowers have two copies of the recessive allele *r* for white flower color (*rr*). Pink flowers result in plants with one copy of each allele (*Rr*), with each allele contributing to a mixing of colors.

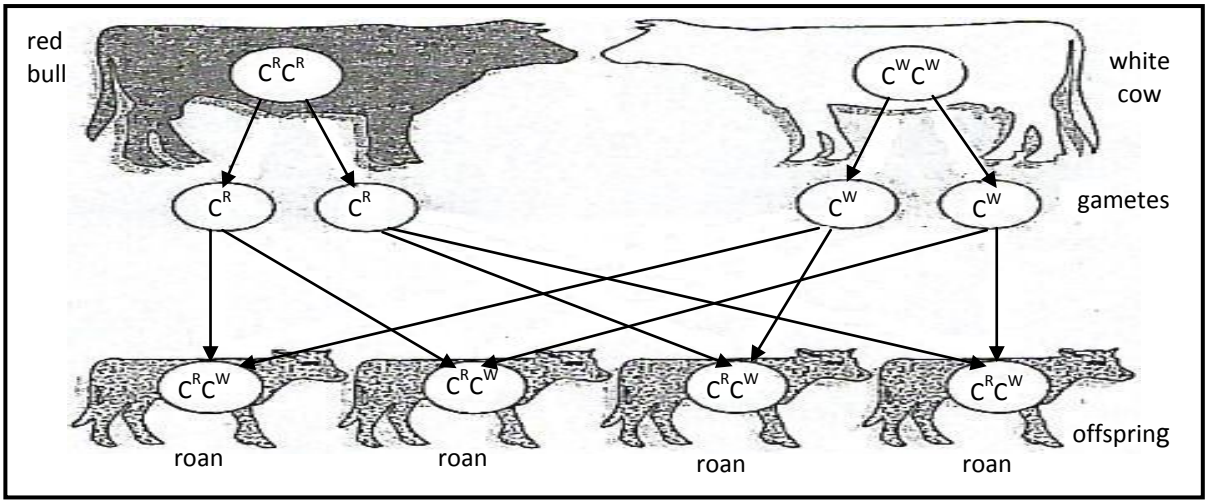


Incomplete dominance

Co-dominance

Co-dominance occurs when both alleles in a heterozygous are equally dominant. Both alleles are independently and fully expressed. This is common in coat colour of animals and blood groups. For example, a cross between a red bull with a white cow will produce a roan. The word **roan** means mixed colour.

Study the diagram below.



Codominance of a trait.

Blood group

Certain traits in living organisms are controlled by multiple alleles that have complex rules of dominance. In humans, for example, the gene for blood type has three alleles: **I^A, I^B,** and **i**. With three alternatives for each member of a gene pair, there are six possible combinations of these genes (**I^AI^A, I^BI^B, ii, I^Ai, I^Bi, I^AI^B**).

Although there are six possible combinations, humans have only four major blood types: **A**, **B, AB,** and **O**. This results because both I^A and I^B are dominant over i, but not over each other, so a person with a gene combination of I^AI^A or I^Ai has blood type A. The gene combinations I^BI^B and I^Bi both produce blood type B. I^AI^B results in a blood type AB, and ii results in blood type O. Study the Punnett square showing the possible alleles for the blood types below.

Possible alleles (genes) in gametes from mother

alleles of blood ABO → / ↓	**A (I^A)**	**B (I^B)**	**O (i)**
A (I^A)	I^AI^A type A	I^AI^B type AB	I^Ai type A
B (I^B)	I^AI^B type AB	I^BI^B type B	I^Bi type B
O (i)	I^Ai type A	I^Bi type B	ii type O

possible alleles in gametes from father

Possible combinations of alleles associated with ABO blood typing.

Results

1. Possible genotype
   1 I^AI^A : 2 I^Ai : 2 I^AI^B : 1 I^BI^B : 2 I^Bi : 1 ii

2. Possible phenotype or blood type
   3 type A : 2 type AB : 3 type B : 1 type O

If you received the blood type A allele (I^A) from one parent and the blood type B allele (I^B) from the other, your blood type is I^AI^B, and your blood phenotype is AB blood.

Blood type o is called **universal donor**. It can be given successfully to almost any person. Blood type AB is called **universal recipient**. It can receive any of the four types of blood.

Incomplete dominance is a pattern of inheritance in which two alleles in a heterozygote are partially expressed. Codominance is a patterns of inheritance in which both alleles in a heterozygote are fully expressed.

It is now time for you to complete Learning Activity 7. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Assignment 1 (which you will send in for assessment)

Learning Activity 7

40 minutes

Answer the following questions on the spaces provided.

1. What is the difference between incomplete dominance and codominance?

   _____
   _____
   _____

2. What are the possible blood groups likely to be inherited by children born to a group AB mother and a group B father? Explain your reasoning. Work out your answer using a Punnett square.

.

3. A red cow has a pair of alleles for red hairs. A black bull has a pair of alleles for white hairs. If a red cow and white bull are mated, the offspring are all 'roan', that is, they have red and white hairs equally distributed over their body.

   a. Is this an example of codominance or incomplete dominance? _____

   b. What coat colours would you expect among the offspring of a mating between roan bull and a roan cow when the genotype for the roan is $C^{B}C^{W}$.

      _____

4. Complete the Punnett squares for the following crosses.

   a. Homozygous black cat (BB) x homozygous black cat (BB)

male gametes

female gametes			

i. Genotype ratio: _____

ii. Phenotype ratio: _____

b. Homozygous black cat (BB) x heterozygous black cat (Bb)

male gametes

female gametes			

i. Genotype ratio: _____

ii. Phenotype ratio: _____

c. Heterozygous Black cat (Bb) x heterozygous black cat (Bb)

male gametes

female gametes			

i. Genotype ratio: _____

ii. Phenotype ratio: _____

Thank you for completing your Learning Activity 7. Check your work. Answers are at the end of this module.

It is now time for you to complete Assignment 3 in your Assessment Book 3 going on to the next topic.

12.3.3: Variations

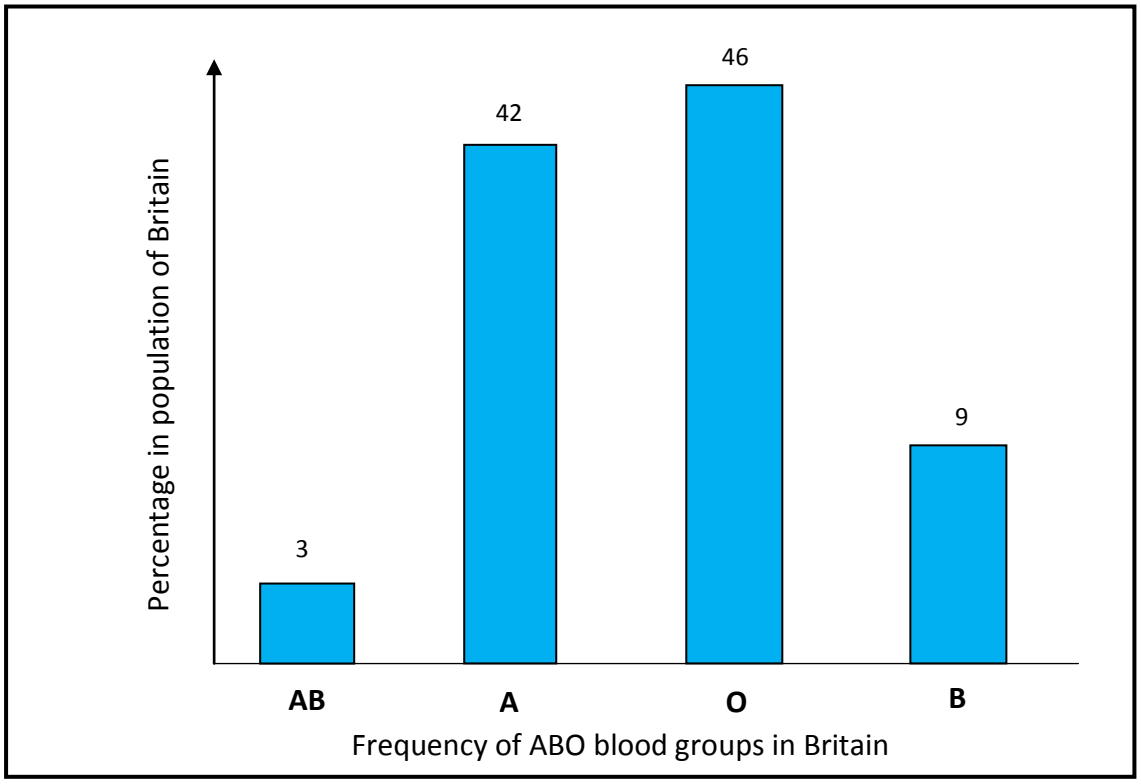
The term 'variation' refers to observable differences within species. All domestic cats belong to a species, but there are many variations of size, coat and eye colour, fur length and others. The variations inherited are determined by genes. Some variations cannot be inherited, but are determined by factors in the environment while others are determined by the changes in the genes and chromosomes due to mutations.

Types of Variations

1. **Discontinuous variations or Acquired characteristics**
   These are variations within species that are inherited from the parents to their offspring. They are determined only by inheritance and are controlled by a single gene. They are not influenced by the environment.

   Below are some examples of discontinuous variations
   i. People can either roll their tongues or they cannot.
   ii. Blood groups: A, B, AB, and O.
   iii. Gender, you are either male or female.

DISCONTINUOUS VARIATION IN BLOOD TYPE



Discontinuous variation

The graph above shows that blood group O has the highest frequency followed by A, B and AB with the lowest frequency.

2. **Continuous variations or inherited characteristics**

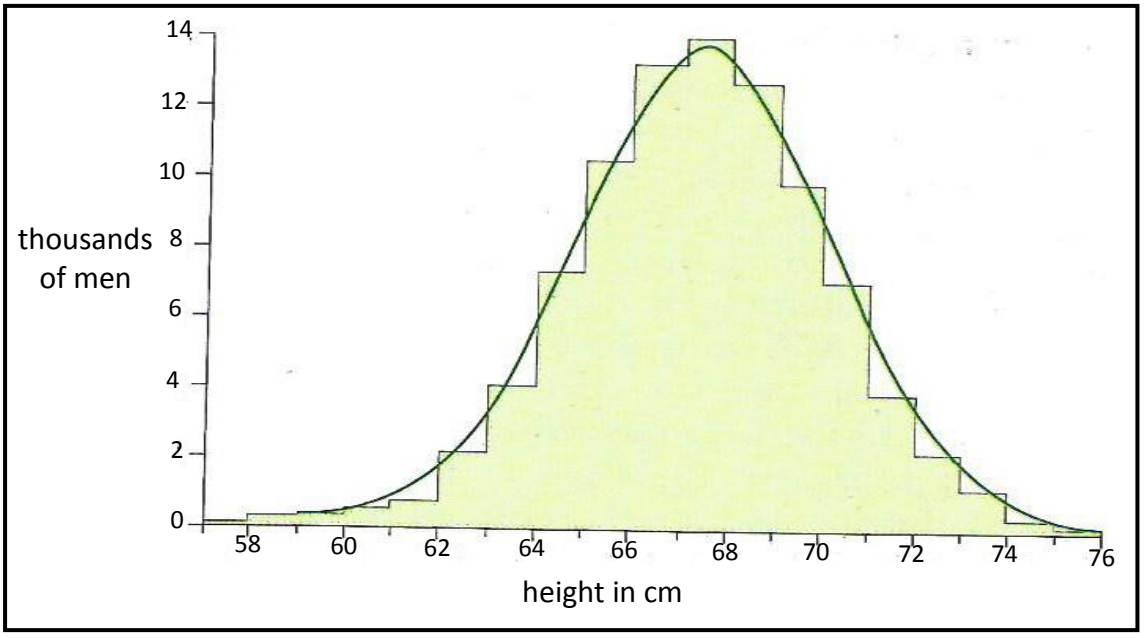
These are variations within a species that can result from both inheritance and environmental factors. With inheritance, the variation is due to a number of genes. For instance, two academically gifted parents may have a similarly gifted child. Parents who are champion athletes may have a gifted athletic child.

The different environmental factors can determine variation within a species. For example:

i. Health of the mother during pregnancy
ii. Diet
iii. Sickness
iv. Height
v. Ability to run fast
vi. Weight at birth

In any population there is a continuous range of heights, skin colour, and the ability to run fast. Shown below is a graph showing variations in heights of human.

CONTINUOUS VARIATION IN HEIGHT



Continuous variation. Heights of 90 000 recruits in 1939

The graph above shows the continuous variation in the heights of men in 1939. This variation is influenced by different environmental factors.

What causes variations within a species?

1. **Inheritance**

An offspring may inherit permanent characteristics from one or both parents through genes. Parents passed traits in chromosomes to their offspring during meiosis and

fertilisation processes. An offspring may inherit permanent characteristics through genes. However, mutation and sexual reproduction will increase the variation within a species.

2. **Mutation**

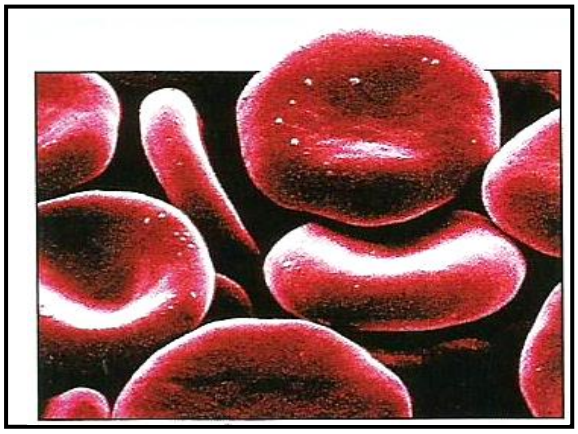
Mutation is a change in a gene, or chromosome of an organism. A factor in the environment that can cause mutations in DNA is called a **mutagen**. Examples of mutagens include radiation, certain viruses, industrial chemicals, tar and smoke.

Types of Mutations

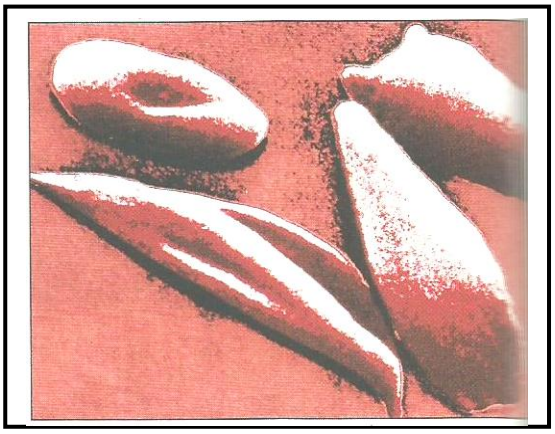
1. **Gene mutations**

Gene mutations are errors that occur within individual genes in a chromosome. They can involve a single nucleotide or they can affect sections of DNA that include many nucleotides**.** Gene mutation usually results in one amino acid missing and proper protein cannot be formed. This can lead to a considerable change in characteristics.

A disease caused by gene mutation is called **sickle-cell anaemia.** It is called sickle-cell because red blood cells are sickle-shaped. Their sickle shape occurs because of a defect in the blood protein haemoglobin due to low oxygen concentration. Sickle-cell anaemia is a serious blood disease.



Normal red blood cells

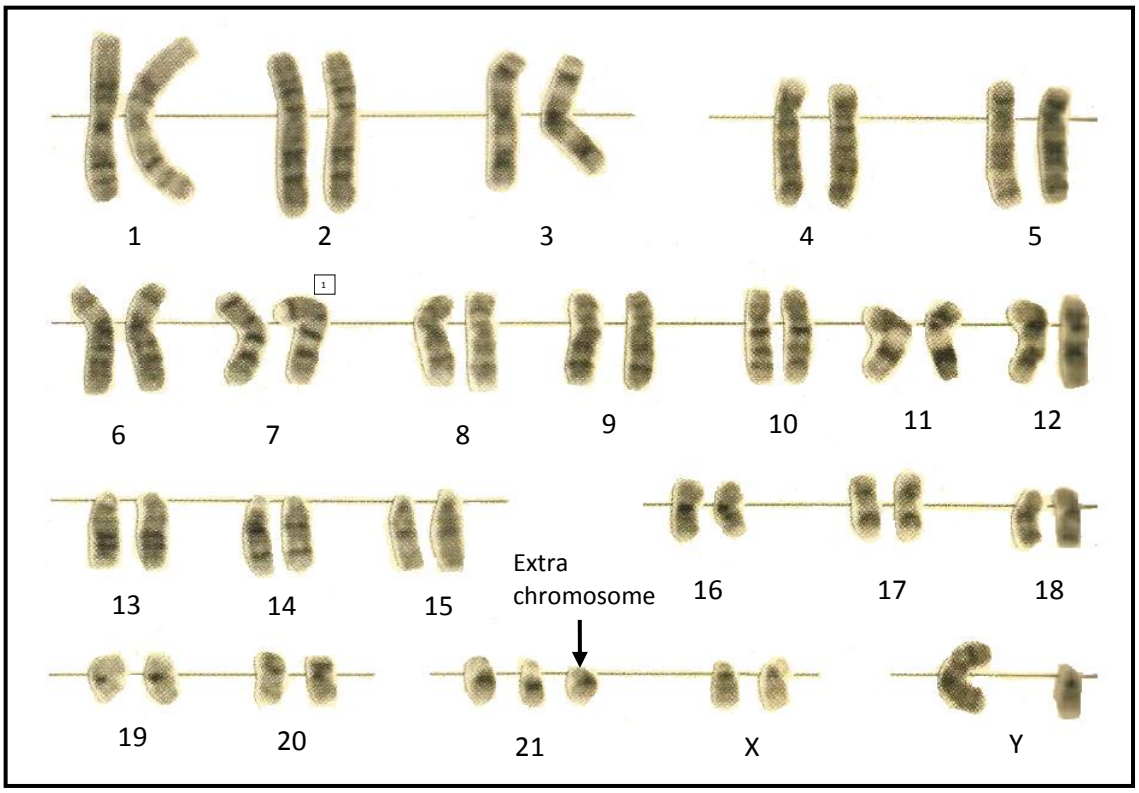


Infected sickle cell

2. **Chromosome mutations**

A chromosome mutation occurs when part of a chromosome is damage or at a loss during mitosis and meiosis. During cell division individual chromosomes are fragmented. Sometimes the fragments (broken pieces) recombine but in wrong order so the genes are reversed. The result will be due to a chromosome with an additional gene from another chromosome attached to it.

The consequences of chromosome mutations are often serious because they involve many genes. This can lead to disease such as **Down's syndrome** caused by the presence of an extra twenty-one chromosome in all body cells. It is an inherited form of mental and physical retardation. Study the diagrams below.



The diagram shows 47 chromosomes in the body cell instead of normal 46

The pictures below show children born with Down syndrome.

Children born with Down syndrome show mental retardation. Their facial characteristics may include a small, flat nose, skin folds at the eye corners, a protruding tongue and small ears. Neck, arms and fingers are often shorter than normal.

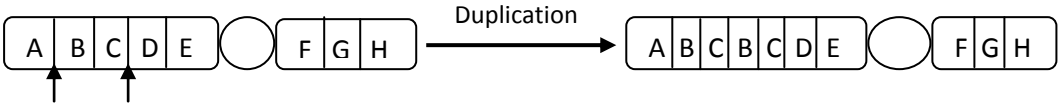
Types of chromosome mutation

i. **Deletion**

A deletion occurs when a chromosome breaks and a piece of it is lost.

ii. **Duplication**

Duplication occurs when part of a chromosome breaks off and is incorporated into its homologous chromosome. The homologous chromosome then has an extra copy of one of its parts. Duplication can result from an unequal crossover of chromosomes.

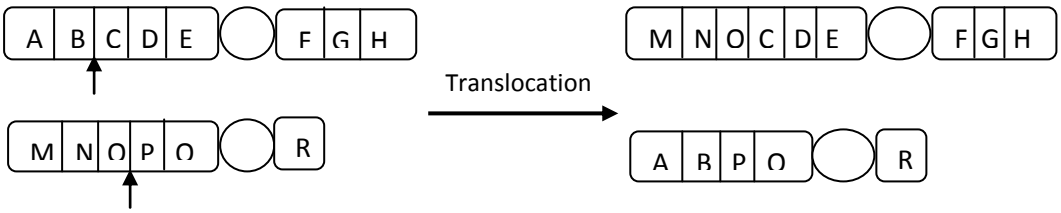


iii. **Inversion**

An inversion occurs when a part of a chromosome breaks off, turns around and reattaches in the reverse order.

iv. **Translocation**

In translocation, a chromosome part breaks off and attaches to a different, nonhomologous chromosome. Changes in the number of genes can harm or kill an organism.



3. **Somatic mutations and reproductive mutations**

The mutation which occurs in a body cell of a plant or animal is called **somatic mutation**. The one that occurs in the reproductive cells is called **germ mutation**. Germ mutation may pass onto the offspring.

Causes of mutation

A mutation can arise when:

- mistakes are made in copying DNA as cell gets ready to divide pairing with the incorrect base.
- damage is made to DNA. Some environmental factors can alter the bases present in the DNA.
- chromosomes are unevenly distributed during cell division.

It is now time for you to complete Learning Activity 8. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Assignment 1 (which you will send in for assessment)

_____

Learning Activity 8

30 minutes

Answer the following questions on the spaces provided.

1. What is meant by variation?

   _____
   _____
   _____

2. Classify the given features as discontinuous or continuous variation
   i. height: _____
   ii. hair colour: _____
   iii. eye colour: _____
   iv. blood group: _____

3. List the two main causes of variations within species and beside each state their main determining factors.
   i. _____
   ii. _____

   Refer to the diagram below to answer question 4.

Average Height for Italian Males	
Year	Average Height (metres)
1938	1.66
1958	1.68
1970	1.70
1976	1.72
1982	1.73

4. State the type of variation shown in the table. _____

5. Variation in a population results from _____ reproduction.

6. What is mutation?

_____

_____

_____

7. List three causes of mutations?

i. _____

ii. _____

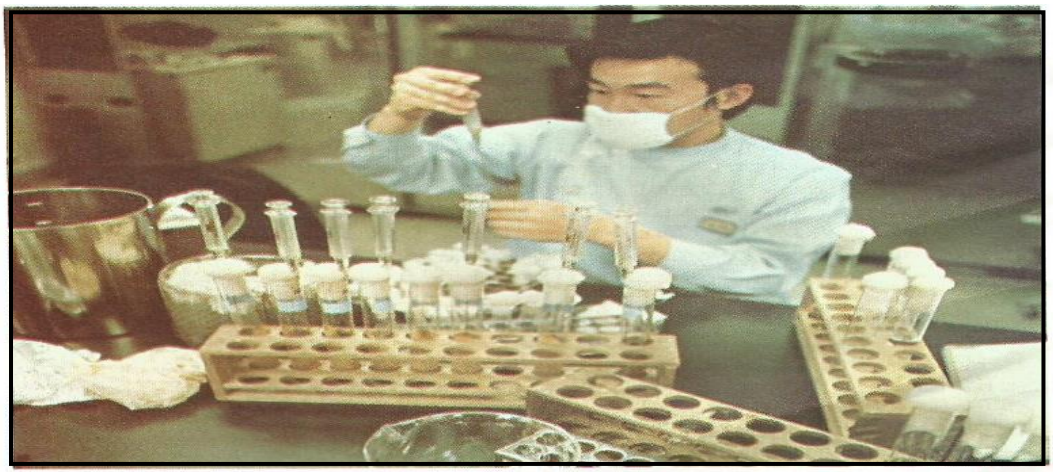
iii. _____

Thank you for completing your learning activity number 3.8. Check your work. Answers are at the end of this unit.

_____

12.3.4: Biotechnological Techniques

Biotechnology is any technological application that uses biological systems and living organisms to modify products or processes for specific use. This definition covers many of the tools and techniques used in agriculture, food processing and preservation, forestry, medicine, waste management, environmental remediation, and even law enforcement. Modern techniques such as genetic engineering have greatly increased the application of biotechnology.



A microbiologist in the bacteriology laboratory

Genetic engineering
Genetic engineering refers to any techniques used to identify or change genes at the molecular level. It involves the transfer of genes from one organism to an unrelated species. When genes are manipulated (controlled), an organism's characteristics are changed. Genetic engineering can change genes in a shorter period of time.

Changing genomes
Genetic engineers do more than identify genes. Using modern techniques, scientists can alter genomes by combining DNA from the genes of different organisms. The DNA with components from different organisms is called **recombinant DNA**. With recombinant DNA technology, scientists can transfer genes from one organism into the cells of another organism.

When genes are transferred, they are copied by the organism's cell along with the organism's chromosomes. The exact copies are called **clones**. Gene cloning is the process of using genetic engineering to make copies of genes.

To transfer DNA into a cell, genetic engineers use a carrier of genetic material called a **vector**. The bacteria that contain vectors are called **plasmids**. Plasmids are small circular pieces of DNA separated from the bacterial chromosomes. Scientists also use viruses as vectors to transfer DNA into cells.

Human Genome Project
The Human Genome Project is the most important project in the history of biology. The project's goal was to identify and sequence the entire DNA in human chromosomes. The project was initiated in 1990 in the United States.

The completed human genome has provided scientists with a detailed blueprint of our complex genetic code. Among the findings about the human genome was that the number of genes in the human genome is much lower than was predicted only about 20000 to 25000 genes compared to the expected 100,000 genes.

A **genome** is the total genetic content of any cell in an organism. It consists of all the genes on all the chromosomes.

Applications of human genome project
It is hoped that knowledge of the human genome will lead to:

- identification of defective genes and hence the opportunity to offer early treatment.
- identification of genes, which are more likely to be affected by certain diseases so individuals can take preventive measures.
- prediction of the proteins that the genes produce, giving the opportunity to design appropriate drugs to enhance the activities of these proteins.

Application of genetic engineering

1. **Gene therapy**

Gene therapy is the transfer of healthy human genes into a person's cells that contain mutant alleles that cause disease. It is one of the fastest growing areas in genetic engineering. Gene therapy is different from medicines because the treatment involves actually changing the genes that cause a genetic disorder.

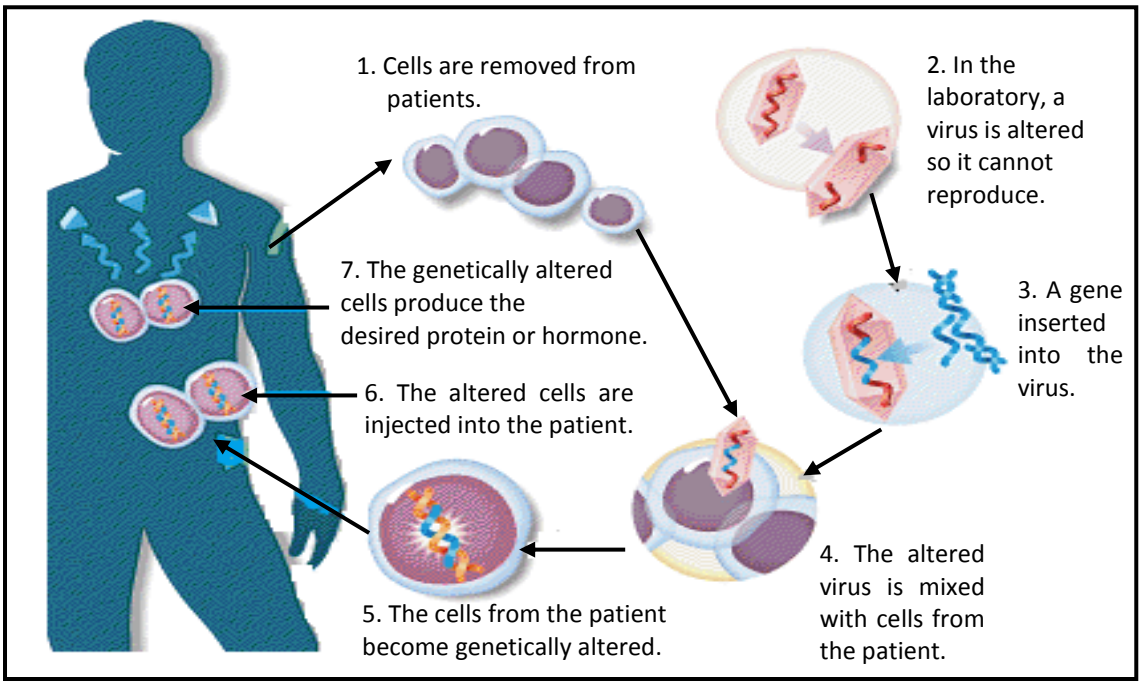


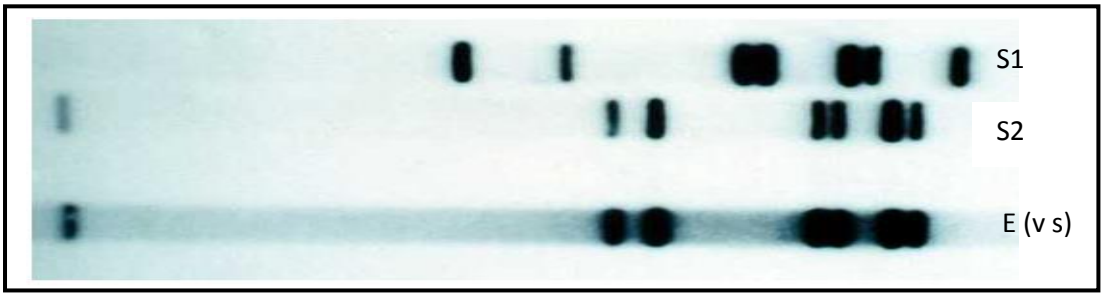
Diagram of a gene therapy

2. **Agriculture and industry**

One goal of genetic engineering is to improve the quantity and quality of food. Genetic engineering can improve food in many ways. This includes making plants resistant to pest and weeds killers resulting in producing fruits and vegetables that are better suited for shipping and storage.

3. **Forensics**

Modern detectives practice forensics, the use of scientific method to solve crimes. DNA fingerprints are used for identification in forensics. They can help investigators identify the suspect in a crime.



DNA fingerprinting or DNA profiling

The horizontal pattern of lines represents a person's genetic makeup. In the sample shown, suspect S2 matches the evidence, blood sample E.

4. **Vaccines and Medicine**
   The area in which genetic engineering has had the greatest effect on our lives is medicine. Insulin is one of the first medicines to be manufactured using genetic engineering. Genetic engineering techniques have been used to develop gene therapy, to improve and develop vaccines and medicines and to diagnose disorder.

Genetically Modified Organisms (GMOs)

The genetically modified organisms are also called **transgenic organisms**. A transgenic organism receives genes from a different organism species. Both plants and animals can be genetically modified. Some examples of genetically modified foods are potatoes and tomatoes, which are made to take much longer time to rot.

Wheat and rice have been modified to increase the photosynthesis rate, and increase in grain yields. Farm animals are modified to grow faster.
The genetically improved crops such as rice can feed the growing world population. The genetically modified foods are just like all other naturally produced food. They are not dangerous for consumption.

The genetic modification involves more than inserting one gene into a crop or animal. New proteins are introduced from bacteria and viruses which have never been part of the human diet. This may cause allergic responses in humans. The genetic engineering of food crops can also reduce the use of pesticides.

The advantages and disadvantages of genetic engineering

The benefits of genetic engineering in medicine, agriculture, and industry seem endless.

Advantages

With genetic engineering we may have:

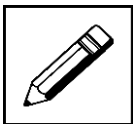
- plants with chemicals in their leaves that kill insects, fungi, and other pests.
- wheat, potatoes, tomatoes, and other crops which can ‘fix’ nitrogen from the air to make proteins without costly fertilizers.
- tomatoes and other fruits can remain fresh for much longer.
- sheep and cow can produce human growth hormone, antibodies, and blood-clotting chemicals in their milk.

Disadvantages

- Pesticides engineered crops are producing pesticide continuously in every cell every day, the amount of pesticide in the environment will increase causing harm to other living organisms.
- New proteins are introduced from bacteria and viruses which have never been part of the human diet and may cause allergic responses in humans.

It is now time for you to complete Learning Activity 9. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Assignment 1 (which you will send in for assessment)

_____



Learning Activity 9

20 minutes

Answer the following questions on the spaces provided.

1. What is meant by

   i. genetic engineering?

   _____

   _____

   ii. recombinant DNA?

   _____

   _____

   iii. vector?

   _____

   _____

2. Name two vectors used in genetic engineering.

   i. _____ ii. _____

3. What is a genome?

   _____

   _____

4. What is the main purpose of Human Genome Project?

   _____

   _____

5. List three major application of genetic engineering.

   _____

   _____

6. What is a transgenic organism?

   _____

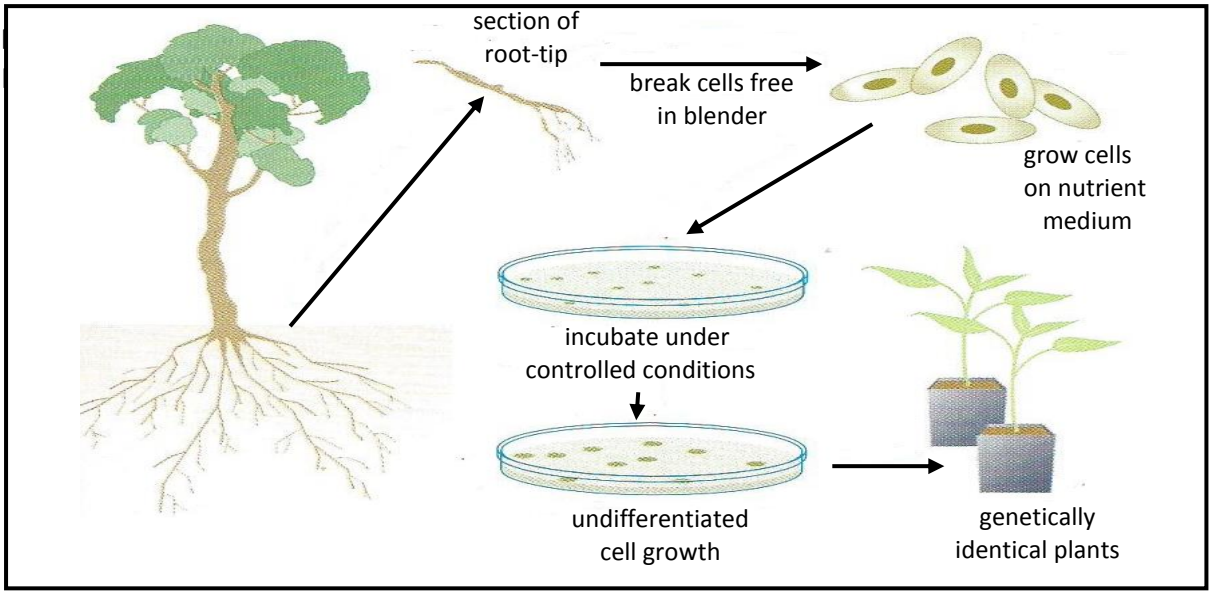
   _____

Thank you for completing your Learning Activity 9. Check your work. Answers are at the end of this module.

Cloning and Tissue Culture Techniques

Clones and cloning

Cloning is a method of producing identical copies of genes, cells, or organisms. The products of cloning are called a **clone**. A clone is a group of genetically identical organisms or cells produced either by asexual reproduction or artificially by cloning techniques. The main advantage of these techniques is that they can make large numbers of plants or animals, which are exact copies of a parent with desirable characteristics. Sometimes cloning is used to produce skin or other tissues needed to treat a patient.



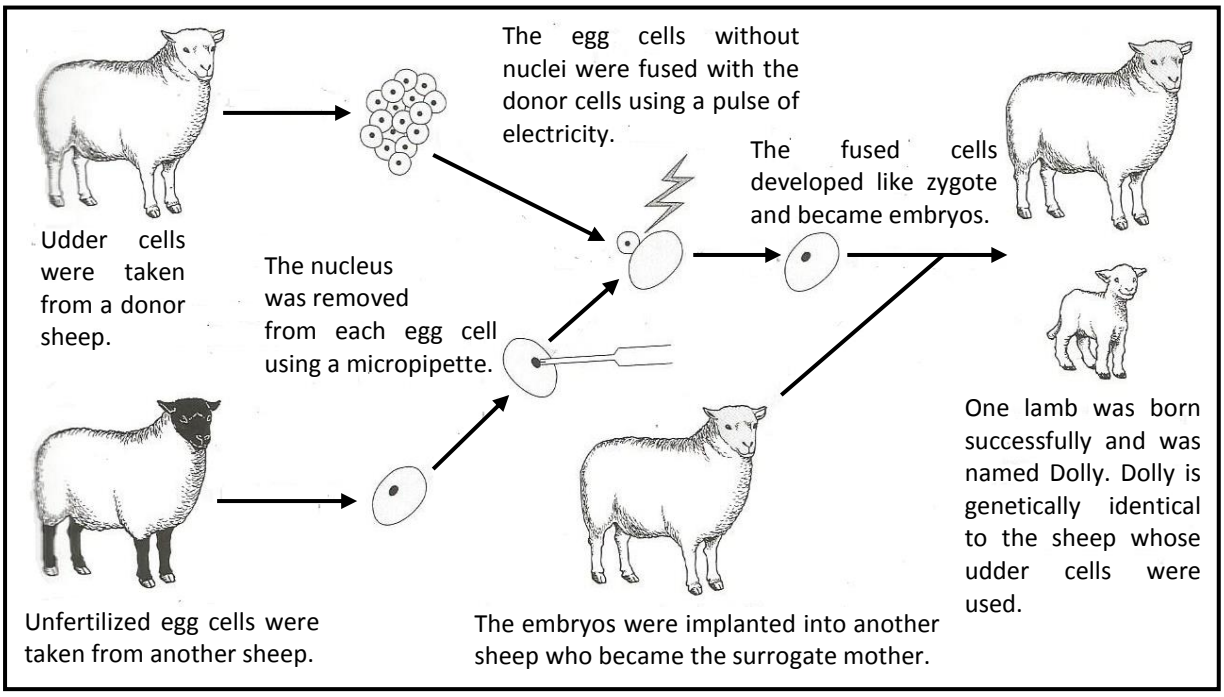
Cloning a tree species

Animal cloning

Animals cannot be cloned in the same way from parts of their bodies. If animal embryos are divided up at an early stage into several pieces, each piece can develop into a separate animal. However, it is hard to predict which embryos can develop into animals with desirable characteristics and should therefore be cloned. The first successful reproductive cloning of an adult with known characteristics is **Dolly** the **sheep**. Dolly was born at 5 pm on5 July 1996, at the Roslin Institute in Scotland

Dolly the cloned ship

Study how Dolly was cloned which is illustrated in the diagram below.



General processes used to cloned Dolly the sheep

Gene cloning is the process of using genetic engineering to make copies of genes.

Advantages of cloning

1. **Conserving endangered wildlife**
   Many wild animals are in danger of extinction because of the loss of habitat and illegal activities of animal hunters. Cloning could save the endangered species if cells of these animals are collected and grown in the laboratory. Animal breeders can sell cloned embryos of animals with other valuable features such as the fertility and health.

2. **In reproductive cloning**
   Cloning is very useful if an organism has a desirable combination of characteristics and more organisms with the same characteristics are wanted.

3. **Medical benefits**
   Scientists used cloning to produce perfect copies of your tissues and organs needed to treat a patient. A cloned heart, liver, kidneys and other organs would not be rejected if you needed a transplant operation.

Some examples of medical benefits

i. Cloned blood by blood group and so ideally suitable for transfusions.
ii. Cloned bone marrow is perfect for use in leukaemia.
iii. Cloned skin is used for cosmetic surgery after burns and other skin disorders.
iv. A cloned heart, liver, kidneys, and other organs are used in transplant operations.

Disadvantages of cloning

1. **Genetic conservation**
   If only a few chosen animals are selected for cloning there is a danger that rejected breeds could die out altogether. A major risk of excessive cloning is that it produces large populations of genetically identical animals with limited genetic diversity. A sudden outbreak of a new disease can result in the dead of tens of thousands of animals.

2. **Human cloning**
   There are many obstacles to producing human clones. Present methods require hundreds of egg cells to receive donor nuclei, with only 1 in 300 chance of successful pregnancy. Women, however, can produce only 5 to 10 eggs at a time. A cloned child will grow up into a different person with its own personality, knowledge, and memories. Cloning cannot be used to replace famous scientists, film stars or a beloved dead child.

Tissue culture

Tissue culture is a technique or process that involves growing cells and tissues of complex organisms outside the body. This method involves growing an entire plant from individual cells or from small pieces of leaf, stem, or root. The technique was developed in 1958 by an American plant physiologist, F.C. Steward. Steward grew an entire carrot plants from tiny pieces of carrot roots.

Today, plant breeders use tissue cultures to produce plants that possess rare or desirable traits. Many plants can be produced by growing tissue cultures.

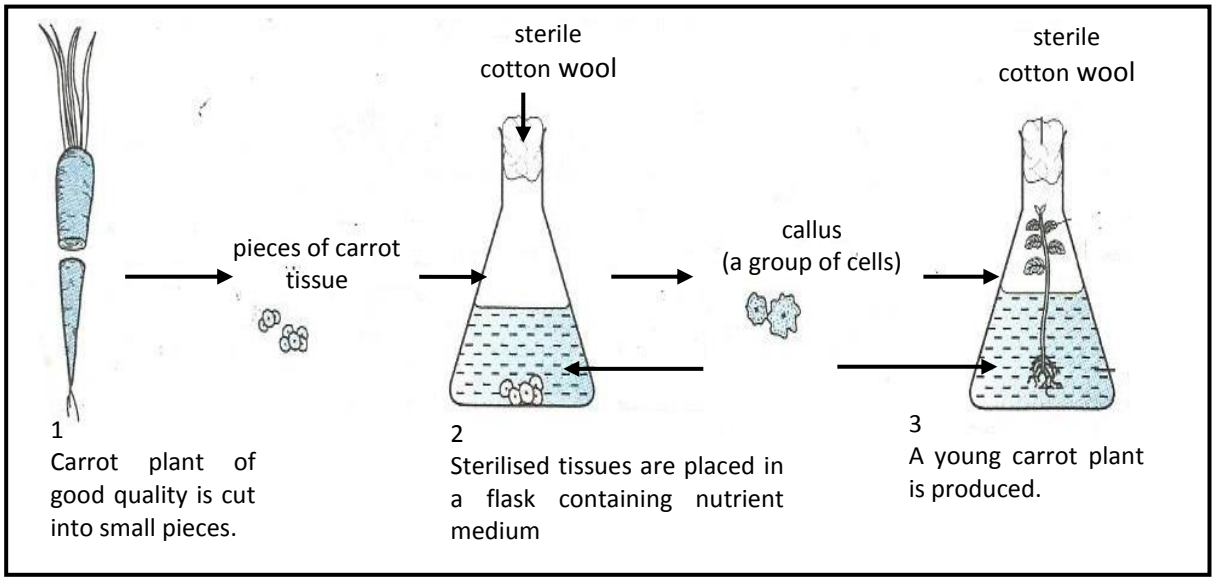
Growing plants using tissue culture generally involves the following steps.

1. Part of a selected plant is cut.

2. The cut part is placed in a liquid containing enzymes. That will separate the plant part into individual cells.

3. The cut part is placed in the liquid containing growth hormones. When the cell divide it will grow into lumps of plant tissue that can form shoots and leaves and in time, become a complete plant.

The tissue culture of a carrot plant is used as an example on the next page. Study the diagram thoroughly. Similar methods are used in cloning other plants, especially in farming and agriculture.



Tissue culture of a carrot plant

It is now time for you to complete Learning Activity 10. Remember, learning activities are not sent in for assessment. However, this learning activity will help you complete Assignment 1 (which you will send in for assessment)

Learning Activity 10

10 minutes

Answer the following questions on the spaces provided.

1. State the difference between cloning and a clone.

   _____
   _____
   _____
   _____

2. Explain the similarity between cloning and asexual reproduction.

   _____
   _____
   _____
   _____

3. What is gene cloning?

   _____
   _____
   _____

4. List three medical benefits of cloning human body tissues and organs.

   i. _____
   _____
   _____

   ii. _____
   _____
   _____

   iii. _____
   _____
   _____

5. Describe two cloning techniques in plants, and the advantages of these methods.

   i. _____
   _____
   _____

   ii. _____
   _____
   _____

Thank you for completing your Learning Activity 10. Check your work. Answers are at the end of this module.

REVISE WELL USING THE MAIN POINTS ON THE NEXT PAGE

SUMMARY

You will now revise this module before doing **SUMMATIVE TEST 3**. Here are the main points to help you revise. Refer back to module topics if you need more information.

- **Genetic** is the scientific study of hereditary. **Heredity** refers to the transmission of traits or characteristics from the parent to offspring. The transmission of different traits is determined by genes that contain genetic information. Genes are located along the chromosomes which are contained in the nucleus. The characteristics of an organism are determined by the genes.
- Genetic information consists of a chemical substance called **deoxyribonucleic acid (DNA)**. Inheritable characteristics are passed on through units of inheritance called **genes**. DNA, genes and chromosomes are related in the following ways:
  - chromosomes are molecules of DNA found in cell nuclei
  - chromosomes consist of genes.
  - genes consist of segments of DNA along chromosomes.
- DNA has a **double helix** structure consisting of repeated units of nucleotides.
  A nucleotide has three parts: a sugar, a phosphate and a nitrogenous base.
  The bases always form complementary base pairs: adenine pairs with thymine and guanine always pairs with cytosine. The DNA is capable of producing its identical copies during the process of **replication.**
- During **transcription** genetic information is copied from DNA into mRNA. During **translation**, the coding of information in the nuclei acid for amino acid occurs.
- The DNA is a double-strand nucleic acid. RNA is a single-strand nucleic acid. DNA has a deoxyribose sugar group and RNA has a ribose sugar group.
- **Cell division** is the splitting of a single cell into two cells. There are two main types of cell division. The cell division which enables the same genetic information to be passed parent cell to daughter cells is **mitosis**. When the cells undergo mitosis, the resulting cells contain **diploid** number of chromosomes like the parent cells. The type of cell division which results in the formation of sex cell (gametes) is **meiosis**. The daughter cells produced in meiosis contain **haploid** number of chromosomes.
- In **monohybrid cross**, one gene or one characteristic is being considered at a time. In **dihybrid cross**, two different characteristics are considered.
- The traits of **dominant genes** or alleles are always expressed and are represented by capital letters. The traits of **recessive genes** or **alleles** are masked by the dominant genes and are represented by the same but small letters. Example Aa.
- The **homozygous dominant** individuals have two dominant alleles. **Homozygous recessive** organisms have two recessive alleles. The **heterozygous** organisms have two different alleles.
- The genes inherited by an organism make up its **genotype**. Because an organism has certain genes, it has particular features. The observable features are the organism's **phenotype**.

- In **incomplete dominance** one allele decreases the expression of the other.
- In the inheritance of blood groups, the alleles I^A, I^B and i can be found in the following possible genotypes for blood groups.

genotype	phenotype
I^AI^A	Blood group A
I^Ai	Blood group A
I^BI^B	Blood group B
IBi	Blood group B
I^AI^B	Blood group AB
ii	Blood group O

That I^Ai has group A blood suggests that I^A is dominant to i. Similarly I^B is dominant to i. When I^A and I^B are together, each expresses its own effect, giving rise to group AB group. This shows that I^A and I^B are **equally dominant** or **codominant**.

- **Mendel's First Law, the Law of Segregation**, states that only one of each pair of allele is carried into a gamete. For example, when an organism of genotype Aa forms gametes, each gamete will carry either 'A' or 'a', but not the two together.
- **Mendel's Second Law, the Law of Independent Assortment** states that each of a pair of alleles may be combined randomly with each of another pair. For example, a gamete may carry gene 'A' with gene 'E' or gene 'A' with gene 'e'. Similarly, a gamete can carry 'a' with 'E' or 'a' with 'e'.
- The difference between members of the same species is known as **variation**. Inherited variations arise from different combinations of genes or from mutation.
- Sexual reproduction produces greater variation than asexual reproduction. The variation controlled by a small number of genes is called **discontinuous variations**. The discontinuous variations cannot be changed by the environment. The **continuous variation** is controlled by a number of genes. Continuous variations can be influenced by the environment.
- **Mutations** are changes in the DNA information on a chromosome or gene. They provide a source of variation in organisms. Radiation and many chemicals are **mutagens** and increase the mutation rate in cells.
- **Biotechnology** is the application of biological concepts to practical problems. The following are examples of where genetic concepts have been applied to biotechnology.
  - **Gene cloning** where copies of the same gene can be produced.
  - **DNA fingerprinting** to identify suspects in criminal offences or to match related individuals.
  - **Tissue culture** where cells and tissues specially cultured to produce useful organic compounds.
- **Genetic engineering** refers to any technique used to identify or change DNA sequences.
- **Human Genome Project** aims to find the location of human genes on chromosomes.

- **Cloning** of human tissues and organs may have medical use in transplant.
- Plants and animals that develop from a cell into which new DNA has been introduced are called transgenic organisms.

NOW DO UNIT TEST 3 IN YOUR ASSESSMENT BOOK AND SEND IN TO THE PROVINCIAL COORDINATOR FOR MARKING.

ANSWERS TO LEARNING ACTIVITIES 1 – 10

Learning Activity 1

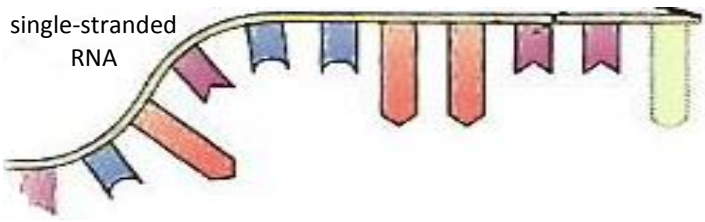
A.

1. They are structures within a cell that contain cell genetic information. They are located within the cell's nucleus.
2. The genes are made of a chemical called DNA. They are located along the length of each chromosome.
3. Genes control traits or characteristics of a particular organism.
4. In the chromosome of the nucleus.
5. a. Cytosine b. Guanine
   c. Adenine d. Thymine
6. Deoxyribose sugars, phosphate and nitrogenous bases.
7. i. A five-carbon sugar
   ii. A phosphate and
   iii. A nitrogenous base.
8. Because the DNA molecule is a double stranded molecule shaped-like a twisted ladder.
9. James Watson and Francis Crick.

B. A. genes B. chromosomes
C. alleles D. dominant

C. DNA is made of nucleotides that consist of sugar, phosphate, and nitrogenous base. The bases include adenine, guanine, cytosine, and thymine. DNA is shaped like a double helix and is the main component in chromosomes.

Learning Activity 2

1. RNA or ribonucleic acid is a single-stranded nucleic acid.
2. 

3. Matches RNA bases with the complementary bases on one strand of the DNA template.

4. Transfer RNA (tRNA) picks up amino acids and transfers them to a ribosome where they linked up to make proteins. Messenger RNA (mRNA) carries the copy of a gene to the ribosome.
5.

RNA	DNA
Single-stranded molecule	Double-stranded molecule
Base pairs: C-G and A-U	Base pairs: C-G and A-T

Learning Activity 3

A

1. i. a. Interhase b. Prophase
c. Metaphase d. Anaphase
e. Telophase f. Prophase 2
g. Metaphase 2 h. Anaphase 2
ii. Four (two pairs)
iii. Two (one of each homologous pair)
iv. Eight
2. i. Mitosis a process of cell division in which the nucleus of a cell divides into two identical daughter nuclei.
ii. Meiosis is a type of cell division in which the diploid number of chromosome is halved.
3. Mitosis is one cell division and occurs in asexual reproduction; two identical daughter cells with diploid number of chromosomes are produced. Meiosis is two cells division and occurs in sexual reproduction; four not identical daughter cells with haploid number of chromosomes are produced.

B. i. Chromatin
ii. Metaphase

Learning Activity 4

1. i. The scientific study of heredity. (The study of inherited characteristics passed from one generation to another generation.
ii. Transmission of genetically controlled characteristics from parents to their offspring.
2. a. Purebreed refers to any organism that receives the same genetic information from each parent. A hybrid refers to an organism that receives different genetic information for a trait from each parent.
b. Monohybrid cross involves parents differing in one pair of traits. Dihybrid cross involves parents differing in two pairs of traits.

3. parent pure breeding black rabbit (BB) x pure breeding white rabbit (bb)

gametes BB x bb

gametes	B	B
b	Bb	Bb
b	Bb	Bb

F_1 generation

Results:
Genotype ratios: All (100%) Bb
Phenotype ratios: All (100%) black

4. parent heterozygous black rabbit (Bb) x heterozygous black rabbit (Bb)

gametes Bb x Bb

gametes	B	b
B	BB	Bb
b	Bb	bb

F_1 generation

Results
Genotype ratios: 1BB: 2Bb: 1bb
Phenotype ratios: 1homozygous black: 2heterozygous black: 1homozygous white
or 3black: 1white
Ratios: 3 : 1

5. a parent RRWW x rrww

gametes RW RW RW RW rw rw rw rw

gametes	RW	RW	RW	RW
rw	RrWw	RrWw	RrWw	RrWw
rw	RrWw	RrWw	RrWw	RrWw
rw	RrWw	RrWw	RrWw	RrWw
rw	RrWw	RrWw	RrWw	RrWw

F_1

Results
Genotype ratios: All (100%) RrWw
Phenotype ratios: All (100%) seeds round and green coat colour

b. parent RrWw x RrWw

gametes RW Rw rW rw RW Rw rW rw

F_2

gametes	RW	Rw	rW	rw
RW	RRWW	RRWw	RrWW	RrWw
Rw	RRWw	RRww	RrWw	Rrww
rW	RrWW	RrWw	rrWW	wwWw
rw	RrWw	Rrww	rrWw	rrww

Results

Genotype ratios: 1RRWW:2RRWw: 2RrWW: 4RrWw: 1RRww: 2Rrww: 1rrWW: 2rrWw: 1rrww

Phenotype ratios: 9round, green: 3round, yellow: 3wrinkled, green: 1wrinkled, yellow.

Learning Activity 5

1. a. A gene is the unit of hereditary or sections of chromosome that represents a code or a trait.
   An allele is a distinct form of a gene.
   b. Dominant genes (alleles) often masked the other genes and are always expressed, shown or visible. Recessive genes are usually masked and are not often expressed or shown.
   c. Homozygous means having two identical genes for a given trait. Example: TT or tt. Heterozygous means having two different genes for a given trait. Example: Tt
2. A pure breed organism is one with identical genotype. It can be homozygous dominant (TT) or homozygous recessive (tt).
3. i. A genotype is the genetic makeup of an organism. Example are AA, Aa, BB, and Ba etc.
   ii. A phenotype is the characteristic or trait that is actually seen such as the colour of the skin, hair, eyes. ww
4. parent: pure black hair dominant (BB) x pure red hair recessive (bb)

   gametes: B B x b b

F_1

	B	B
b	Bb	Bb
b	Bb	Bb

   Results

   Genotype ratios: All Bb

   Phenotype ratios: All black. The offspring will have black hair colour.
5. a. Purple wings and green eyes are both dominant traits because they appear most often.
   b. Yellow wings and white eyes are both recessive traits they appear less often.
6. i. Aa is heterozygous dominant.
   ii. AA is homozygous dominant.
   iii. aa is homozygous recessive.

Learning Activity 6

1. a. The Law of Segregation states that each pair of genes is segregated or separated, during meiosis, and each gamete contains one gene from each gene pair.
   b. The law of independent assortment states that gene pairs segregated into gametes randomly and independently of each other.
2. a. Principle of segregation; the diploid organisms inherit a pair of genes for each trait.
   Two genes segregate from each other at meiosis, so each gamete formed after meiosis has an equal chance of receiving one of the other genes, but not both.
   b. Principle of independent assortment; each gene pair tends to assort (fit) into gametes independently of other gene pairs that are located on non-homologous chromosomes.
3. i. Mendel's first hypothesis; inherited characteristics are controlled by genes, which occur in pairs.
   ii. Mendel's second hypothesis; one gene in a pair may mask the other or prevent it from having an effect. That means it is hidden and cannot be seen.
   iii. Mendel's third hypothesis**;** a pair of genes is segregated during the formation of gametes in meiosis or law of segregation.

Learning Activity 7

1. Incomplete dominance is a pattern of inheritance in which two alleles (genes) in a heterozygous are partially expressed. Neither nor is dominant or fully expressed. Codominance is a pattern of inheritance in which both alleles in a heterozygous are fully expressed.
2. parent: group A mother (I^AI^A) x group B father (I^BI^B)

   gametes: $I^A\ I^A$ x $I^B\ I^B$

	I^A	I^A
I^B	I^AI^B	I^AI^B
I^B	I^AI^B	I^AI^B

Results
i. Genotype: All IAIB
ii. Phenotype: All are AB blood group.

3. a. Codominance

b. parents: Roan bull x Roan cow

gametes: C^BC^W x C^BC^W

C^B C^W C^B C^W

	C^B	C^W
C^B	C^BC^B	C^BC^W
C^W	C^BC^W	C^WC^W

Results:
Genotype ratio: $1C^BC^B$: $2C^BC^W$: $1C^WC^W$
Phenotype ratio: 1Black: 2Roan: 1White

4. a. homozygous black cat (BB) x homozygous black cat (BB)

male gametes

female gametes	**B**	**B**
B	BB	BB
B	BB	BB

Results
i. Genotype ratios: BB
ii. Phenotype ratios: All Black (Homozygous black)
iii. Ratios: 100%

b. Homozygous black cat (BB) x Heterozygous black cat (Bb)

male gametes

female gametes	**B**	**B**
B	BB	BB
b	Bb	Bb

Results
i. Genotype ratios: 2BB : 2Bb
ii. Phenotype ratios: 2 homozygous black : 2 heterozygous black

c. Heterozygous Black cat (Bb) x Heterozygous black cat (Bb)

male gametes

female gametes	**B**	**b**
B	BB	Bb
b	Bb	bb

Results

i. Genotype ratios: 1BB: 2Bb: 1bb
ii. Phenotype ratios: 3black: 1white.

Learning Activity 8

1. A feature or characteristic which is different within a species.
2. i. continuous
   ii. discontinuous
   iii. discontinuous
   iv. discontinuous

3. i. Inheritance: Inheritance is mostly influenced by genes.
   ii. Environment: Variations caused by environment may due to factors such as disease, lifestyle, and type of food eaten (nutrition).
4. The table indicates a form of inheritance that is influenced by environment.
5. A mutation is a random change to a gene or number of genes or a whole chromosome.
6. Mutations are caused by X-rays and ultraviolet radiations, chemicals and sudden rise in temperature.
7. The three main causes include
   i. Mistakes are made in copying DNA as cell gets ready to divide pairing with the incorrect base.
   ii. Damage is made to DNA. Some environmental factors can alter the bases present in the DNA.
   iii. Chromosomes are unevenly distributed during the cell division.

Learning Activity 9

1. i. Refers to the use of biochemical techniques to identify, study, and modify genes.
   ii. A DNA with components from different organisms.
   iii. A carrier of genetic material used in genetic engineering.
2. i. Viruses ii. Plasmids
3. The base sequence of the entire DNA in an organism.
4. A genome is the total genetic content of any cell in an organism.
5. Any of: Agriculture, Medicine, Industry, Law enforcement
6. A genetically engineered organism that has recombinant DNA from a species added to its genome.

Learning Activity 10

1. Asexually reproduced organisms which have arisen from the same parent.
2. Both produce offsprings which are identical to their parent organism or cell.
3. Process of using genetic engineering to make copies of genes.
4. i. Cloned blood cell can be used for transfusion
   ii. Cloned bone marrows be used to replace damaged by bone marrows
   iii. Cloned skins can be used for cosmetic surgery, cloned body tissues and organs can be used for transplant operation.
5. i. Cutting: many identical copies can be made from one plant cutting off parts of its shoots, leaf or root.
   ii. Tissue culture: involves separating cells in a piece of plant by placing it in an-enzyme containing liquid. When a cell is isolated and placed in a liquid containing growth hormone, it will divide and grow into a complete organism.

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FODE PROVINCIAL CENTRES CONTACTS

PC NO.	FODE PROVINCIAL CENTRE	ADDRESS	PHONE/FAX	CUG PHONE (COORDINATOR)	CUG PHONE (SENIOR CLERK)
1	ALOTAU	P. O. Box 822, Alotau	6411343/6419195	72228130	72229051
2	BUKA	P. O. Box 154, Buka	9739838	72228108	72229073
3	CENTRAL	C/- FODE HQ	3419228	72228110	72229050
4	DARU	P. O. Box 68, Daru	6459033	72228146	72229047
5	GOROKA	P. O. Box 990, Goroka	5322085/5322321	72228116	72229054
6	HELA	P. O. Box 63, Tari	73197115	72228141	72229083
7	JIWAKA	c/- FODE Hagen		72228143	72229085
8	KAVIENG	P. O. Box 284, Kavieng	9842183	72228136	72229069
9	KEREMA	P. O. Box 86, Kerema	6481303	72228124	72229049
10	KIMBE	P. O. Box 328, Kimbe	9835110	72228150	72229065
11	KUNDIAWA	P. O. Box 95, Kundiawa	5351612	72228144	72229056
12	LAE	P. O. Box 4969, Lae	4725508/4721162	72228132	72229064
13	MADANG	P. O. Box 2071, Madang	4222418	72228126	72229063
14	MANUS	P. O. Box 41, Lorengau	9709251	72228128	72229080
15	MENDI	P. O. Box 237, Mendi	5491264/72895095	72228142	72229053
16	MT HAGEN	P. O. Box 418, Mt. Hagen	5421194/5423332	72228148	72229057
17	NCD	C/- FODE HQ	3230299 ext 26	72228134	72229081
18	POPONDETTA	P. O. Box 71, Popondetta	6297160/6297678	72228138	72229052
19	RABAUL	P. O. Box 83, Kokopo	9400314	72228118	72229067
20	VANIMO	P. O. Box 38, Vanimo	4571175/4571438	72228140	72229060
21	WABAG	P. O. Box 259, Wabag	5471114	72228120	72229082
22	WEWAK	P. O. Box 583, Wewak	4562231/4561114	72228122	72229062

FODE SUBJECTS AND COURSE PROGRAMMES

GRADE LEVELS	SUBJECTS/COURSES
Grades 7 and 8	1. English
	2. Mathematics
	3. Personal Development
	4. Social Science
	5. Science
	6. Making a Living
Grades 9 and 10	1. English
	2. Mathematics
	3. Personal Development
	4. Science
	5. Social Science
	6. Business Studies
	7. Design and Technology- Computing
Grades 11 and 12	1. English – Applied English/Language& Literature
	2. Mathematics – General/Advance
	3. Science – Biology/Chemistry/Physics
	4. Social Science – History/Geography/Economics
	5. Personal Development
	6. Business Studies
	7. Information & Communication Technology

REMEMBER:

- For Grades 7 and 8, you are required to do all six (6) subjects.
- For Grades 9 and 10, you must complete five (5) subjects and one (1) optional to be certified. Business Studies and Design & Technology – Computing are optional.
- For Grades 11 and 12, you are required to complete seven (7) out of thirteen (13) subjects to be certified.

Your Provincial Coordinator or Supervisor will give you more information regarding each subject and

Notes: You must seek advice from your Provincial Coordinator regarding the recommended courses in each stream. Options should be discussed carefully before choosing the stream when enrolling into Grade 11. FODE will certify for the successful completion of seven subjects in Grade 12.

GRADES 11 & 12 COURSE PROGRAMMES			
No	**Science**	**Humanities**	**Business**
1	Applied English	Language & Literature	Language & Literature/Applied English
2	Mathematics -General/Advance	Mathematics -General/Advance	Mathematics –General/Advance
3	Personal Development	Personal Development	Personal Development
4	Biology	Biology/Physics/Chemistry	Biology/Physics/Chemistry
5	Chemistry/ Physics	Geography	Economics/Geography/History
6	Geography/History/Economics	History / Economics	Business Studies
7	ICT	ICT	ICT

REMEMBER:

You must successfully complete 8 courses: 5 compulsory and 3 optional.

CERTIFICATE IN MATRICULATION STUDIES		
No	**Compulsory Courses**	**Optional Courses**
1	English 1	**Science Stream:** Biology, Chemistry, Physics
2	English 2	**Social Science Stream:** Geography, Intro to Economics and Asia and the Modern World
3	Mathematics 1	
4	Mathematics 2	
5	History of Science & Technology	