CELL DIVISON

Cell division refers to the division of the nucleus and cytoplasm of a cell to form daughter cells.

There are two types of cell division:

- Mitosis
- Meiosis

MITOSIS

This is the type of cell division in which **two daughter cells** are formed and each has the same number of chromosomes as the parent cell.

A chromosome is a long rod-like structure that appears at cell division in a nucleus and is thought to carry hereditary material (genes).

The daughter cells formed during mitosis are the same when compared to each other and to the parent.

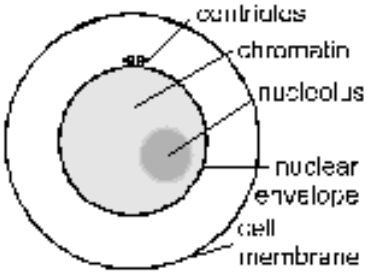
Stage involved in mitosis

There are five stages involved in mitosis:

- **I**nterphase
- **P**rophase
- **M**etaphase
- **A**naphase
- **T**elophase

NB: for simplicity the process can be abbreviated as **IPMAT**

A. Interphase



During Interphase, the following occurs;

- The chromosomes are long and invisible
- The cell stores enough energy in form of ATP
- New cell organelles (cell parts) are formed

NB. Interphase is sometimes referred to as the *resting stage*.

B. Prophase

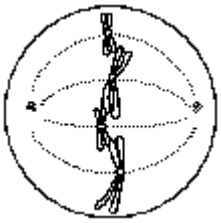
During prophase, the following occurs;

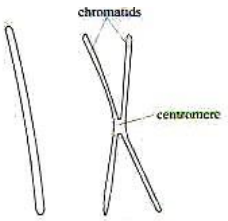
- The centrioles begin to separate and the spindle form between them
- The chromosomes become short, thick and visible
- The nuclear membrane disintegrates
- The nucleolus disintegrates
- Each chromosome is seen to consist of two **chromatids**

C. Metaphase

During metaphase, the following occurs;

- The centrioles move to opposite ends of the cell
- The chromosomes **replicate** (form exact copies of themselves) but remain in contact along the entire length.
- Chromosomes arrange themselves on the equator of the spindle fibres

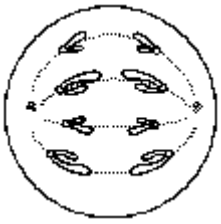




D. Anaphase

During anaphase, the following occurs;

- The two chromatids separate at the centromere
- Each chromatid moves to an opposite pole of the cell

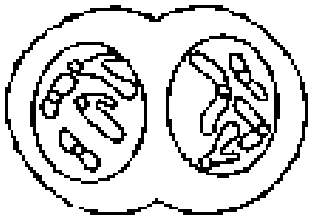
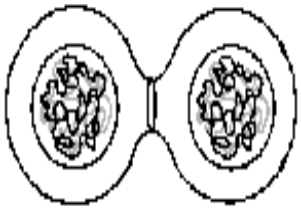
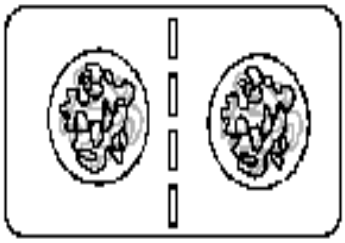


E. Telophase

- The spindle fibre disintegrates
- The chromatids become long, thin and hence they become chromosomes of the daughter cells
- A nuclear membrane forms around each group of chromosomes

- The cytoplasm divides and two daughter cells are formed

NB: at the end of telophase, each daughter cell goes into the *resting stage called interphase*.

IMPORTANCE/SIGNIFICANCE OF MITOSIS

1. Mitosis provides the basis for sexual reproduction
2. It brings about repair and replacement of damaged cells
3. Mitosis leads to growth of the organism due to increased number of cells
4. It ensures that all cells in the body are genetically identical i.e. daughter cells resemble parent cells

NB: Mitosis occurs in all cells of the body apart from the gamete producing cells

MEIOSIS

This is the type of cell division resulting into formation of **four daughter cells** each having half of the number of chromosomes of the parent cell.

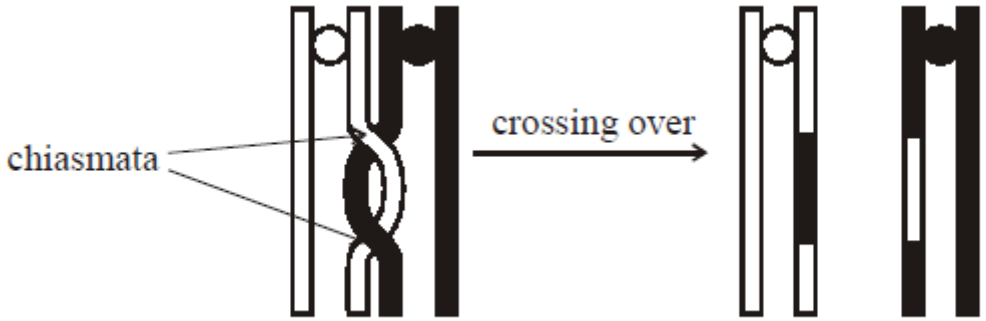
Meiosis occurs in cells that produce gametes i.e. it occurs in organisms that carryout sexual reproduction.

- In animals it occurs in the **testis** during sperm formation and in **ovaries** during ova formation
- In plants, it occurs in the **anthers** during formation of pollen grains and in **ovaries** during the formation of the egg cell nucleus

IMPORTANCE/SIGNIFICANCE OF MEIOSIS

1. It leads to formation of the gametes
2. It leads to variation of genetic material due to **crossing over** which occurs during meiosis only. Crossing over is the exchange of portions of genetic material [at regions called chiasmata, singular called chiasma] between chromatids before they separate at the centromere.

Diagram showing crossing over



DIFFRENCES BETWEEN MEIOSIS AND MITOSIS

MITOSIS	MEIOSIS
It occurs in body cells (somatic cells)	It occurs in gonads
Leads to production of body cells (somatic cells)	Leads to production of gamete cells
Produces two daughter cells	Produces four daughter cells
Daughter cells have the same number of chromosomes as the parent cells	Daughter cells have half the number of chromosomes as compared to the parent cells
The gene number is diploid	The gene number is haploid
No crossing over	Crossing over occurs
Does not lead to variation of individuals	Leads to variation of individuals
No formation of chiasmata	There's formation of chiasmata
Homologous chromosomes do not separate	Homologous chromosomes separate
It occurs in one division	It occurs in two divisions
Involved in asexual reproduction	Involved in sexual reproduction

VARIATION

Variation refers to differences among members of the same species.

Variation may be brought about by the influence of:

- The environment (environmental variation)

– Inborn characteristics (genetic variation)

ENVIRONMENTAL VARIATION

The environment in which an individual lives may affect the appearance of that individual. The environmental factors that affect the appearance of an individual include:

a) Temperature

Organisms which live in regions with high temperatures usually develop features which enable them to adjust to high temperatures so as to lose little water and maintain the rate of growth. Plants living in such areas usually develop small leaves, thick epidermis and few stomata. The same plants if grown under low temperatures would have large leaves, thin epidermis and more stomata.

b) Nutrient content (availability of food)

Nutrients encourage healthy growth of an organism. Organisms lacking nutrients usually grow poorly and they differ from those supplied with nutrients

c) Availability of light

Plants grown in dim light usually develop long stems and light green leaves as compared to those which grow in an area having a lot of light.

Other factors which bring about environmental variation include;

- Availability of light
- Space
- Humidity
- Air currents
- Chemicals

GENETIC VARIATION

The characteristics of an individual are brought about by the nature of factors possessed by his/her genetic makeup. Genetic variation occurs as a result of change of parts of chromosomes during **crossing over**, which occurs **during anaphase stage of meiosis**. It is these factors that are passed on to the offsprings when fertilisation occurs.

Genetic variation is further divided into two;

i. Continuous variation

ii. Discontinuous variation

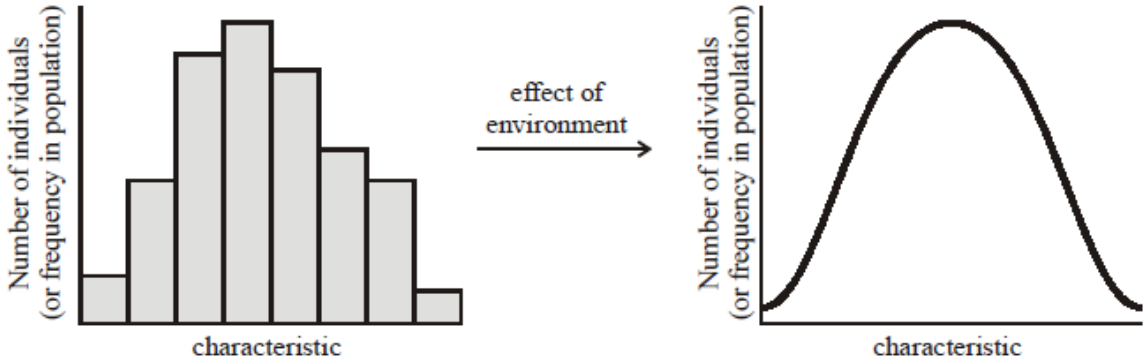
Continuous variation

This is the type of variation where by there's **no clear cut point** (distinction) between individuals of the same species.

Continuous variation can be exemplified by intelligence, body size (weight and height), skin colour e.t.c.

NOTE;

- Continuous variation may be called *quantitative variation*
- When the number of organisms is plotted against a characteristic, a bell shaped curve forms as shown in the graph below.

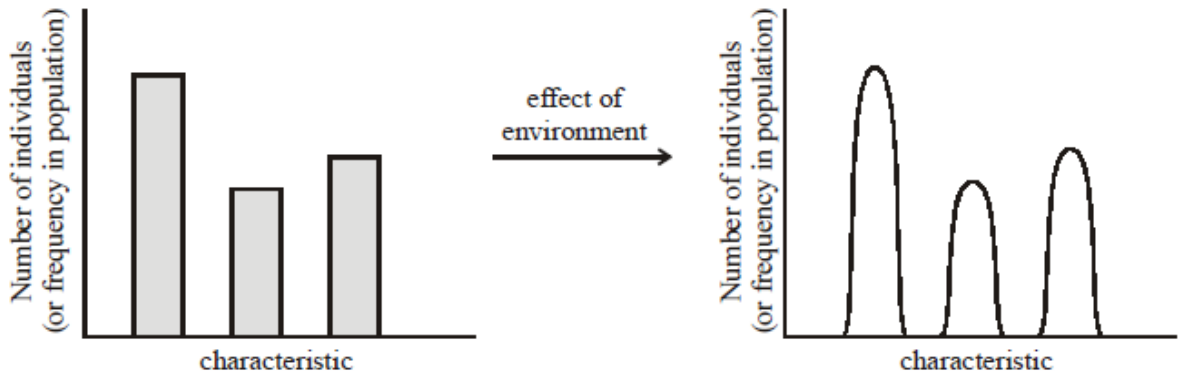


Discontinuous variation

This is the type of variation whereby there's **a clear cut point (distinction)** between individuals of the same species.

In this type of variation, there's a clearly defined difference between individuals of the same species.

Examples of naturally existing types of discontinuous variation include tongue rolling, blood groups, albinism, gender (sex) e.t.c.



NOTE;

Some variations maybe passed on from one generation to another while some variations cannot be passed on. The variations that are passed on are never the same as in the parent generation, but the offsprings show closer similarities due to crossing over.

GENETICS

Genetics is the study of heredity.

Heredity is the process by which parents pass on characteristics to their offsprings during reproduction.

TERMS USED IN GENETICS

Generation: a group of organisms of approximately the same age within a population.

F_1 generation: offsprings produced by two pure breeds carrying contrasting variations. (F_1 refers to first filial)

F_2 generation: offsprings produced by mating the F_1 generation.

Phenotype: is the external appearance of a given characteristic

Genotype: is the genetic makeup of a given organism that determines the expression of a given characteristic

Trait: an observable characteristic that is under study

Allele: an alternative form of a gene that determines a given characteristic.

In genetics, alleles are represented by letters (upper case/capital or lower case/small). The letter chosen must be obtained from the trait **BUT** it must be one in which the upper case form can easily be distinguished from the lower case form and can easily be written in a clear cut way. For example;

TRAIT	**LETTER**	
	Upper case	Lower case
Black	B	b
Red	R	r
Tall	T	t
Green	G	g
Yellow	Y	y

Dominant allele: this is an allele that expresses itself in both homozygous and heterozygous conditions. The dominant allele is always represented by the upper case letter e.g. G, B, R, T e.t.c.

Recessive allele: this is an allele that only expresses itself in the homozygous condition. The recessive allele is always represented by the lower case letter e.g. g, b, r, t e.t.c.

Genome: this refers to all the alleles or genes that an organism posses.

Homozygous: this is a description of a character controlled by identical alleles. For example TT, BB, rr, ee, hh e.t.c. Homozygous can be homozygous dominant e.g. TT, GG or it can be homozygous recessive e.g. tt, gg.

Heterozygous: this is a description of character controlled by two different alleles e.g. Yy, Bb, Rr, Hh, RW.

Homologous chromosomes: chromosomes of the same size and they carry the same number and type of chromosomes.

Haploid (n): a condition where there's one set of unpaired chromosomes in the nucleus.

Diploid (2n): a condition of having two sets of homologous chromosomes.

Note: Human beings have 23 pairs of chromosomes having inherited 23 chromosomes from the father and 23 from the mother i.e. each gamete (sperm and ovum) possesses one set of the homologous chromosomes.

A gene is a portion of DNA that determines the expression of a given characteristic.

Gene locus: the specific position on a chromosome where a given gene is found.

Pure breeds: breeds which are either homozygous dominant or homozygous recessive.

GREGOR MENDEL AND MONOHYBRID INHERITANCE

Gregor Mendel was an Austrian monk who crossed pure breeds with contrasting characteristics which he called the **parental generation**. He called the offsprings of pure breeds the F_1 generation. He then crossed two individuals from the F_1 generation and the offsprings of this cross he called the **F_2 generation.**

The results, using proportions only, are summarised in the table below;

Character	**Type of cross**	**F_1 generation**	**F_2 generation**	**Ratio**
Stem length	Tall X Short	All tall	787tall, 277short	2.84:1
Seed colour	Green X Yellow	All yellow	6022yellow, 2001green	3.01:1

Seed shape	Round X Wrinkled	All round	5474 round, 1850wrinkled	2.96:1
Seed coat	Coloured X White	All coloured	705 coloured, 224 white	3.15:1
Pod colour	Green X Yellow	All green	428 green, 152 yellow	2.82:1
Pod shape	Inflated X Constricted	All inflated	882 inflated, 299 constricted	3:1
Flower position	Terminal X Axial	All axial	651 axial, 207 terminal	3.14:1
Flower colour	Purple X white	All purple	705 purple, 224 white	3:1

He noted that in the F_1 generation all the offsprings were the same. However in the F_2 generation, both the variations of the characteristic under study that were in the parental generation occurred in the offsprings in the ratio of 3:1, he called this the **3:1 ratio of monohybrid inheritance.**

From the ratio above, Mendel formulated a law called **Mendel's law of mono hybrid inheritance**. It states that "***an organism's characteristics are controlled by internal factors (alleles) that occur in pairs and only one of the pair of such factors can be represented in a single gamete***"

The above law may be called the ***law of segregation*** and in human beings characteristics that follow this law include albinism and tongue rolling. Characters such as blood groups do not follow this law.

COMPLETE DOMINANCE

This is a condition whereby the presence of one gene hinders (hides) the expression of the other gene in the allele pair.

Worked examples

1. A tall pea plant was crossed with a short one and only tall plants were obtained in the F_1 generation.

a) Explain why F_1 contains only tall pea plants

b) What is the phenotypic and genotypic ratio of the F_2 generation

2. In cattle the gene for hornless condition is dominant over the one for horned condition. A hornless cow was mated with a horned bull.

    a) Using genetic symbols show the possible genotypes and phenotypes of the offsprings

    b) A bull whose horns were removed was mated to a horned cow. Show the possible genotypes and phenotypes of the F_1 generation.

Solutions

1. (a) ***Check notes***

(b)

Let **T** represent the allele for tallness

Let **t** represent the allele for shortness

Parental phenotype Tall X Short

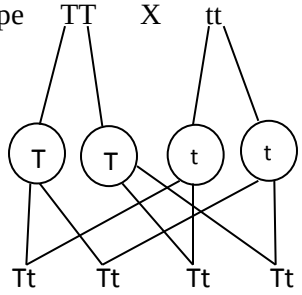
Parental genotype TT X tt

Meiosis

Gametes

Fertilisation

F_1 genotype



F_1 genotype: all Tt

F_1 phenotype: all tall

F_1 phenotype Tall X Tall

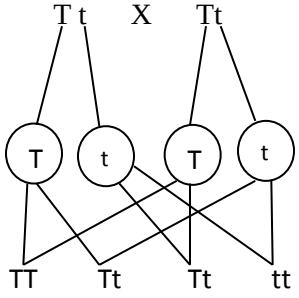
F_1 genotype T t X Tt

Meiosis

Gametes

Fertilisation

F_1 genotype



Phenotypic ration Tall: short

3 : 1

Genotypic ratio TT: Tt: tt

1: 2: 1

2. (a)

Let **H** represent the allele for hornless condition

Let **h** represent the allele for horned condition

Parental phenotype hornless X horned

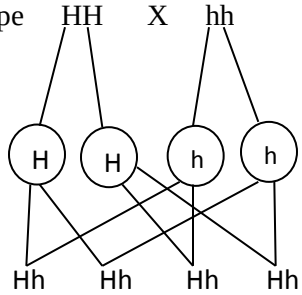
Parental genotype HH X hh

Meiosis

Gametes

Fertilisation

F_1 genotype



F_1 genotype: all are Hh

F_1 phenotype: all are hornless

(b)

Parental phenotype horned X horned

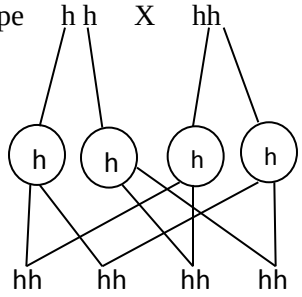
Parental genotype h h X hh

Meiosis

Gametes

Fertilisation

F_1 genotype



F_1 genotype: all are hh

F_1 phenotype: all are horned

Exercise

1. The fruit fly, *Drosophila melanogaster*, usually has wings about twice as long as its abdomen. However, certain individuals have vestigial (very short) wings. A long winged male fly was crossed with a vestigial-winged female fly: eighty seven eggs were laid, all of which developed into flies with long wings. When members of this long winged **F_1** generation were mated, the resulting **F_2** generation consisted of 61 long-winged flies and 20 vestigial-winged flies.

   (a) Suggest reasons why *Drosophila* is a very suitable animal for use in experiments on heredity

   (b) Using genetic symbols show the formation of

      i. **F_1** generation

      ii. **F_2** generation

2. (a) What is meant by the term complete dominancy

   (b) In drosophila, the genes for blue eyes is recessive to the gene for brown eyes

      i. Carry out a cross to show formation of **F_1** between true breeding flies

      ii. Carry out a cross to determine the phenotypic ratio if one **F_1** fly is crossed with the blue eyed parent

INCOMPLETE DOMINANCE AND CO-DOMINANCE

Incomplete dominance is a condition where by the heterozygous individual is phenotypically distinguishable from both parents.

An example of incomplete dominant genes is shown when a cross between a plant with the alleles for red colour (RR) for flowers and one with alleles for white colour (WW) for flowers are crossed, pink flowers (RW) are produced.

Note: Neither of the alleles is fully dominant over the other and the displayed phenotype in the heterozygous individual is as a result of the partial influence of both alleles.

Co-dominance is a condition that arises when genes for the same character are dominant and are fully expressed in the phenotype of the heterozygous individual.

An example of co-dominant genes is the genes for blood groups in man. The inheritance of blood groups is determined by three alleles (**multiple alleles**). These alleles influence the formation of antigens on the

red blood cells. Alleles A and B show co-dominance to each other and yet both are dominant over allele O i.e. allele O is recessive to both alleles A and B.

Note:

- Multiple alleles are a group of alleles (more than one pair) which collectively determine a characteristic of an individual
- Allele A determines the formation of antigen A on the red blood cells
- Allele B determines the formation of antigen B on the red blood cells
- Allele O prevents the formation of antigens A and B on the red blood cells when in homozygous state.

The table below shows the relationship between the blood group and its possible phenotype.

Blood group	**Possible genotype**	**Antigen formed on the red blood cell**
A	AO	Antigen A
A	AA	Antigen A
B	BO	Antigen B
B	BB	Antigen B
AB	AB	Antigen A and antigen B
O	OO	None

Worked examples

1. (a) Define the term incomplete dominance

   (b) In cattle white coat colour exists as well as red coat colour. When a white cow is crossed with a red bull, the resultant progeny are all roan (intermediate).

   i. Using genetic symbols, work out the cross to show the formation of the F_1.

   ii. What results are obtained when the F_1 progeny are selfed?

2. In Dandelion, red flowers exist as well as white flowers. The allele for red petal colour and the allele for white petal colour are co-dominant. If one F_1 offspring (pink) from a cross between red and white flowers is crossed with a red coloured variety. What is the phenotypic ratio in the F_2 generation?

3. (a) Carryout a cross for parents who are both heterozygous for blood group A?

   (b) If a man homozygous blood group A marries a woman who is heterozygous for blood group B, determine the blood group of their children.

Solutions

1 (a) *check notes*

b) (i)

Let W represent the allele for white coat colour

Let R represent the allele for red coat colour

Parental phenotype white cow X red bull

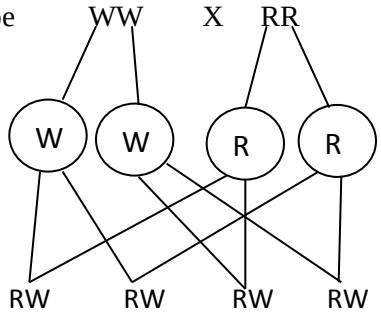
Parental genotype WW X RR

Meiosis

Gametes

Fertilisation

F_1 genotype



(ii)

F_1 phenotype roan cow X roan bull

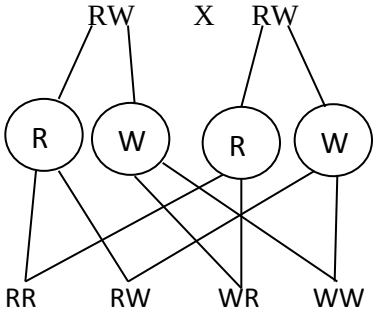
F_1 genotype RW X RW

Meiosis

Gametes

Fertilisation

F_2 genotype



Genotypic ratio RR: RW: WW

1: 2: 1

Phenotypic ratio red: roan: white

1: 2: 1

Example 2

Let W represent the allele for white petal colour

Let R represent the allele for red petal colour

Parental phenotype white X red

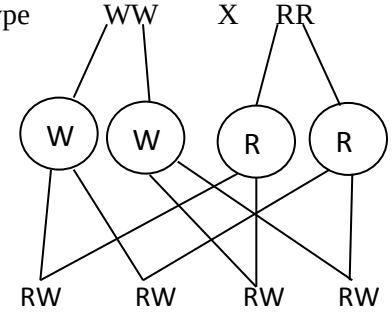
Parental genotype WW X RR

Meiosis

Gametes

Fertilisation

F_1 genotype



All are pink

(ii)

F_1 phenotype Pink X Red

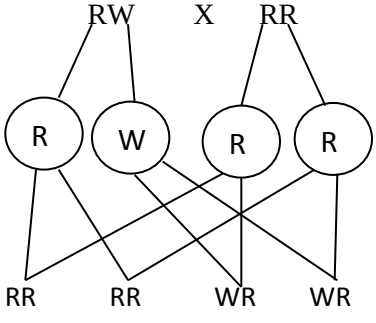
F_1 genotype RW X RR

Meiosis

Gametes

Fertilisation

F_2 genotype



Genotypic ratio RR: RW

2:2 = 1:1

Phenotypic ratio red: pink

1:1

Example 3

(a)

Let A represent the allele for antigen A

Let O represent the allele for no antigen B

Parental phenotype man of blood group A X woman of blood group A

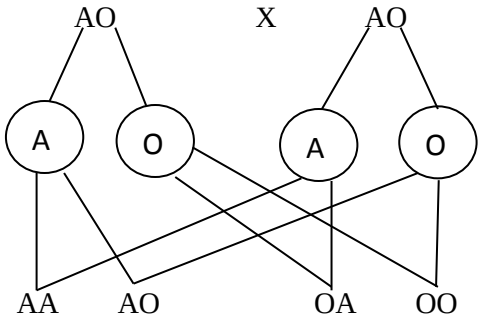
Parental genotype AO X AO

Meiosis

Gametes

Fertilisation

F_1 genotype



Genotypic ratio AA: AO: OO

1:2:1

Phenotypic ratio Blood group A: Blood group O

3 : 1

(b)

Let A represent the allele for antigen A

Let O represent the allele for no antigen

Let B represent the allele for antigen

Parental phenotype man of blood group A X woman of blood group B

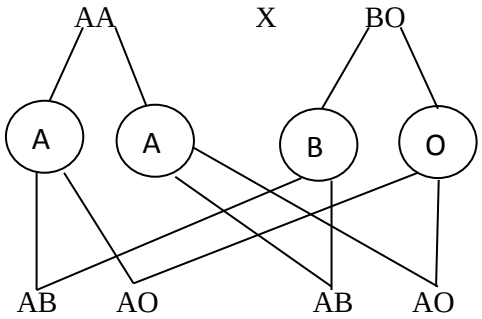
Parental genotype AA X BO

Meiosis

Gametes

Fertilisation

F_1



Blood groups of children AB and A

Exercise

1. Abraham married twice. With his first wife he had two children whose blood groups were B and O. With his second wife he had two kids of blood groups AB and O. His first wife remarried a universal donor and their one child was of blood group A. What were the genotypes of the man and his wives? Show your working.

2. Plants with red flowers were crossed with plants with white flowers. The resultant F_1 generation had pink flowers.

    i. Without using symbols, explain why a cross between red flowered plants and white flowered plants produced pink flowered plants.

    ii. Using R for red flowers and W for white flowers. Work out the genotypes and phenotypes of the F_2 generation and determine the phenotypic ratio.

3. Mary gave birth to a son of blood group O and claims that John a fellow student is the father. John is of blood group AB and Mary is of blood group A. John claims that Joseph a fellow student is the father. Joseph is blood group B. Use your knowledge of genetics to determine the identity of the father.

4. In mice grey fur is dependent on a dominant gene (G) and black fur on a recessive gene (g). What would be the resultant of a cross between two true breeding mice? Show your working.

    (b) If you selfed the offsprings in (a) above, what would be the;

i. Genotypic ratio

ii. Phenotypic ratio.

(Show your working)

5. A woman, Janet claims that her child was stolen by another woman in the maternity ward. The alleged thief and her husband are both of blood AB. The child is of blood group O and Janet is blood A while her husband is of blood group B.

    i. Is Janet right in her claim?

    ii. Support your answer in (a) by working out genetic crosses to show to;

        - Whom the baby can belong
        - Whom the baby can't belong

SEX DETERMINATION IN HUMANS

In humans, the sex of an individual is determined by the X-chromosome and the Y-chromosome.

Females posses an XX chromosome pair while males posses an XY chromosome pair. Females produce gametes with same chromosomes and are therefore said to be **homogametic**. Males produce 2 types of gametes one possessing the X chromosome and the other possessing the Y-chromosome. Males are therefore said to **heterogametic**.

NOTE: Males determine the sex of the child to be born since they produce the Y-chromosome i.e. presence of the Y-chromosome leads to a male child and presence of an X chromosome from the man leads to a female child.

TWINS

Twins are two human beings or animals born to the same mother from the same pregnancy at the same time. There are two types of twins;

i. Identical twins

ii. Fraternal twins

Identical or monozygotic twins

These are twins which develop from one egg fertilised by one sperm cell but the zygote later splits into two, each developing into a baby.

Such twins are closely similar because they have the same genetic material. They are also of the same sex.

Fraternal or dizygotic twins

These are non-identical twins resulting from fusion of two different ova fertilised by two different sperm cells.

Such twins can be of the same or different sex. They differ genetically because they arise from different genetic material. Twins produced from separate ova and sperms though not necessarily of the same sex, they have the usual family resemblance of brothers and sisters.

SEX LINKED GENES

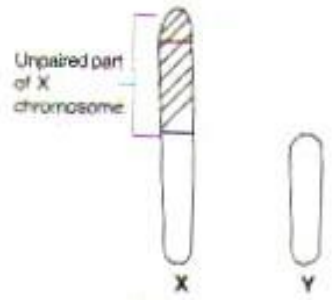
Genes that are located on either the X or Y chromosome are said to be linked. Sex linked genes may be located on the X-chromosome (X-linkage) or they may be located on the Y-chromosome (Y-linkage).

Sex-linked characteristics are characteristics determined by genes located on and transmitted along with the sex chromosomes

X-linkage

The X chromosome is much larger than the Y chromosome and therefore most linkage characters are located on the X chromosomes.

Diagram



In addition to carrying genes used for determination of female sex characteristics, the X chromosome also carries genes for none sexual characteristics e.g.

i. Ability to see colour

ii. Mature bolding

iii. Ability of blood to clot efficiently

Y-linkage

Genes for non-sexual characteristics that are located on the Y-chromosome include genes responsible for;

i. Long hairs on the ears

ii. Thick skin

iii. Some-quill like hairs in some porcupines

iv. Long hairs in the nose

NOTE: there are genes which are expressed in accordance with one's sex but are not carried on the sex chromosomes, such genes control **sex limited characteristics** and are strongly affected by the level of hormones in an individual e.g. lactation in females and facial hairs in man.

HAEMOPHILIA

Haemophilia is a heritable disorder of blood characterised by slowness or inability of blood to clot during bleeding.

Haemophilia is a sex-linked character caused by a recessive allele on the X-chromosomes.

Let X^h represent the X chromosome with the allele for haemophilia

Let X^H represent the X chromosome with the allele for normal clotting

Possible genotype	**Phenotype**	**Clotting factor**
$X^H X^H$	Normal female	Normal
$X^H X^h$	Carrier female	Normal
$X^h X^h$	Defective	Haemophiliac female
$X^H Y$	Normal	Normal male
$X^H Y$	Defective	Haemophiliac male

COLOUR BLINDNESS

This is known as the re-green colour blindness. The person suffering from this blindness cannot distinguish red colour from green colour.

Let X^b represent the X chromosome with the allele for colour blindness

Let X^B represent the X chromosome with the allele for normal colour vision

Possible genotype	**Phenotype**	**Colour vision**
$X^B X^B$	Normal female	Normal
$X^B X^b$	Carrier female	Normal

$X^b X^b$	Defective	Colour blind female
$X^B Y$	Normal	Normal male
$X^b Y$	Defective	Colour blind male

Worked example

1. Haemophilia is a sex-linked disease. A carrier woman for this disease got married to a normal male and had four children. Using your genetic knowledge, determine the percentage of their children that will be normal boys, normal girls, carrier girls and haemophiliac girls

2. A colour blind man married a woman who delivered both colour blind daughters and colour blind sons. Using your genetics knowledge determine how many of their 8 children can differentiate color.

Solutions

1.

Let X^h represent the X chromosome with the allele for haemophilia

Let X^H represent the X chromosome with the allele for normal clotting

Parental phenotype carrier woman X normal man

Parental genotype $X^H X^h$ X $X^H Y$

Meiosis

Gametes X^H X^h X^H Y

Fertilisation

F_1 genotype $X^H X^h$ $X^H Y$ $X^h X^H$ $X^h Y$

Phenotypic ratio 1:1:1:1

Normal girl: normal boy: carrier girl: haemophiliac boy

i. Normal boy

$$= \frac{normal boys}{tota\ln umber of children} = \frac{1}{4} \times 100 = 25\%$$

ii. Normal girls

$$\frac{norma\lg irls}{tota\ln umberofchildren} = \frac{1}{4} \times 100 = 25\%$$

iii.Carrier girls

$$\frac{carrier\,girls}{tota\ln umberofchildren} = \frac{1}{4} \times 100 = 25\%$$

iv. Haemophiliac boys

$$\frac{haemophiliacboys}{tota\ln umberofchildren} = \frac{1}{4} \times 100 = 25\%$$

2.

Let X^b represent the X chromosome with the allele for colour blindness

Let X^B represent the X chromosome with the allele for normal colour vision

Parental phenotype carrier woman X normal man

Parental genotype X^BX^b X X^BY

Meiosis

Gametes X^B X^b X^B Y

Fertilisation

F_1 genotype X^BX^b X^BY X^bX^B X^bY

Kids that can differentiate colour = $\frac{2}{4}$ X 8 = 4 children

MUTATIONS

A mutation is a sudden change in the number and arrangement of the DNA of a cell.

A **mutagen** is a substance which can influence the rate of mutation.

Mutagens include;

a. High energy radiations e.g. X-rays and gamma rays
b. Presence of high energy particles such as Alpha and Beta particles
c. Fluctuation of temperature

d. Dangerous chemicals such as mustard gas and nitrous acid.

Characteristics of mutations

1. They are spontaneous in nature
2. They are not directed by the environment but can be induced by mutagenic agents
3. They are rare
4. They occur at random
5. They do not occur slowly but occur is a single abrupt step
6. Most of them are disadvantageous to organisms

Importance of mutations

1. Enables some organisms to survive adverse conditions e.g. bacteria
2. Brings about evolution in a population
3. Improving on animal and plant bleeding leading to good yields.

Types of mutations

1. Gene mutations
2. Chromosomal mutations

Assignment

Make brief notes on the types of mutations

Conditions that occurred as a result of mutations include;

a. Haemophilia

b. Albinism

c. Sickle cells

ALBINISM

This is a condition in which an individual lacks the normal melanin pigment.

This occurs because the gene needed to make the enzyme which catalyses the production of the pigment has changed or undergone mutations. Albinism is an example of complete dominance in the animal kingdom and it is not restricted to humans only. An albino has white hair and skin plus pink eyes.

The allele for the pigment to develop is **A** and it is dominant whereas the allele for albinism is **a** and it is recessive.

The table below summarises the possible phenotypes and genotypes

Genotype	**Phenotype**
AA	Normal
Aa	Normal (carrier)
Aa	Albino

SICKLE CELLS

Sickle cell anaemia is a condition whereby the red blood cells have an abnormal shape.

These red blood cells become sickle shaped and as a result they are not able to transport oxygen efficiently. The normal shape of the red blood cell is the bi-concave shape and this makes the red blood cells efficient in transporting oxygen.

The shape of the red blood cell is determined by the type of heamoglobin present and the type of haemoglobin is determined by two alleles. One allele determines the formation of normal haemoglobin and is noted as **H**. The other allele determines the formation of abnormal haemoglobin which is noted as **S**. The table below shows the possible genotypes and phenotypes depending on the alleles present.

Alleles present	**Possible genotype**	**Phenotype**
H only	HH	Normal (biconcave red blood cells)
S only	SS	Sickler (sickle shaped red blood cells)
H and S	HS	Normal nut carrier (bi-concave red blood cells)

Worked examples

1. An albino male marries a heterozygous female. If the female has 6 children what would be the phenotypic and genotypic ratio of their children.

2. A normal man whose father was an albino and mother normal got married to an albino woman. They had twelve children. Determine the percentage of their children that are albinos.

3. Sickle cell anaemia is a genetically transmitted disease. If a carrier woman gets married to a carrier man and they have four children, how many of their children will be sicklers?

4. A child is normal and his father is also normal but the mother is a sickler.

a. Determine the genotypes of the two parents and their daughter

b. Use your genetic knowledge to determine the genotypes and phenotypes of other children in the family

c. If the daughter got married a carrier man, determine determine the genotypic and phenotypic ratio of their children

Solutions

1.

Let A represent the allele for production of melanin

Let a represent the allele for lack of melanin

Parental phenotype albino man X normal woman

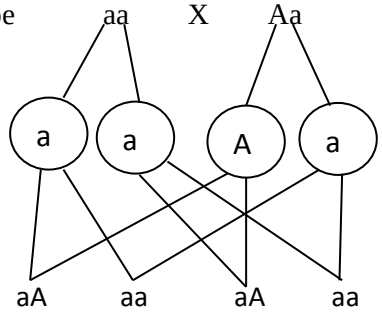
Parental genotype aa X Aa

Meiosis

Gametes

Fertilisation

F_1 genotype



Genotypic ratio Aa : aa

2: 2 = 1:1

2.

Let A represent the allele for production of melanin

Let a represent the allele for lack of melanin

Parental phenotype normal man X albino woman

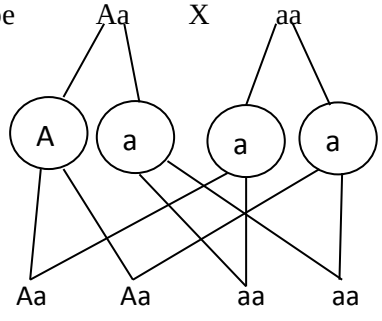
Parental genotype Aa X aa

Meiosis

Gametes

Fertilisation

F_1 genotype



Percentage of children who are albinos = 50%

3.

Let H represent the allele for formation of normal haemoglobin

Let S represent the allele for formation of sickle shaped heamoglobin

Parental phenotype carrier woman X carrier man

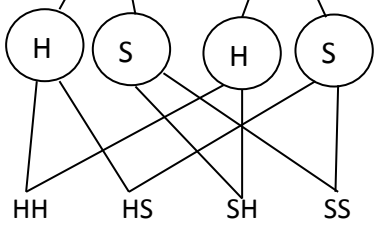
Parental genotype HS X HS

Meiosis

Gametes

Fertilisation

F_1 genotype



Phenotypic ratio normal : carrier : sicklers

1 : 2 : 1

$\frac{1}{4}$ X 4 = 1

4. (a)

Let H represent the allele for formation of normal haemoglobin

Let S represent the allele for formation of sickle shaped heamoglobin

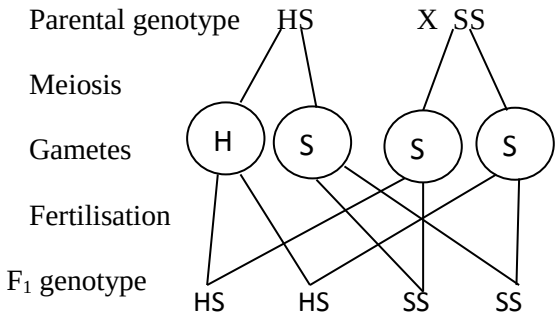
- Father HS
- Mother SS
- Son HS

(b)

Let H represent the allele for formation of normal haemoglobin

Let S represent the allele for formation of sickle shaped heamoglobin

Parental phenotype normal man X sickler woman



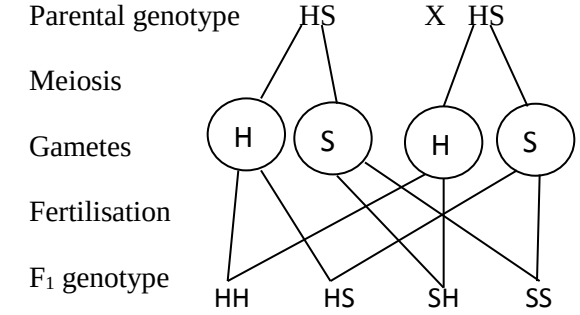
Phenotypes of the children 2 sicklers and 1 carrier.

(c)

Let H represent the allele for formation of normal haemoglobin

Let S represent the allele for formation of sickle shaped heamoglobin

Parental phenotype normal son X carrier woman



Phenotypic ratio HH: HS: SS

Genotypic ration 1:2:1

APPLICATIONS OF GENETICS

1. Production of human insulin by microorganisms
2. Productions of high yielding and resistant varieties of crops and animals
3. Marriage counseling, to detect and probably avoid combinations which may give rise to inheritable diseases such as haemophilia.
4. Overcoming drug resistant pathogens and pests
5. Awareness of mutagenic agents and control of their use for example minimal exposure to x-rays

NATURAL SELECTION

Variation is the raw material for natural selection to act on. Organisms in a natural environment produce a very high number of young ones than what the environmental resources can support (***over production***). Because the environment in which these organisms live has limited resources (these resources include food, water, light, temperature, shelter, breeding grounds and problems such as diseases and predators). These offspring have to compete for the limited resources that the environment can offer (***struggle for existence***). During the competition, some organisms die while others will survive. The genetic makeup determines which individuals have characteristics that improve their ability to survive and which individuals die and perish (***survival for the fittest***). So in each generation, there will be a slight increase in the proportion of individuals having characteristics favourable for survival. Only these well adapted organisms will be able to reproduce successfully, and will pass on their advantageous characteristics to their offspring (***advantageous characteristics passed on to the offspring***) Over a period of time, a period of time, the population will lose all the poorly adapted individuals (***gradual change***). The population will gradually become better adapted to the environment. There is a selective force occurring in nature, which makes sure the individuals with the traits best fitted for survival in those conditions will live. This selecting force is called **natural selection**.

When the favoured individuals reproduce, they pass the favourable traits onto their offspring. If natural selection continues over many generations, it leads to a change in the type of organisms found in that population. We can assume that the earlier forms of present-day organisms were subjected to similar conditions and gave rise to the present-day organisms, a phenomena called **speciation**.

Speciation is the process by which one species splits into two or more new species which develop into different genetic lineages. **A species** is a population whose members can interbreed and produce viable fertile offspring, but are unable to produce viable fertile offspring with members of other populations. A single species may give rise to new offspring i.e. **intraspecific hybridisation** e.g. breeding organisms that are pure breeds but one having better characters than another which results in the formation of a hybrid, with hybrid vigor, that doesn't resemble any of the parents or two different species may give rise to one new species i.e. **interspecific hybridisation**

Since new species arise from pre-existing species, we can further assume that all present-day species gradually arose from one common simple species in a process called **evolution**.

ORIGIN OF LIFE

Different theories have been put forward to explain the origin of the first simple species which split up into several present-day species. The theories include the following;

a. **Special creation**. It is believed that living organisms were created by the almighty God in the very forms they exist today. This implies that there has not been any evolution or change of life form.

b. **Spontaneous generation theory.** This theory suggests that living organisms emerged from non-living forms spontaneously (suddenly).

   i. This is supported by the fact that dead decomposing materials may lead to formation of maggots.

ii. A newly constructed pond of water may eventually contain certain organisms such as fish
iii. Dirt may lead to the emergence of lice in the hair.
However, this theory was rejected by scientists who believe that living organism must originate from the already existing living organisms of their kind (Pre-existing life)

c. Steady state theory. This theory suggests that life has no origin, it has been available and has not undergone any change and it will continue being available. This is also referred to as the Cosmozoan theory.

d. **The synthetic theory**. Simple molecules joined together by use of external energy to form complex molecules that eventually lead to a living organism. This is supported by the fact that inorganic compounds like water and carbon dioxide can be used to synthesise organic compounds under sunlight energy by green plants.

e. **Organic evolution theory**. Pre-existing species give rise to new species due to natural selection. This is the most widely accepted theory for the origin of life. This theory was developed by Charles Darwin.

EVIDENCE FOR EVOLUTION

a. Fossils. A fossil is the remains or impression of a living organism which have preserved in a rock. It is possible to determine the age of the rock and hence know when the fossil was formed. Very old rocks have fossils of only simple organisms and recently formed younger rocks have more complex organisms.

b. Comparative anatomy. A comparison of the structures of different species shows close similarity and this is an indicator that these organisms had a common ancestor, if they do not show any similarity then they have different ancestors.

i. **Homologous structures.** Homologous are structures which have the same basic plan but perform different functions in different species. The limb bones of several different kinds of vertebrates e.g. the horse, man, monkey, bat and the whale i.e. **the pentadactyl limb** (five-fingered limb).
Some plants and animals possess structures which do not seem to be used for anything. Structures like this are called **vestigial** e.g. the small limb bones of some snakes. Snakes evolved from other reptiles which used their limbs for walking. The limb bones have gradually become smaller and there's no longer any trace of them in most snakes.

ii. **Analogous structures.** These are structures which have different basic plans but perform the same function as seen in the wings of insects and birds. This indicates that birds and insects have different ancestors.

c. Comparative embryology. At certain stages of embryonic development, some groups of animals look very similar e.g. fish, birds, amphibians, reptiles and mammals.

d. Comparative physiology. Different species use the same chemical substances to carry the same processes in their bodies, this indicates these organisms have a common ancestor e.g. catalase enzyme in different organisms

e. DNA evidence. The genetic material is the same in all species, it differs in the arrangement which leads to formation of different proteins in different organisms hence forming different species.

PRESENT DAY EVOLUTION

Evolution can be observed currently taking place in some organisms

i. Malaria mosquitoes and insecticide resistance

ii. Antibiotic resistant strains of bacteria

iii. Artificial selection (the selection of and breeding by man of the best varieties of domestic animals and plants, in order to improve the strain)

iv. Heavy metal resistant plants

GENETICS REVISION QUESTIONS

1. (a) Explain briefly what you understand by the terms:

   i. Meiosis

   ii. Mitosis

   b) Where do meiosis and mitosis occur?

   c) A plant with yellow leaves was crossed with a plant with green leaves. The gene for yellow leaves is recessive to that of green leaves. The offspring obtained were all green.

   i. What is the genetic ratio if F1 is selfed? Show your working.

   ii. What is the phenotypic ratio of F2?

2. (a) What is meiosis and where does it occur in plants and animals?

   (b) What is the relevance of meiosis in reproduction?

   (c)In a breeding experiment, plants which were homozygous for white flowers were crossed with those homozygous for red flowers. The resultant F_1 generation all had red flowers.

   i. Explain the absence of white flowers in the F_1 generation.

   ii. Using genetic symbols show the results in the F_2 generation after selfing the F_1 generation.

3. In an experiment, a long winged male Drosophillia was crossed with a short winged female Drosophillia. All the offspring in the F_1 generation were long winged. When two members of the F1 generation were mated, the F_2 generation consisted of 62 long winged files and 21 short winged files.

   (a) Suggest an explanation why all the F_1 generation flies were long winged.

   (b) (i) What type of files would develop from a mating between short winged flies in the second generation?
   (ii) Give a reason for your answer.
   (c) Mating between a short winged fly in F_2 generation with a long winged fly in F_1 generation produced 90 flies. How many of them were long winged? Show your working.

4. (a)(i) Which chromosomes are responsible for determining sex in humans?
   (ii) Using appropriate symbols show how sex is determined in humans.
   (b) Red - green colour blindness is a defect caused by a recessive gene carried on the X Chromosome. What would be the phenotype of the offspring when a normal woman marries a colour blind man? Show your working.

5. (a) What is meant by the term mutation?

(b)The gene for normal production of haemoglobin is dominated to the mutant gene which causes sickle cell anaemia. If a female heterozygous for the sickle cell anaemia marries a Norman man, illustrate, using suitable symbols, the possible genotypes and phenotypes of the offspring.

6. In an experiment, a long winged male drosophila was crossed with a short winged female drosophila. All the offspring in the F_1 generation were long winged. When two members of the F1 generation were mated, the F_2 generation consisted of 62 long winged files and 21 short winged files.

(a) Suggest an explanation why all the F_1 generation flies were long winged.

(b)(i)What type of files would develop from a mating between short winged flies in the second generation?

(ii)Give a reason for your answer.

(c)Mating between a short winged fly in F_2 generation with a long winged fly in F_1 generation produced 90 flies. How many of them were long winged? Show your working.

7. a) (i)Which chromosomes are responsible for determining sex in humans?

(ii) Using appropriate symbols show how sex is determined in humans.

(b) Red - green colour blindness is a defect caused by a recessive gene carried on the X chromosome. What would be the phenotype of the offspring when a normal women marries a colour blind man? Show your working.

8. (a) Distinguish between dominance and co-dominance in genetics. (02 marks)

(b) When tall pea plants were crossed with short pea plants, all the plants in F1 generation were tall. When two plants of the F_1 generation were crossed, both tall and short plants were produced in the F_2 generation.

(i) why were all plants tall in the F_1 generation.

(ii) using suitable symbols, show the crosses to produce the F_1 and F_2 generations.

(c)In rose plants, when a red flowered plant is crossed with a white flowered plant, all plants produced bear pink flowers. Using suitable symbols show the result of crossing a pink flowered plant and a white flowered plant.

9. (a) What do you understand by a recessive gene

(b)A man who is a carrier for albinism married a normal woman. Using suitable symbols, work out the proportions of the possible genotypes and phenotypes of their children.

(c)Give two benefits of studying human genetics.

END