# CELL DIVISION AND GENETICS

## CELL DIVISION

This refers to the process by which cells give rise to new cells

All living things are made up of cells. Even the life of a multicellular organism starts as a single cell (Gamete). Gametes fuse to form a zygote which undergoes successive cell divisions to develop into a multicellular organism.

The process of cell division is **controlled by the nucleus**. Actually it starts with division of the nucleus and then the whole cell divides. The nucleus contains the genetic material called DNA (Deoxyribonucleic Acid) which controls all cellular activities including the process of cell division. DNA occurs in form of threadlike structures called chromosomes. It is on these chromosomes that genes are located. Each gene is responsible for a specific characteristic of the organism. E.g. skin colour, height, sex, blood group etc.

In each cell, chromosomes occur in pairs. Pairs of identical (similar) chromosomes are called homologous chromosomes. These carry genes determining similar characteristics. The total number of chromosome pairs in a cell is called the haploid number (n). The total number of chromosomes in a cell is called the diploid number and is given by twice the haploid number (2n). The haploid and diploid numbers are the same for all cells in the body of an organism but differ among organisms of different species as shown below.

| Organism | Haploid number (n) | Diploid number (2n) |
|---|---|---|
| Man | 23 | 46 |
| Rat | 19 | 38 |
| Maize | 10 | 20 |
| Peas | 07 | 14 |
| Mosquito | 03 | 06 |

## THE CELL CYCLE

This refers to the sequence of events between two successive divisions of the cell. It involves growth of the cells, division of the genetic material and then the whole cell

**Types of cell division**

There are two types of cell division

- Mitosis
- Meiosis

## MITOSIS

This is the division of a cell to form **2 daughter cells** with the **same number of chromosomes** as the parent cell. The cells are genetically identical to each other and to the parent cell

Mitosis can also be defined as the division of the cell to form 2 daughter cells with the same amount of the genetic material as the parent cell

**Stages of mitosis**

The process of mitosis is divided into 5 sequential stages as follows:

- Interphase
- Prophase
- Metaphase
- Anaphase
- Telophase

INTERPHASE

This is the first and longest stage of the cell cycle. It involves growth of the cell and formation of materials needed for cell division. It involves the following events:

- Formation of cell organelles like mitochondria
- The cell grows rapidly and increases in size
- Formation of large energy stores (for use during cell division)
- Replication of DNA
- Chromosomes appear as tinny threadlike structures

PROPHASE

- Chromosomes shorten and thicken (condense)
- They appear as a pair of (two) chromatids joined at the centromere
- Centrioles move to opposite poles, spindle fibre formation starts
- Later, the nucleolus disappears and the nuclear membrane disintegrates (Breaks down)

METAPHASE

- Spindle fibres are fully formed
- Chromosomes line up at the spindle equator
- Each chromosome is attached to spindle fibres by the centromere
- Later in metaphase, sister chromoatids begin to separate

ANAPHASE

- Sister chromatids separate completely and rapidly move to opposite poles of the spindle apparatus
- Anaphase ends when the chromatids (now chromosomes) reach their destination

TELOPHASE

- Chromosomes reach their destination
- Spindle fibres disintegrate, chromosomes lengthen and became threadlike again
- Nuclear membrane forms around each set of chromosomes and nucleolus reappears
- The cell membrane constricts by the middle forming 2 daughter cells
- In plant cells, the daughter cells are separated by formation of the cell plate (Cell wall is rigid)

NB: Cells formed by mitosis are identical to the parent cell and to each other in terms of number of chromosomes and genes present

SQ: Where in organisms does mitosis occur?

In animals, mitosis occurs in body cells (somatic cells). In plants, mitosis occurs in meristems (Growing points at the tip of roots and shoots). It leads to formation of new body cells

*Significance (importance) of mitosis*

- It leads to growth by adding new cells to the body
- Mitosis leads to repair of damaged body tissues. In case of damage, epithelial cells show rapid mitotic division to replace the worn out cells
- It is a form of asexual reproduction in unicellular organisms. This is because mitosis leads to formation of new individuals
- Mitosis ensures genetic stability among all body cells. This is because daughter cells are genetically identical to the parent cell

NB: Some cells become so specialised that they can no longer divide to form new cells. This explains why specialised tissues like the brain are not capable of regeneration in case of damage.

## MEISOSIS

This is the division of a cell to form **4 haploid daughter** cells that are **genetically different** from each other and from the parent cell.

Meiosis involves two successive divisions following a single replication of DNA; these are **meiosis I and Meiosis II.** Each of the first and second meiotic divisions involves five sequential stages: **Interphase, prophase, metaphase, anaphase and telophase.**

### *MEIOSIS I*

This involve five sequential stages

- Interphase I
- Prophase I
- Metaphase I

- ✓ Anaphase I
- ✓ Telophase I

INTERPHASE I

It involves the following events:

- ✓ Formation of cell organelles like mitochondria
- ✓ The cell grows rapidly and increases in size
- ✓ Formation of large energy stores (for use during cell division)
- ✓ Replication of DNA
- ✓ Chromosomes appear as tinny threadlike structures

PROPHASE I

- ✓ Chromosomes shorten and thicken
- ✓ Each chromosome appears as a pair of chromatids joined by the centromere
- ✓ Homologous chromosomes pair up to form bivalents. The process of pairing of homologous chromosomes is called synapsis
- ✓ Crossing over occurs.
- ✓ Later in prophase I, centrioles move to opposite poles, and begin to form spindle fibres
- ✓ The nucleolus disappears and nuclear membrane disintegrates.

NB: Crossing over refers to the exchange of the genetic material between homologous chromosomes. It occurs at points of interaction called chiasmata (Singular; Chiasma)

METAPHASE I

- ✓ Spindle fibres are fully formed
- ✓ The bivalents line up at the spindle equator, being attached by the centromeres
- ✓ Later homologous chromosomes begin to separate

ANAPHASE I

- ✓ Homologous chromosomes separate and rapidly move to opposite poles
- ✓ Anaphase ends when the chromosomes reach their destination

TELOPHASE I

- Chromosomes reach their destination
- Spindle fibres disintegrate
- Chromosomes un coil and lengthen to become threadlike again
- Nuclear membrane forms around each set of chromosomes, and nucleolus reappears
- The cell membrane constricts by the spindle equator, leading to formation of 2 daughter cells. These undergo a second meiotic division to form 4 daughter cells

MEIOSIS II

This occurs in the same way as mitosis, and involves the same steps which include Interphase II, Prophase II, Metaphase II, Anaphase II and Telophase II

*In summary, these are the characteristic features of meiosis*

- Four daughter cells are produced
- Daughter cells are haploid
- It involves 2 phases of successive division following one replication of DNA
- Crossing over occurs
- It leads to genetic variation
- There is pairing of homologous chromosomes
- Occurs in gamete producing organs

Significance of meiosis

- It forms the basis for sexual reproduction by formation of gametes
- Meiosis leads to variation in organisms
- It maintains a constant number of chromosomes from generation to generation. This is because meiosis halves the number of chromosomes in gametes such that fusion of gametes restores the diploid number in the zygote.

NB: Meiosis leads to variation through crossing over and independent assortment of chromosomes. This explains why gametes are genetically different from each other and from the parent cell

*S.Q; where does meiosis occur?*

Meiosis occurs in reproductive organs leading to formation of gametes (which are haploid and genetically different). In plants it occurs in anthers and ovaries while in animals meiosis occurs in testes and ovaries.

COMPARING MEIOSIS AND MITOSIS

Similarities

- Both involve replication of DNA
- Both involve condensing (constriction) of chromosomes
- Both involve formation of spindle fibres
- Mitosis and meiosis involve the same stages; Interphase, prophase, metaphase, anaphase and telophase.

Differences

| Mitosis | Meiosis |
|---|---|
| 2 daughter cells | Produces 4 daughter cells |
| Produces diploid cells | Produces haploid cells |
| Mitosis involves one division phase | Involves 2 phases of division |
| Daughter cells are genetically identical (No genetic variation ) | Daughter cells are genetically different (Causes genetic variation) |
| There is no crossing over | Crossing over occurs |
| There is no chiasmata formation | Chiasmata are formed |
| No pairing of homologous chromosomes | Homologous chromosomes pair up |

Genetics refers to the study of inheritance

It is a branch of science that explains resemblance among organisms of the same species and explaining the causes of variation among organisms of the same species

NB: The term inheritance refers to the process by which characters are passed from parents to offsprings

## TERMS USED IN GENETICS

*Gene*

A gene is the basic unit of inheritance. An organism has many genes located on chromosomes and each gene determines a specific characteristic in the organism; e.g. height, skin colour, blood group etc.

*Locus*

This refers to the position/location of a gene on the chromosome

*Linkage*

This is when 2 or more genes are located on the same chromosome. Such genes are called linked genes and their respective characteristics are called linked characters/traits.

Usually each chromosome has several genes just like beads on a thread.

*Alleles*

Alleles are alternative forms of a gene. Each gene is known to occur in pairs, each on one of the homologous chromosomes. Alleles may be dominant or recessive and maybe represented by alphabetical letters

*Dominant gene/allele*

This is a gene whose character is expressed even in presence of a different gene. Such alleles are represented by capital letters

*Recessive gene/allele*

This is a gene whose character cannot be expressed in presence of a different gene. They are only expressed in a homozygous recessive state

*Genotype*

It refers to the genetic makeup of an organism. This is determined at fertilisation and is independent of the environment. The genotype of an organism may be homozygous or heterozygous

*Homozygous genotype*

This is when an organism has identical alleles for a given gene. E.g. TT, AA, bb etc

*Heterozygous* genotype

This is when an organism has different alleles for a given gene. E.g. Tt, Aa, Bb etc

*Phenotype;*

This is the physical appearance of an organism. It depends on the interaction of both genotype and the environment. E.g. Tall, black, female

A pea plant which is homozygous tall (genotype TT) but growing on nutrient-poor soil will become stunted and appears short. Such a plant is genotypically tall but the environment in which it grows modified it into a phenotypically short/dwarf plant.

*Pure breeding (true breeding)*

This refers to individuals that are homozygous for a given character (trait)

*Crossing (X).*

This refers to the mating of the male and female organisms under a consideration. It is indicated by a cross (X)

*First filial generation ($F_1$)*

This refers to the set of offsprings obtained from crossing two pure breeding parents.

*Second filial generation ($F_2$)*

This refers to the set of off springs that are obtained by crossing mature $F_1$ hybrids.

## MENDEL'S GENETIC EXPERIMENTS AND

## MONOHYBRID INHERITANCE

**Monohybrid inheritance** refers to the inheritance of a single pair of contrasting characteristics. Examples include inheritance of height, blood groups, albinism, sickle cell anaemia etc.

The mechanism of inheritance was discovered by Gregor Mendel who performed several experiments using garden peas.

*Why Mendel used garden peas*

- They occurred in many varieties with distinct characters

- The plants were easy to cultivate
- All their offsprings were fertile
- They have a short life cycle that they reproduced so quickly
- The plants also had many contrasting characters with no intermediates

<u>Mendel's experiments</u>

In one of his experiments, Mendel crossed **tall pea plants** with **dwarf pea plants** (by cross pollinating them). The resultant seeds were planted and he observed that all the $F_1$ off springs were tall.

He then self pollinated (selfed) the $F_1$ pea plants to get $F_2$. This generation comprised of **a mixture of tall and short** pea plants in a ratio of **3 tall: 1short plants**.

**NB**: The **3:1** ratio is known as Mendel's monohybrid ratio of the dominant and recessive characters respectively in the $F_2$ generation.

**Mendel observed that neither of the $F_1$ nor $F_2$ generations had intermediate phenotypes.**

He then concluded that inheritance does not involve mixing characters to produce intermediates. It rather involves certain internal factors which may or may not be expressed in the phenotype. These internal factors are currently called **genes** which may or may not be expressed depending on whether they are dominant or recessive.

**Mendel's first law of inheritance**

From his conclusions, Mendel was able to formulate his first law of inheritance which is well known as the law of monohybrid inheritance/law of segregation/law of particulate inheritance

It states that "***The characteristics of an organism are controlled by alleles which occur in pairs but singly in gamete".***

**Explanation:**

Each characteristic in organisms is determined by a gene which occurs in two forms called alleles. These alleles are located on homologous chromosomes which separate during meiosis such that each gamete gets only one.

This can be explained by a genetic cross which also explains the 3:1ratio as follows.

**Let;**

*T represent the allele for tallness, t represents the allele for shortness*

| | | | | |
|---|---|---|---|---|
| *Parents* | : | male | x | female |
| *Phenotypes* | : | Tall | x | short |
| *Genotypes* | : | TT | x | tt |
| *Meiosis* | | | | |
| *Gametes* | | T   T | | t   t |
| *Random fertilization* | : | | | |
| *$F_1$ genotypes* | : | Tt   Tt | | Tt   Tt |

Genotypic ratio : All Tt, Phenotypic ratio : All tall

To obtain $F_2$ generation, $F_1$ hybrids were selfed as shown below

**Let;**

*T represent the allele for tallness, t represents the allele for shortness*

| | | | | |
|---|---|---|---|---|
| *Parents* | : | male | x | female |
| *Phenotypes* | : | Tall | x | tall |
| *Genotypes* | : | Tt | x | Tt |
| *Meiosis* | | | | |
| *Gametes* | | T   t | | T   t |
| *Random fertilization* | : | | | |
| *$F_2$ genotypes* | : | TT   Tt | | Tt   tt |

Genotypic ratios : 1TT : 2Tt : 1tt; Phenotypic ratios : 3tall : 1Short

**Note; for any genetic cross:**

- Appropriate letters are 'let' to represent respective alleles involved
- A cross(X) must be indicated to symbolize mating between the parents
- Directive words must be indicated to define each step of the cross
- In case of identical gametes, only one can be indicated

EXAMPLES

1. In a garden pea plant there are two forms of heights. When a pure breeding tall pea plant was crossed with a short pea plant all the offsprings obtained where tall

   a. Using suitable genetic symbols, workout the genotypes and phenotypes of the $F_1$ and $F_2$ generations

   b. What are the phenotypic and genotypic ratios of the $F_2$ generation

   c. Suppose 700 pea plants where produced in the $F_2$ generation

      i. How many were tall?

      ii. How many were short?

2. Suppose a man who is a tongue roller marries a woman who is a non-tongue roller and all the children obtained in $F_1$ are tongue rollers.

   (a) Work out the phenotypic and genotypic ratio as obtained in $F_2$ generation.

   What is the probability that any child produced in a tongue roller

**NB:** It became so obvious to predict which trait of a given pair is dominant over the other. In a cross starting with pure breeding parental stocks, all the $F_1$ hybrids show the dominant trait. In addition, a larger proportion of the $F_2$ hybrids show the dominant trait while those showing the recessive one are always fewer.

In case of individuals showing the dominant trait (as phenotype), the genotype may either be **homozygous dominant or heterozygous**. Such genotypes can be distinguished by performing **a test cross**; that is, crossing the unknown with a homozygous recessive individual.

**Dfn: a test cross is a cross between an organism whose genotype is not known with a homozygous recessive organism to determine the un known genotype**.

If the unknown is homozygous, the resultant hybrids will all show the dominant trait but otherwise, a mixture of dominant and recessive traits are produced in a ratio of 1:1

In a test cross, a homozygous dominant individual cannot be used because in such a case; regardless of the unknown genotype, all the resultant hybrids would show the dominant trait

Example

When a pure breeding tall pea plant was crossed with a short pea plant all the offsprings obtained where tall.

(a) Using suitable genetic symbols, explain these results.

(b) Show the expected results of a test cross if carried out on the $F_1$ above

## EXAMPLES OF MONOHYBRID INHERITANCE IN MAN

There are many genetically determined abnormalities and diseases that affect man. Since these are genetic diseases, they can only be inherited from parents and their occurrence is determined by those genes inherited from parents during fertilization

Examples of such diseases include:

- Sickle-cell anaemia
- Albinism
- Achondroplasia
- Cystic fibrosis and many more

NB: Research has showed that all the genetic abnormalities are caused by recessive genes (alleles) and the genes responsible for normal conditions are dominant. This implies that for an individual to suffer from such diseases, they must be homozygous recessive for the trait. The heterozygotes and the homozygous dominant individuals are normal. Though the heterozygous individuals are phenotypically normal, their cells contain a copy of the recessive allele and are described as **carriers**

### Inheritance of sickle-cell anaemia

Sickle-cell anaemia is a recessive character that leads to formation of abnormal haemoglobin in red blood cells. This haemoglobin (usually called Haemoglobin S) forms crystals which distort the shape of red blood cells from the normal biconcave to a crescent (sickle) shape; hence its name. The abnormal haemoglobin in sickle-shaped red blood cells is carries very little oxygen leading to symptoms of anaemia.

The table below shows the possible genotypes and the corresponding phenotypes.

*Let A represent the gene for normal haemoglobin, a represent abnormal haemoglobin*

| Genotype | Phenotype |
|---|---|
| AA | Normal |
| Aa | Normal |
| aa | Sick |

Example

If two people are heterozygous for sickle cell anaemia, what is the probability that they will produce an anaemic child? Which portion of their children may be carriers?

### Complications due to sickle cell anaemia

- Fatigue (weakness)
- Poor physical development

- ✓ Dilation of the heart which may lead to heart failure
- ✓ Liver damage
- ✓ Enlargement of the spleen because the sickle cells collect in the spleen for destruction

The effects above make the homozygous sufferers to often die before reproductive age.

Inheritance of albinism

Albinism is a recessive character which leads to failure of formation of body pigments.

Albinos have the following characteristics as a result;

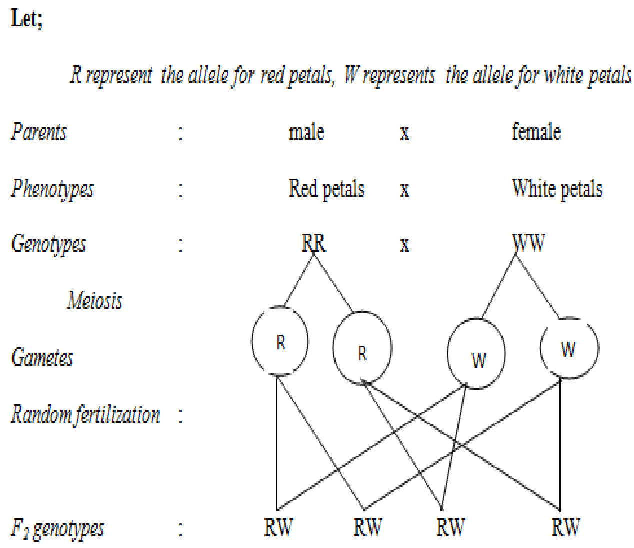
- Light-coloured skin
- White hair
- Pink eyes

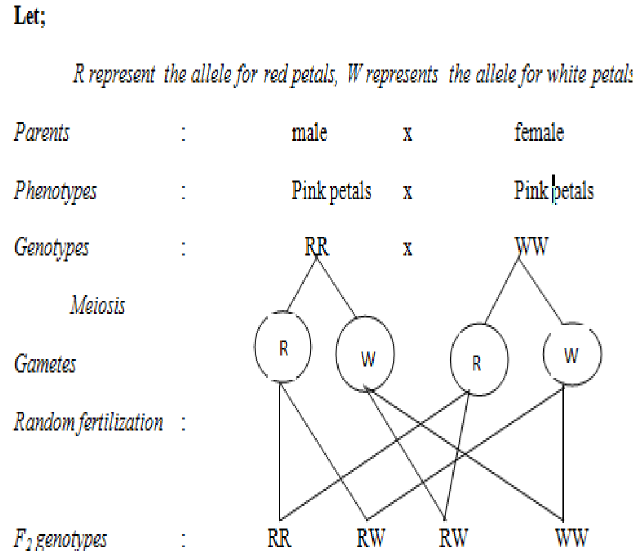
SQ; man with normal skin marries a carrier for albino skin. What is the probability that some of their children will be albinos?

## EXCEPTIONS TO MENDEL'S LAW

It should however be noted with concern that the Mendel's 3:1 ratio of monohybrid inheritance may not be obtained for crosses involving some characteristics. Such characteristics that do not give the 3:1 ratio of phenotypes in the $F_2$ are described as exceptions to Mendel's first law of inheritance.

*Incomplete dominance and codominance*
**Complete dominance** is when dominant allele is **fully dominant** over the recessive allele; heterozygous individuals show the dominant character only.
In some cases however, neither or both of the two alleles may be fully dominant over the other, this is called incomplete and codominance respectively.
**Incomplete dominance**
This is when none of the alleles is dominant over the other such that their phenotypes **blend (mix) to produce an intermediate**.
When red snapdragon plants are crossed with plants having white flowers, all the $F_1$ hybrids have pink flowers, while $F_2$ hybrids produced **1red: 2pink:1white** plants as shown below.
**Note:** Given that both alleles of the same gene are dominant, we let a single letter for the gene and alleles attached as superscripts. I.e. $C^R$ and $C^W$ or simply R and W represent alleles for red and white petals respectively.



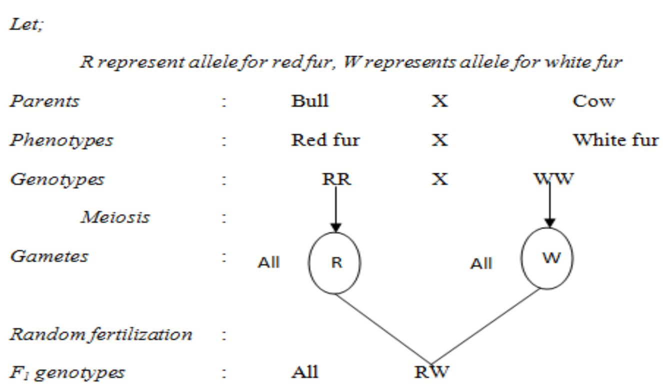

Other examples of incomplete dominance include:

| Characteristic | Allelomorphic characteristics | Heterozygous phenotype |
|---|---|---|
| Mirabilis Japalla (4-oclock plant) | Red and White | Pink |
| Angora rabbit hair length | Long and short | Intermediate |
| Plumage colour in domestic fowls | Black and white | Blue |

## Codominance

This is when both alleles are fully dominant such that their phenotypes are independently produced.

During the inheritance of fur/coat colour in short-horned cattle, when red and white cattle are mated, the $F_1$ hybrid has white fur thickly interspersed with red fur. This phenotype is referred to as **roan**




## Multiple alleles

These are three or more forms of the same gene.

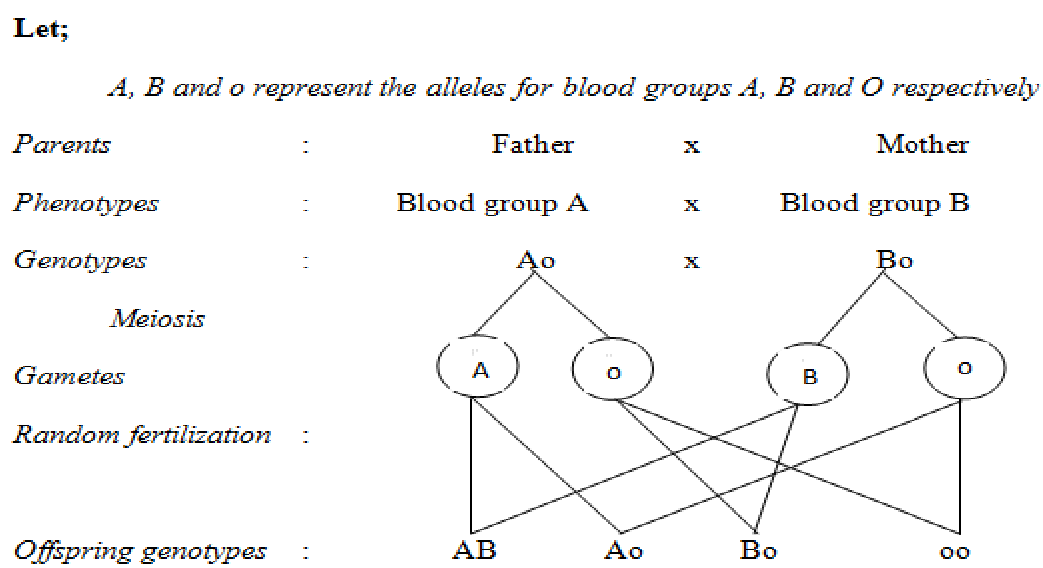
In Mendelian inheritance, genes are known to occur in two alternative forms. Some genes are known to occur in more than two allelic forms **called multiple alleles.** A common example is the gene responsible for blood groups in man.

The gene for human blood group is known to occur in three allelic forms; A, B and o. Alleles A and B are codominant while o is recessive to both. This is known as the ABO blood grouping system, with three alleles producing six possible genotypes and four phenotypes as follows.

| Blood group | Possible genotypes |
|---|---|
| A | Ao, AA |
| B | Bo, BB |
| AB | AB |
| O | Oo |

**Sample question**: The father and a mother are known to be heterozygous for blood groups A and B. Show the possible genotypes of their children. What is the probability of producing a child with blood group A

Solution




Offspring phenotypes: Blood groups AB, A, B and O

Probability for a child with blood group A = ¼

Example:

Work out the possible blood groups of the offsprings produced if a man of blood group A marries a woman of blood group AB

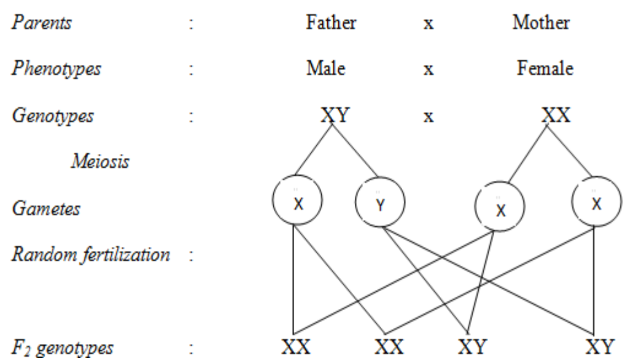
<u>SEX DETERMINATION IN MAN</u>

In man, there are 23 pairs of chromosomes; of these only one pair carries genes for sex determination. These are called sex chromosomes **(heterosomes)** designated X and Y, and the other 22 pairs are called **autosomes**.

*How is sex determined?*

In man, the genotype XX produces a female whose gametes therefore contain X. Genotype XY is male whose gametes may contain X or Y. During fertilization, the sex of the offspring is determined by which of the X or Y chromosome is present in the sperm. A sperm carrying an X chromosome fuses with the ovum to form XX which is female while a sperm carrying a Y chromosome would fuse with the ovum to produce XY which is male.

Illustration:




Genotypic ratios: 1XX: 1XY

Phenotypic ratios: 1female: 1male

This shows that there is a 50% chance of any child being a male or female

Sex linkage:

This is a condition when genes that are not involved in sex determination are carried on sex chromosomes.

Sex linked genes therefore are genes carried on sex chromosomes. The traits determined by such genes are called sex linked traits

Examples of sex linked characters in man include

- Haemophilia
- Colour blindness
- Pre-mature balding

NB: Just like other genetically determined disorders, Haemophilia and colour blindness are determined by recessive genes.

It should also be noted that all sex linked genes are carried on the X sex chromosome but not the Y chromosome. The Y chromosome does not carry genes and is said to be genetically inert. These genes are represented as superscripts on the X chromosome; E.g. $X^a$, $X^B$ etc.

Given that females have 2 X chromosomes, they may be normal, carriers (Heterozygous) or sick. Males have one X chromosome and are either normal or sick

Haemophilia (bleeders' disease)

Haemophilia is a recessive sex-linked disorder that leads to prolonged bleeding even from minor cuts. This usually results from inability of the body to produce the necessary blood clotting factors which interferes with the process of blood clotting.

Just like other sex-linked traits, haemophilia is carried on the X chromosome and caused by a recessive gene

**Example:** When a carrier woman is married to a normal man

**Let;**

*H represent the allele for normal blood clotting, h represents the allele for haemophilia*

| | | | | |
|---|---|---|---|---|
| *Parents* | : | Female | x | Male |
| *Phenotypes* | : | Normal | x | Normal |
| *Genotypes* | : | $X^HX^h$ | x | $X^HY$ |
| *Meiosis* | | | | |
| *Gametes* | | $X^H$ $X^h$ | | $X^H$ $Y$ |
| *Random fertilization* | : | | | |
| *$F_1$ genotypes* | : | $X^HX^H$ $X^HY$ | | $X^HX^h$ $X^hY$ |

NB: Sons can only inherit haemophilia (and other sex linked traits) from their mothers but not fathers as they only inherit the father's Y chromosome and not the X chromosome that carries sex linked genes. Girls can inherit from both parents.

Today, people with hemophilia are treated as needed with intravenous injections of the missing protein.

<u>Colour blindness</u>

It is a recessive sex linked character that leads to inability of the individual to distinguish between colours. This usually results from absence of some cones in the retina, which responsible for colour vision.

Example

A man who is colour blind married to a woman with normal colour vision. Show the phenotypic ratios of their children

SEX LIMITED CHARACTERISTICS

Se limited characters are characters that are more pronounced in one sex than the other.

Though both sexes may carry genes responsible for these characteristics, pronounced expression is strictly limited to one of the two sexes. They are usually carried on autosomes but may largely be influenced by the level of sex hormone in the body.

Examples include;

Facial hair, deep voice, baldness etc in males

Breasts, lactation, widening of hip bones, high pitched sound etc in females

# VARIATION

Variation refers to the differences in the characteristics shown by organisms of the same species.

Organisms belonging to the same natural population **(same species)** would be expected to exhibit general similarity in their structural, physiological and biochemical characteristics but this is never the case; differences always occur even in identical twins and these are collectively referred to as **variation**.

TYPES OF VARIATION

There are two types/forms of variation, namely

- Continuous variation
- Discontinuous variation

**Continuous variation**

This is the occurrence of differences among organisms of the same species with no clear cut, hence producing intermediates.

Continuously varying characteristics have the following features:

- They are measurable hence described as quantitative characteristics
- They show intermediates
- There is no clear cut among organisms
- Such characters are much affected by the environment
- They are usually determined by many genes (poly genes)

**Examples include** height, weight, intelligence, size etc.

Given their quantitative (measurable) nature, the results of a large population represented on a frequency distribution curve usually produce a normal distribution curve as shown below.

The normal distribution curve shows that most human beings show intermediate height with only a few individuals being very tall or very short.

Discontinuous variation

This is the occurrence of differences among organisms of the same species with clear cuts hence producing no intermediates.

Features/characteristics of discontinuous variation

- ✓ Organisms show clear cuts hence no intermediates formed
- ✓ They are usually determined by only one gene
- ✓ They are not affected by environment
- ✓ Such characteristics cannot be measured hence described as qualitative characters

Examples include blood groups, sex, eye color, petal color in plants etc.

Given their discontinuous variability, such characteristics can only be represented in form of bar graphs or even pie charts but not frequency curves.

## SOURCES OF VARIATION

The ultimate (fundamental) factor that determines the phenotype is the genotype. However, the subsequent degree of expression is greatly influenced by environmental factors during growth and development of the organism.

The sources of variation are therefore both environmental and genetic.

Environmental sources of variation

This is when organisms of the same species show differences in their characteristics due to differences in their environments. Such factors include temperature, light intensity, food supply, water supply social environment etc.

Genetic sources of variation

This is when organisms of the same species show differences in characteristics due to differences in their genetic makeup (Constitution)

Causes of genetic variation

The causes of genetic variation mainly include

- ✓ Crossing over

- Independent assortment
- Random fusion of gametes
- Mutations

**Crossing over**

This refers to the reciprocal exchange of the genetic material between homologous chromosomes. It occurs during prophase I of meiosis during cell division.

Crossing over leads to new gene combinations along the chromosomes which lead to genetic variation in gametes

**Independent/random assortment of chromosomes**

The random alignment of homologous chromosomes leads to many gene combinations in gametes which leads to genetic variation.

**Random fusion of gametes (fertilisation)**

During fertilization, fusion of male and female gametes leads to mixing of genes from both parents which leads to genetic variation in the zygote.

## MUTATIONS

A mutation is a sudden/spontaneous change in the structure or amount of DNA of an organism.

*Causes of mutations*

Mutations usually happen spontaneously without a specific cause. The occurrence can be increased by environmental factors which are called mutagenes.

Mutagenes are substances which induce mutations in cells. Examples include the following:

- Chemicals like formaldehyde and some food preservatives
- High energy particles like alpha and beater particles
- High energy radiations like X-rays, gamma radiations, ultra violet and cosmic radiations
- Viral infections like hapes
- Some pesticide like DDT, Mustard gas

*Characteristics of mutations*

- Mutations are spontaneous; they can occur suddenly at any time.
- Mutations are recessive; the mutant alleles are recessive to the normal forms of the genes
- They are usually disadvantageous; most mutations interfere with normal body function

hence exerting negative effects onto the organism. Some mutations are lethal and lead to death of the organisms. Some few mutations can be advantageous though less frequently.

- They are permanent/persistent; a mutation once occurred may stay in the population for very many generations without change.
- Mutations are rare; they do not occur regularly

TYPES OF MUTATIONS

- ✓ Gene mutations
- ✓ Chromosome mutations

GENE MUTATIONS (Point mutations)

This refers to change in the structures of DNA at a single point/locus.

Types of gene/point mutations

- Deletion; this is where a gene is completely lost from DNA
- Substitution; the replacement of one gene with a different one
- Insertion (addition); the addition of one gene into the DNA strand
- Duplication; this is where a gene is repeated
- Inversion; the reversal of two or more genes in DNA

Chromosomal mutations (chromosome abberations)

These involve change in the structure of chromosomes

Chromosomal mutations include;

- Deletion; this involves total loss of a portion(s) from a chromosome. Such a mutation will lead to shortening of chromosomes.
- Substitution; involves replacement of chromosome portions with different ones
- Insertion; the addition of portions into the chromosomal strand
- Duplication; is where the gene sequence of a chromosomal portion is repeated
- Inversion; this is when the sequence of genes on a chromosome is reversed.
- Translocation; a chromosomal portion breaks and joins another chromosome.

THE END

*bmw*