CELL CYCLE & CELL DIVISION

During the process of growth, and formation of reproductive cells, cells divide to give rise to new cells refered to as daughter cells.

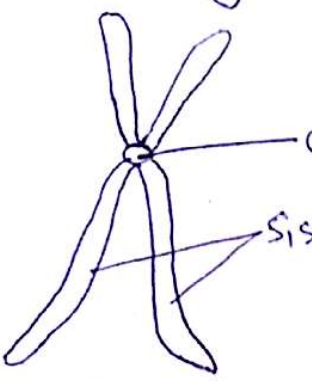
A cell divides so that the genetic material it Contains is divided and shared by the daughter cells, a process that maintains resemblelance or variation between offsprings and the parents.

CHROMOSOMES:

A chromosomes are thread-like coiled protein structures found in the nucleus of a cell. Chromosomes carry the genetic material (DNA) which contains genes.

A gene is a smallest and basic unit of heredity, which determines a particular Character (trait) of an organism and Can be passed on from the parents to their offsprings.

Structure of a chromosome



During Cell division, chromosomes divide ~~into chromatids~~ at the centromere into chromatids. The genes are carried onto the chromatids. Chromatids of the same chromosome are called sister chromatids and ~~each of~~ these ~~goes into the daughter cell~~ are shared by the daughter cells formed.

Cell division: This is a process by which cell's nucleus and cytoplasm divide into ~~two~~ two to form daughter cells.

There are two types of cell division. ie

1. Mitosis
2. Meiosis

(a) Mitosis: Mitosis is a type of cell division by which two daughter cells are formed each having exactly the same number of chromosomes as the parent cell. In other words, Mitosis is the formation of diploid daughter cells.

The term diploid denoted by (2n) refers to the condition where by each daughter cell formed has the same number of chromosome, ~~like~~ as the parent cell.

Mitosis is composed of 5 stages, namely

i) Interphase
ii) Prophase
iii) metaphase
iv) Anaphase
v) Telophase.

~~Each of~~ These stages involve a sequency of events, from interphase to telophase as the last stage

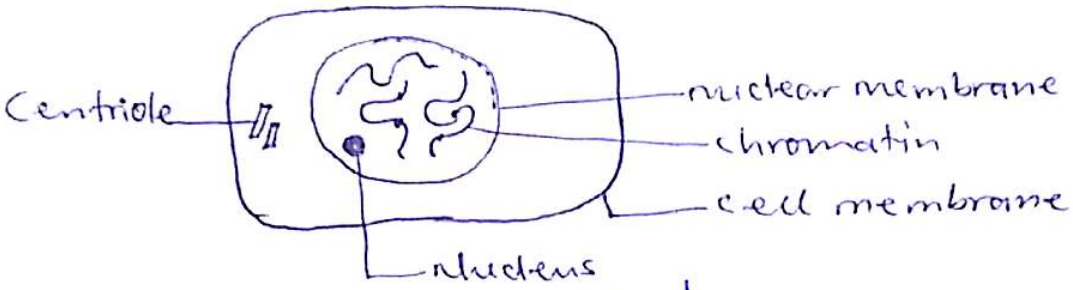
Interphase

This is the ~~first~~ Non dividing stage of cell division, usually refered to as "resting stage" although during this stage the cell is not actually resting. The following events occur

- There is replication (doubling) of the genetic material (DNA)
- There is replication of the chromosome. (ie the chromosome number in the parent cell doubles)
- There is ATP (energy) formation in the mitochondria and hence a large store of energy is built up

- There is formation of new cell organelles e.g mitochondria, ribosomes, chloroplasts etc
- Chromosomes are thin, long, coiled invisible thread-like structures called chromatins

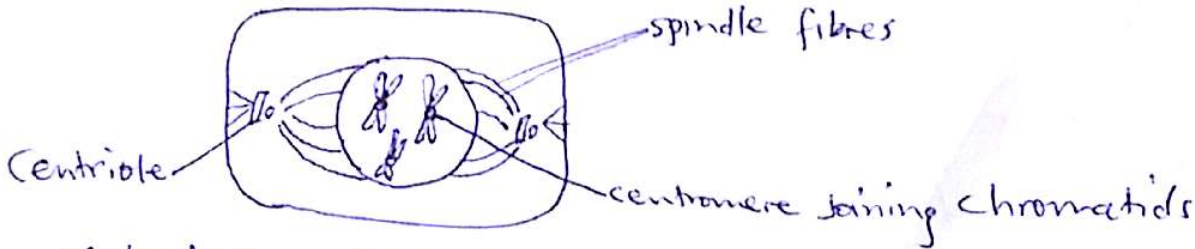
Illustration



Prophase: This is the ~~second~~ first stage of mitotic cell division. During this stage,

- ~~The chromosomes~~
- The chromatins thicken (Condense), ~~and~~ shorten and become visible chromosomes.
- Each chromosome is seen to consist of a pair of chromatids lying parallel to each other but joined at the centromere
- The centrioles migrate to the opposite poles of the cell
- The spindle fibres begin forming
- The nuclear membrane shrinks

Illustration

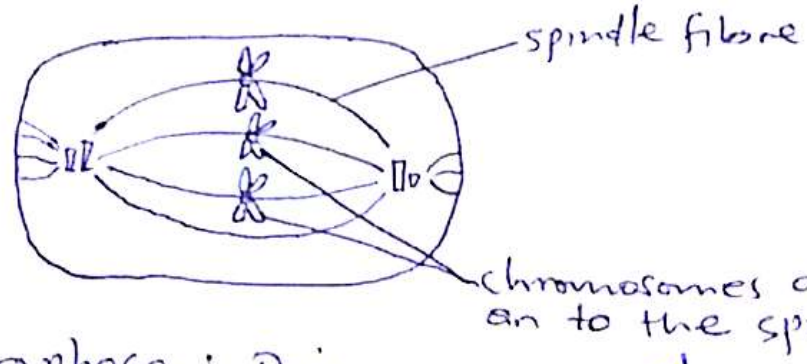


Metaphase: This is the ~~2~~ 3rd stage of mitosis during which the following ~~occurs~~ occur

- The nuclear membrane further shrinks and disappears
- Spindle fibres fully form and run from one pole of the cell to the other
- Chromosomes ~~assemble~~ aline themselves ~~to~~ on the ~~the~~ spindle fibres, attached on to the spindle by the centromere and occupy the middle plane (the spindle equator)

(iv)

Illustration

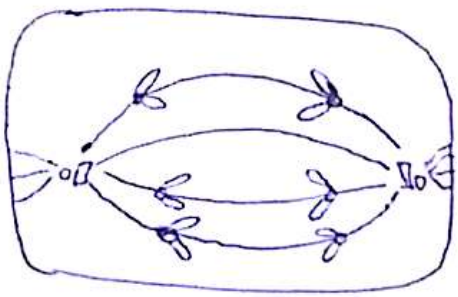


Anaphase: This is the 3rd stage of mitosis during which the following events occur

- The chromosomes divide at the centromere each into two sister chromatids.
- The sister chromatids of each chromosome migrate to the opposite side/poles of the cell due to pulling action by the spindle fibres

This stage ends when the ~~daughter~~ ~~Cells~~ chromatids have reached the opposite poles of the cell.

Illustration



Significancy (role) of mitosis

Formation of daughter cells which are exact copies of the parent cell is important in the following ways;

1. Mitosis leads to increase in number of cells that have same genetic constitution thereby causing growth of individual organism; due to increase in no. of cell
2. Mitosis leads to repair and replacement of damaged tissues after an injury hence healing of wounds. due to dead/ new cells are formed
3. Mitosis ~~aids a~~ is a basis of asexual reproduction in those organisms that reproduce asexually, e.g vegetative ~~reproduct~~ propagation in plants, binary fission in protozoa etc. due to no gamete formed
4. Mitosis leads to formation of cells whose nucleus have the same number and type of chromosomes. Therefore ~~Sinte~~ no genetic varriation, which ensures genetic stability from generation to generation. ; due to no crossing over

Where does mitosis occur in plants, and in animals?

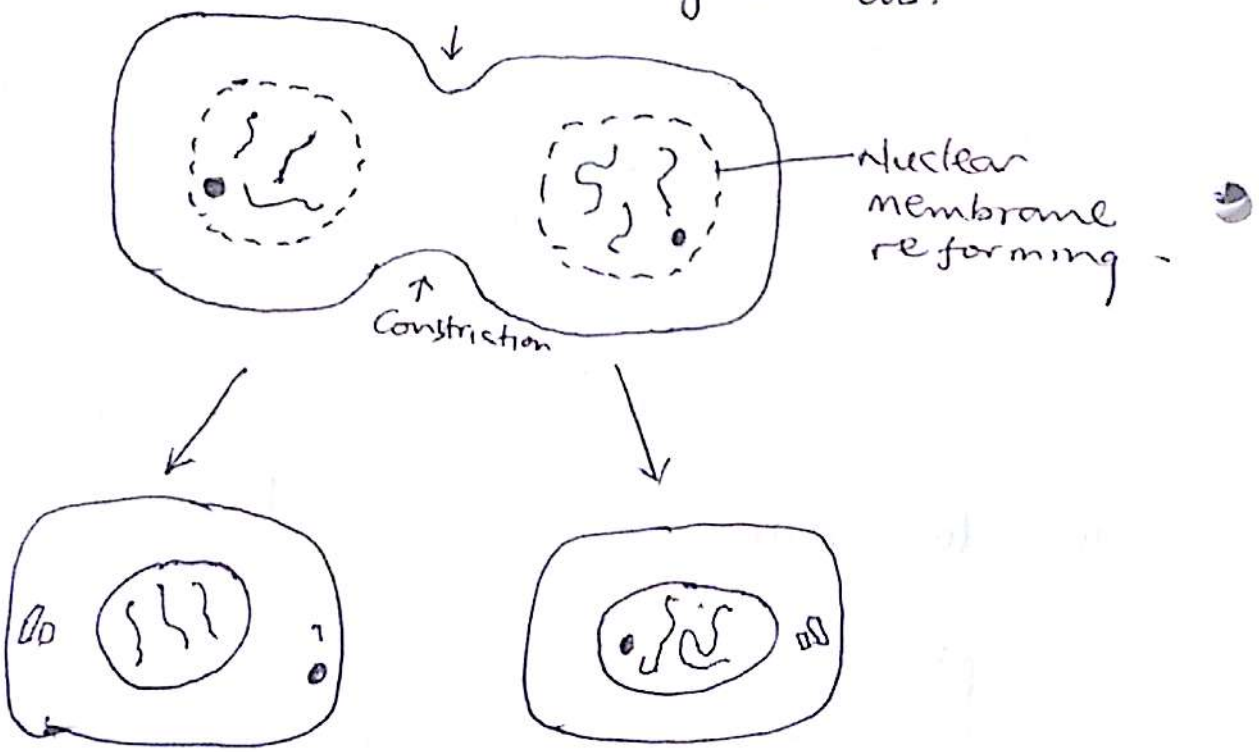
In plants, mitosis occurs in the region where active growth takes place. These

14/6

Telophase: This is the last stage of mitosis. Changes that occur in a cell during telophase include;

~~Constriction of the cell membrane~~

- Chromatids have reached the poles of the cell, they unwind into long thin threadlike structures which eventually become individual chromosomes.
- The nuclear membrane forms again
- spindle fibres shrink and break down
- Nucleolus re-appears.
- The cell membrane constricts in the midle and at a later stage, the cytoplasm and the nucleus divide forming two daughter cells.



regions are called meristems. Actualy the meristematic region (region of active growth in plants) are;

- Tips (apices) of shoot and root ~~leaves~~. These are responsible for primary growth in plants and therefore are called primary meristems.
- ~~in~~ Cambium tissue in the stems. This leads to secondary growth leading to increase in size of the stem.

In animals; growth takes place all over the body, hence mitosis occurs all over the body causing general growth. ie occurs in somatic/body cells

~~MITOSIS~~ MEIOSIS

This ~~a~~ is a type of cell division involving two successive division of the nucleus and cytoplasm but single division of chromosomes, that results into formation of four ~~daug~~ daughter cells each with half the number of chromosomes (haploid) as contained in the parent cell.

Meiosis therefore gives rise to haploid cells. The term haploid as opposed to diploid, ~~means~~ refers to a condition where each daughter cell formed has half the number of chromosome compared to the parent cell. Haploid condition is denoted by (n).

Like in mitosis, before the cell divides by meiosis it first undergoes interphase stage in which similar events as explained before, take place. Then the same stages of cell division follow in the order

- prophase
- metaphase
- anaphase
- Telophase.

However, unlike mitosis, meiotic division involves two phases of cell division hence the order of divisional stages take place as follows

- prophase I
- metaphase I
- anaphase I
- Telophase I

then

- prophase II
- metaphase II
- anaphase II
- Telophase II.

Prophase I

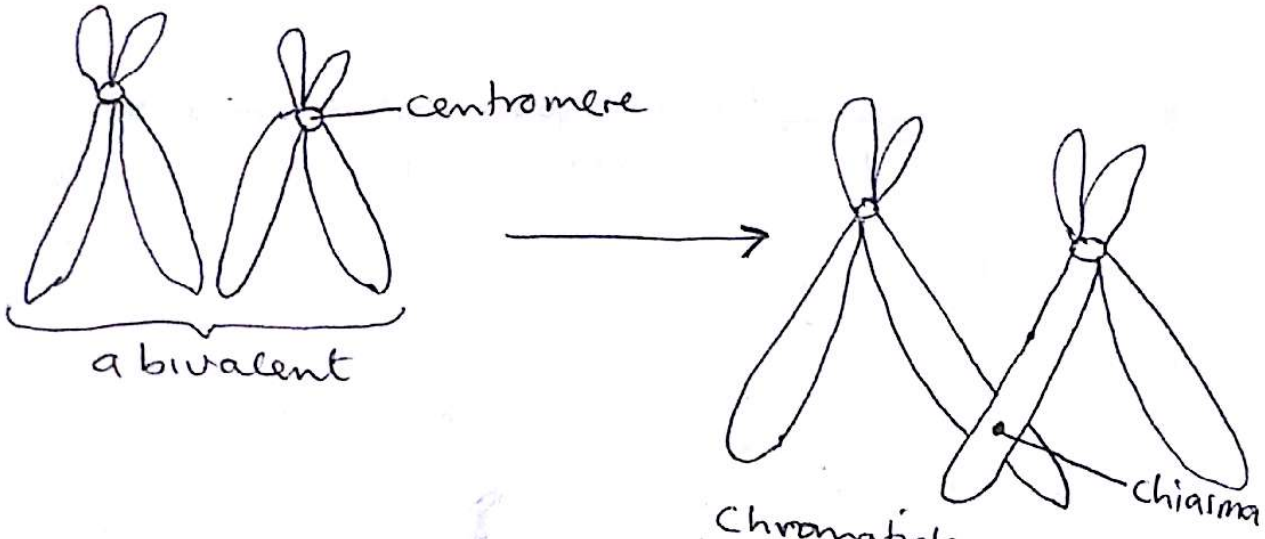
The events that occur include;

- Chromosomes condens (thicken) and become visible, and are seen to consist of chromatids.
- Nucleus shrinks and nuclear membrane breaks down

~~- Centrio~~

- Centrioles move to opposite poles of the cell.
- Spindle fibres begin forming
- Homologous chromosomes pair up to form a bivalent, a process called Synapsis. During this process, the association of homologous chromosomes may become so intimitate that, ~~thro~~ crossing over may take place. Crossing over is a process by which genes are exchanged between sister chromatids of a homologous pair.

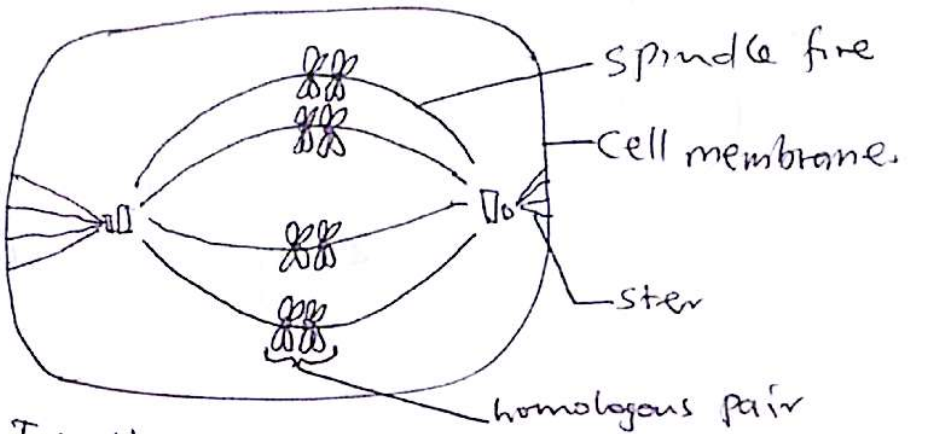
i.e



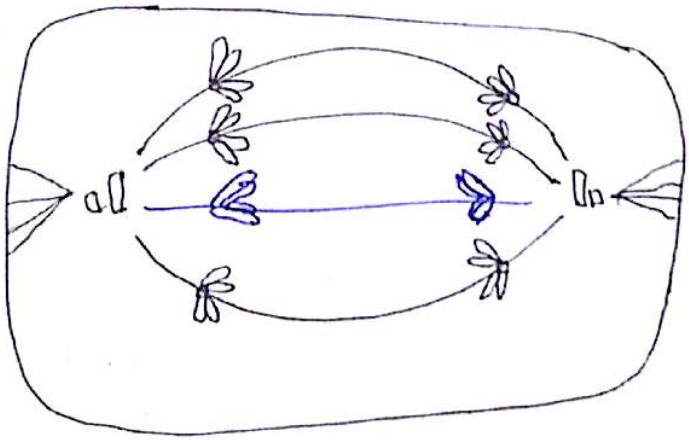
Chromatids cross each other at a point called Chiasma. This is where portions of chromatids break and rejoin leading to genetic exchange, a process called crossing over

Metaphase I: This follows prophase I and involves the following events;

- Homologous chromosomes arrange themselves at the equator (central plane) of the spindle fibres.

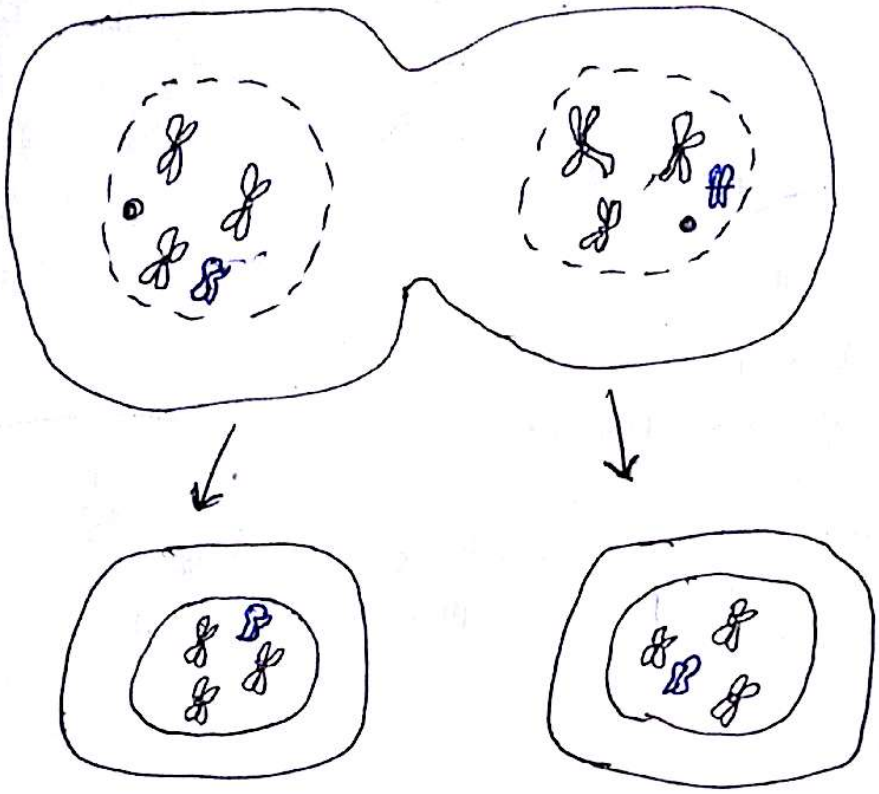


Anaphase I: Homologous chromosomes part company (seperate) and ~~move~~ each chromosome moves to the opposite pole of the cell, along the spindle fibre with the centromere leading.



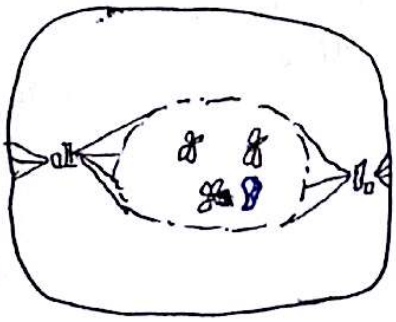
Telophase I: - The individual chromosomes reach the ~~of~~ poles of the cell,
- Nuclear membrane reappears
- spindle fibres break down
- The cell constricts leading to division of the nucleus and cytoplasm.
- Two daughter cells are formed, each of which undergoes the second meiotic division.

7.



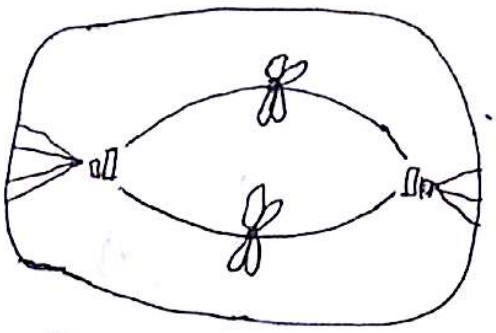
Prophase II

- The nuclear membrane breaks down
- Spindle fibres form
- centrioles form and move to opposite pole of the cell.



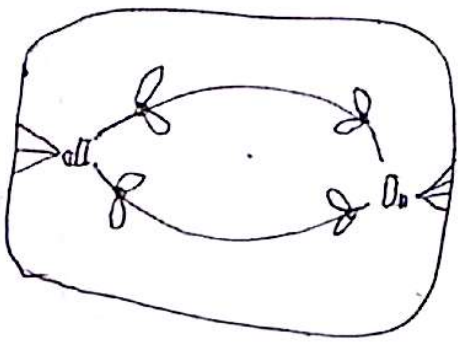
Metaphase II

- The individual chromosomes aline themselves on the equator of the spindle fibres.



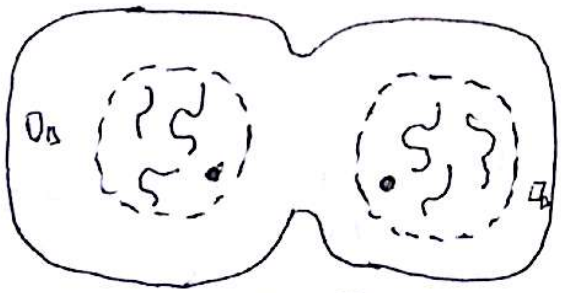
Anaphase II:

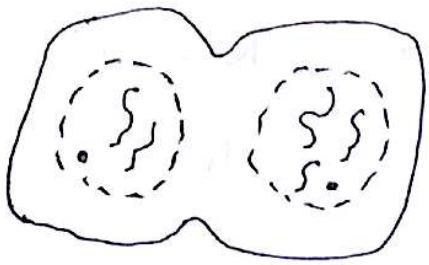
- Each individual chromosome divides into two sister chromatids.
- The sister chromatids move to the opposite poles of the cell.



Telophase II

- each chromatid has reach the opposite pole of the cell and turn into thread like structures called chromatins
- Nuclear membrane re-forms
- The spindle fibres break down
- The cell constricts in the ~~ae~~ midle leading to division of each cell into two daughter cells.





As a result, ~~E~~ four daughter cells are formed each having half the number of chromosomes ~~compar~~ compared to the parent cell.

~~Importance of meiosis~~:

Qn: Where does meiosis occur in Plants and in animals? It occurs in reproductive cells i.e

In plants, meiosis takes place in

i) the anthers during formation of pollen grains
ii) ovary during formation of ~~ovules~~ egg cells.

In animals: It takes place in

(i) germinal epithelial cells in the testis during formation of spermatocytes (sperm cells).
(ii) the ovary during formation of ovum/ova.

Importance of meiosis.

1. Meiosis promotes sexual reproduction through formation of reproductive cells (gametes)
2. Meiosis promotes genetic variation among organisms. This occurs as a result of crossing over in prophase I, and also as a result of independent assortment of chromosomes.
3. Since meiosis gives rise to haploid gametes, it maintains diploid state in organisms after fertilization. Due to genetic variation it lead to increased chances of survival.

Qn: Compare meiosis and mitosis.

Similarities:

- Both involve division of nucleus
- Both involve single duplication of chromosomes
- Both involve similar stages of cell division
- In both, ~~inter~~ spidles are form.
- ~~Both involve~~
- In both, cell division follow interphase in which DNA, cell organelles replicate
- In both, chromosomes arrange themselves ~~on~~ at the equator of spindle fibres.

Differences:

Mitosis	Meiosis
- Occurs in non reproductive cells	Occurs in reproductive cells
- Involves single division of the nucleus	Involves double division of the nucleus
- Two daughter cells are formed	Four daughter cells are formed.
- Same number of chromosomes present in each daughter cell	- Half the number of chromosomes present (haploid) compared to parent cell
- Homologous chromosomes do not associate	- Homologous chromosomes associate to form abivalent.
- Chiasma never form	- chiasma may form
- No crossing over	- ~~Thro~~ crossing over occurs
- Daughter cells are identical to parent cells	- daughter cells are genetically different from parent.
- chromosomes form a single row at the equator of spindle	- chromosomes form double row at the equator of spindle.

- In ~~Pro~~ anaphase, chromatids move to opposite pole of the cell

In anaphase I, individual chromosomes move to opposite pole of the cell.

GENETICS & EVOLUTION:

Genetics: This is the study of heredity and variation, it is the study of how traits ~~(the~~ [Character] are passed on from the parents to offsprings.

The traits are carried by genes which are the small units of a genetic material (DNA) located on chromosomes.

~~Variation~~ Variation

Variation refers to structural or physiological differences between organisms of the same species.

Variation is brought by.

① environmental factors e.g temperature, topography, salinity ~~etc~~ diet, soil factor,

② Differences in genetic constitution (genotypes)

~~Environmental~~ acquired variation, are ~~not~~ inherited

Types of variation: There are two major types of variation i.e

a) Continuous Variation

This is a type of variation where organisms of the same species do not show a clear-cut difference about a given trait (character) i.e There is no clear extremes of the character among the individuals.

Continuous variation brings about many intermediates of organisms whose extreme can not be clearly determined.

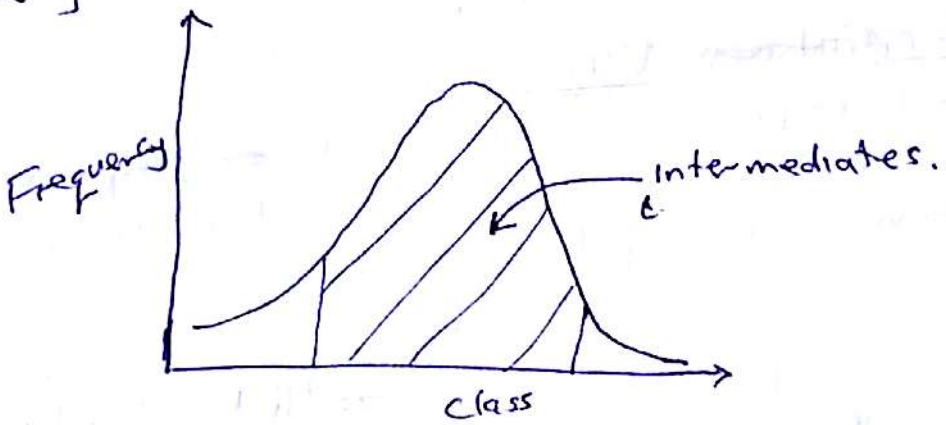
examples of continuous variation are

1. Height
2. Weight
3. Intelligence
4. Skin colour
5. Milk yield in cattle
6. number of grains on a maize kob

etc.

For such characters, when the frequency is plotted against the class of individuals, a normal distribution curve is obtained.

e.g



b) Discontinuous Variation

This is a type of variation where there is a ~~clear~~ clear-cut difference between individuals of the same species, about a given traits. Here, there are clear extremes of the traits i.e the population can be divided into two extremes and there are no intermediate organisms.

Examples include;

- Sex i.e you are either a male or female
- Blood groups A, B, AB, O

- tongue rolling
- albinism
- Colourblindness
-

Variation is important in that, it enables organisms to get adapted ~~to~~ for survival in their environment. Those which acquire traits that give them ~~at a better~~ ability to exploit their environment at the expense of those ~~with~~ which are less adapted, survive ~~and~~ reproduce and pass on their genes to next generations. This is a basic of Natural Selection (Survival for the ~~fittest~~).

Differences between continuous and discontinous variation

Continuous variation	Discontinuous variation
- It's measurable eg height	not measurable
- It's quantitative	- It's qualitative
- Controlled by multiple genes	- Controlled by a single gene

Mutations

A mutation is a sudden random change in the structure or content of genetic material (DNA) or chromosome in a cell. This causes that particular cell and others that arise from it to ~~defer~~ become abnormal.

Since mutations affect DNA or chromosome, they become inherited

Mutations are caused by substances called Mutagens examples are:

- ~~X-rays~~
- High energy particles such as x-rays,
- ultraviolet light (u.v light).
- Mustard gases from nuclear weapons
- Nitrous acid.
- Sulphur dioxide gas
- excessive heat etc.

The individual organisms that show abnormality due to mutations are called Mutants.

Mutations are ~~ca~~ classified into two:

(i) Gene mutations:

This is a sudden change in the genetic constitution. examples of gene mutations are

(i) Albinism — a condition where synthesis of a skin pigment ~~fact~~ melanin fails. Albinos have light skin brown hair and pink eyes.

(ii) Sickel cell anaemia; — a condition where the red blood cells attain an abnormal shape (sickel shape) and hence fail to carry enough oxygen in the body.

(iii) Haemophilia — a condition where blood takes too long to clot or may fail to clot after an injury due to lack of clotting factors and some one bleed to death.

(iv) Colourblindness:

Individuals with this condition are unable to distinguish between certain colours e.g between green and red colour

2. Chromosomal mutations: These are mutations due to change in the structure of chromosomes.

Advantages of mutations.

Although mutations are a disadvantage in life, some mutations are beneficial on the other hand especially when they are artificially induced (when they are caused by man).

In plants, induced mutations have advantages such as

1. They give rise to plant varieties which are resistant to drought, ~~and~~ diseases and pests.
2. They give rise to plants with high yield ~~eg larger~~ and improved quality e.g large fruits, fruits with more juice etc.
3. They enable agriculturalists to obtain genetically modified food

In ~~animals~~

In animals;

- Mutations lead to improved milk yied in cattle
- Mutations lead to improved fertility and hence high rate of reproduction.

GENETICS

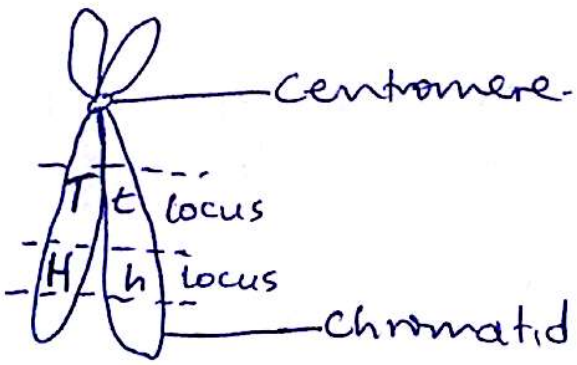
Genetics refers to the study of inheritance of traits/characteristics from parents to their offsprings.

The characteristics of parents are passed to their offsprings by genes

Important terms in genetics.

1. Genes: A geen is a unit of inheritance.
2. Locus : This a space on the chromosome, occupied by a gene.

e.g For gene Tt and Hh, on different loci, can be illustrate as



3. Alleles: These are alternative forms of a gene.

e.g the gene controlling height in a plant can be expressed as

TT, Tt or tt.

each individual letter of a pair, is ~~a~~ an allele

4. Dominant allele: This is an allele which expresses it's character in both homozygous condition and heterozygous Condition.

Dominant alleles are represented by capital letter. e.g T, H, A, B etc.

5. Recessive allele: This is one which cannot express it's character ~~in presence~~ in the presence of a dominant allele. It is represented by small letter.

i.e Hh

dominant ↑ ↖ recessive.

6. Homozygous condition: This is when both alleles of a given gene are similar e.g TT, tt, AA, aa, gg, RR etc.

~~It is~~

A gene can be homozygous dominant or homozygous recessive.

Homozygous dominant genes	homozygous recessive
HH	hh
TT	tt
RR	rr
BB	bb

7. Heterozygous condition:

This is when the alleles of a given gene are not identical (not similar). One is dominant and thee allele is recessive

e.g Tt, Hh, Bb, Aa etc.

8. Genotype: This is the genetic make up of an organism

9. Phenotype: This is the outward expression/appearance of an organism.

e.g black, tall, yellow, male, female etc.

F_1 generation: Refers to the first generation of offsprings from the parents.

F_2 generation: is the second generation offsprings from the parents.

MENDEL's LAWS

Mendel's first law (the law of Segregation).

States that: The characteristics of an organism is determined by internal factors which occur in pairs.

Of a pair, only one such factor is represented in a single gamete.

The internal factors are actually the alleles, which segregate (seperate) during formation of gametes by meiosis.

Monohybrid Inheritance

This is the inheritance of a single character at a time, from parents to offsprings.

Example:

1. In maize, ~~the~~ tall condition is dominant over short condition.
A homozygous tall maize plant was crossed with a short plant. Using suitable genetic symbols, determine the phenotypes of the offsprings.

working

First define symbols;

let the allele for tallness be ..... T
let the allele for shortness be --- t.

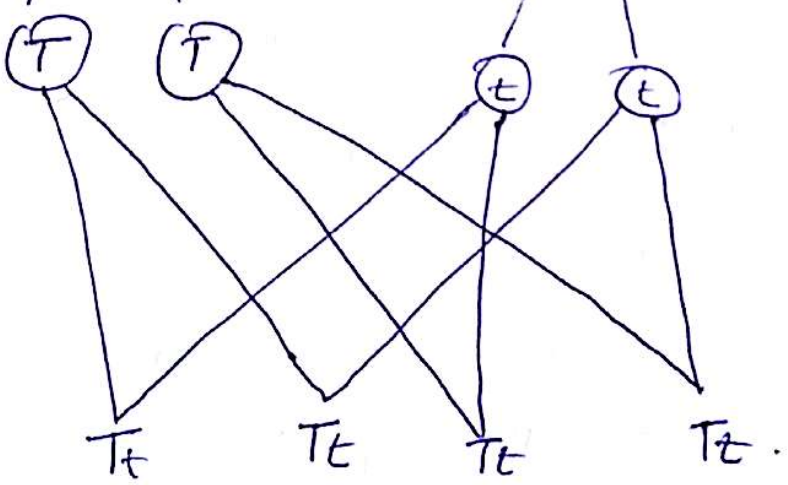
Phenotypes of parents: Tall Short.

genotypes of parents: TT x tt

meiosis:

gametes: T T t t

~~Fertiz~~ Fertilization:



F_1 genotypes: Tt Tt Tt Tt.

Phenotype: All are Tall.

2. From the previous example, assuming a heterozygous tall plant was crossed with a short plant;

working.

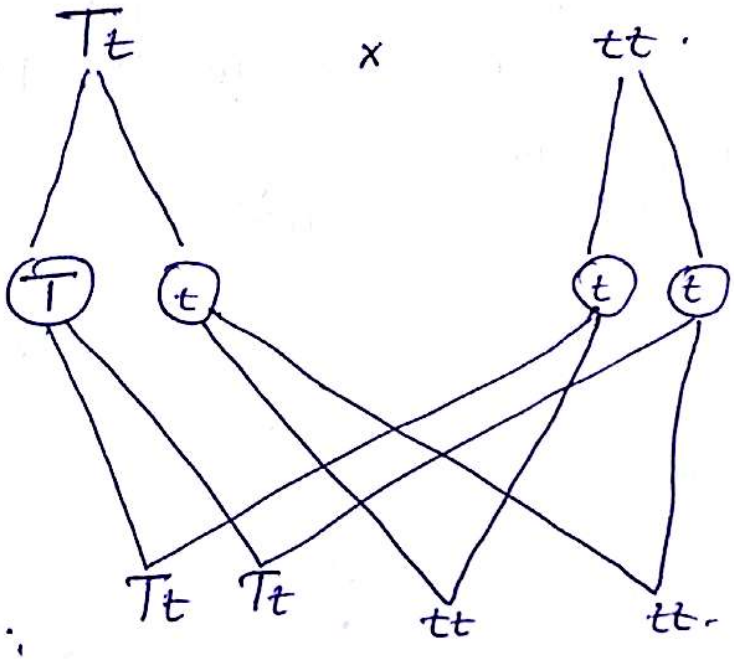
Phenotype of Parent: Tall × short.

genotype: Tt × tt.

meiosis

gametes: T, t × t, t

Fertilization



F1 genotypes: Tt, Tt, tt, tt.

Phenotypes: 2 tall and 2 short.

N.B: The phenotypic ratio in this case is 1:1

3. Make a genetic cross if two heterozygous tall plants were crossed. Determine the genotype, ~~and~~ phenotype and phenotypic ratio

4. In pea plants, green colour of flowers is dominant over purple colour. Make a genetic cross of and determine the phenotype of offspring if homozygous plant with green petals was crossed with a purple flowered plant.

Working:

Let allele for green be ---- H
Let allele for purple be --- h.

Phenotype of parent: Green flower · Purple flower

Genotype: HH x hh

Meiosis:

Gametes: (H) (H) (h) (h)

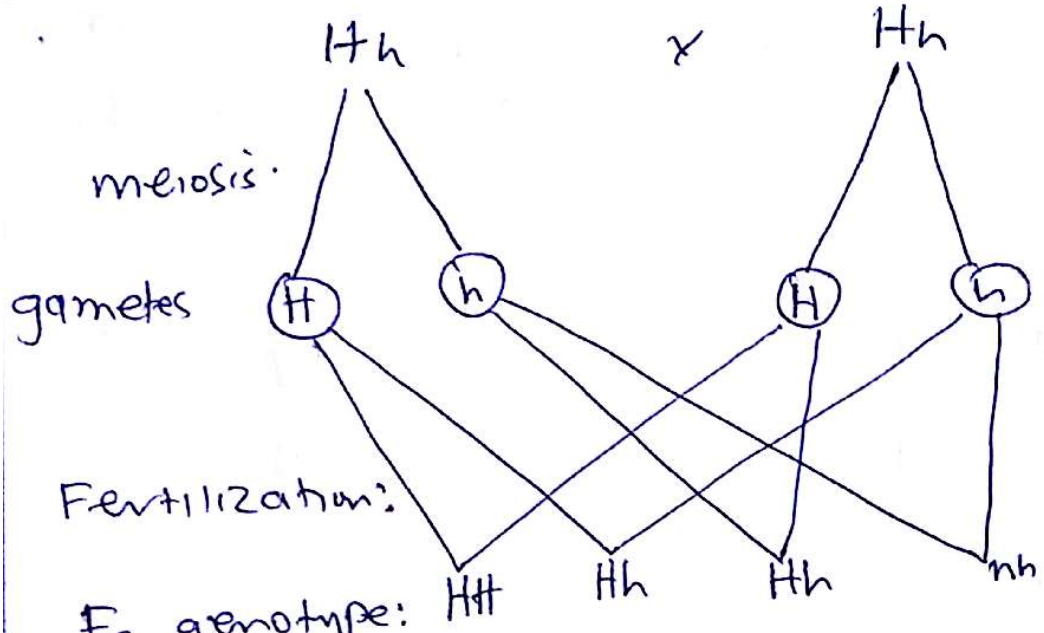
F_1 genotype: Hh Hh Hh Hh

Phenotype: All have green flowers.

N.B: To get F_2, you pick two organisms from F_1 and cross them.

For this case,

P.T.O



F_2 phenotype: 3 green flower : 1 with purple flower.

Incomplete dominancy

This is the inheritance where neither of the two alleles of a gene is dominant over the other. Each contributes equally to the phenotype/there is equal expression of each allele in the phenotype, resulting into a ~~mixture~~ phenotype which is intermediate between those of the parent.

This is seen in the inheritance of flower colour in some plants where crossing a plant with red flowers and another one with white flowers gives rise to offsprings all with pink flowers.

let allele for red flower be - - - R
let the allele for white flower be B.

red flowered plant.

white flowered plant

Genotypes RR x BB

meiosis;

gametes (R) (R) (B) (B)

Fertilization:

F_1 genotype: RB RB RB RB.

Phenotype: All have pink flowers.

N.B: For F_1, non has characteristic similar to that of either parents.

However, when F_1 are crossed (selfed), F_2 obtained ~~have~~ show a phenotypic ratio of 1:2:1

ie RB x RB.

(R) (B) (R) (B)

RR RB RB BB.

red pink white

Co dominance

This is the inheritance where the alleles of a gene are equally dominant. Both express themselves in the phenotype.

In man, codominance is seen in the inheritance of blood groups. There are four types of blood groups.

i.e

blood group	determined by	genotypes
A	gene A	AA or AO
B	gene B	BB BO
AB	both genes A and B	AB
O	gene O	OO

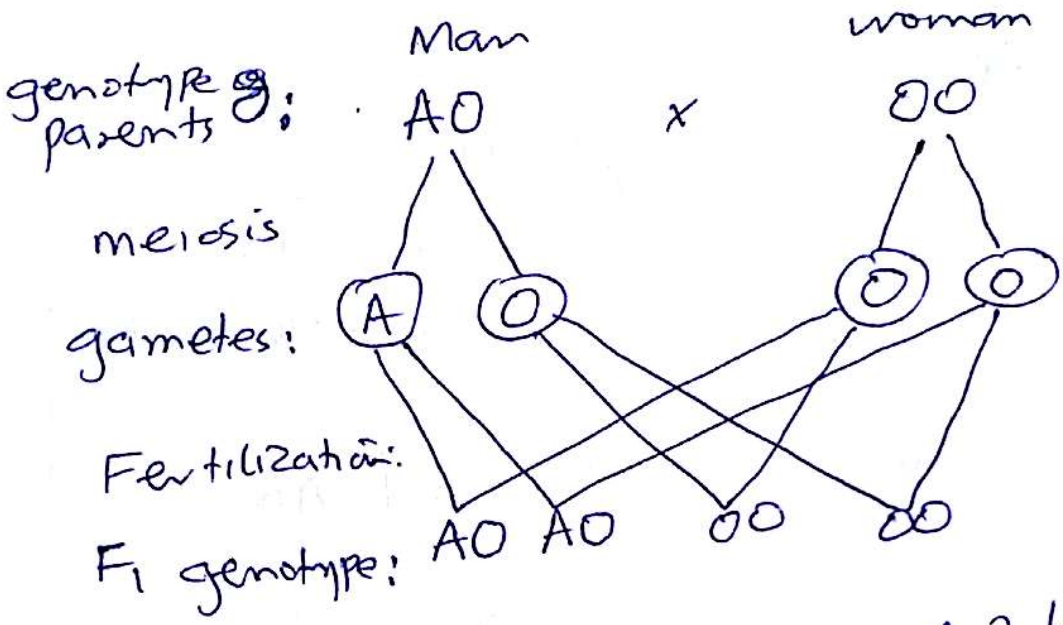
~~Alleles~~ Genes A and B are codominant ~~to~~ ~~while~~ while gene O is recessive to both A and B.

hence allele O can only express it's self in homozygous condition. (i.e in absence of A and B)

genetype	blood group
AA	A
AO	A
BB	B
BO	B
OO	O

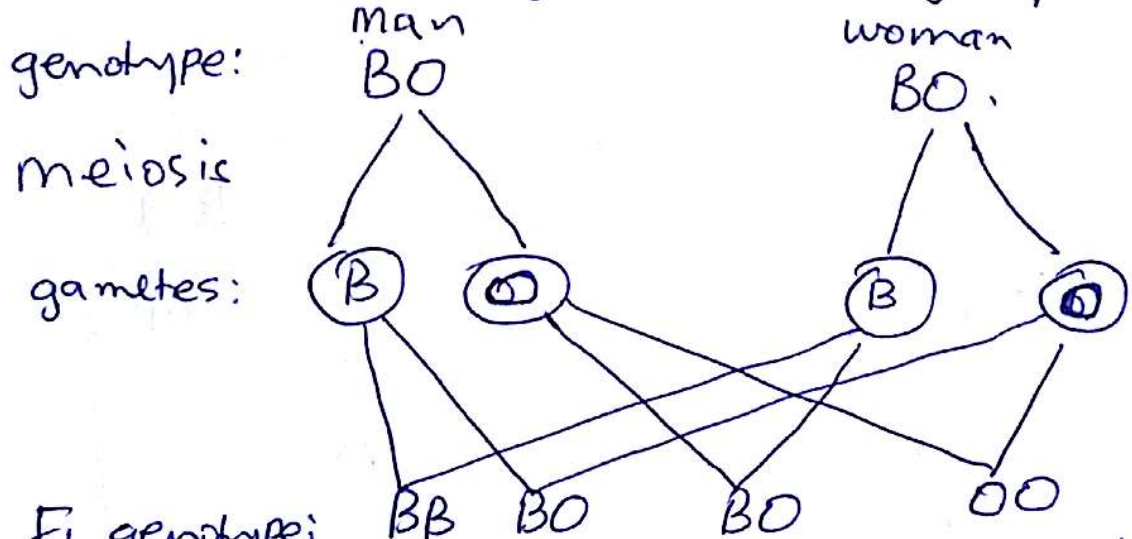
Examples of crosses involving blood group

1. A man heterozygous for blood group A was married to a woman with blood group O. What are the phenotypes of their children?



phenotype: 2 have blood group A, and 2 have blood group O.

2. Assuming both the man and woman were heterozygous for blood group B.



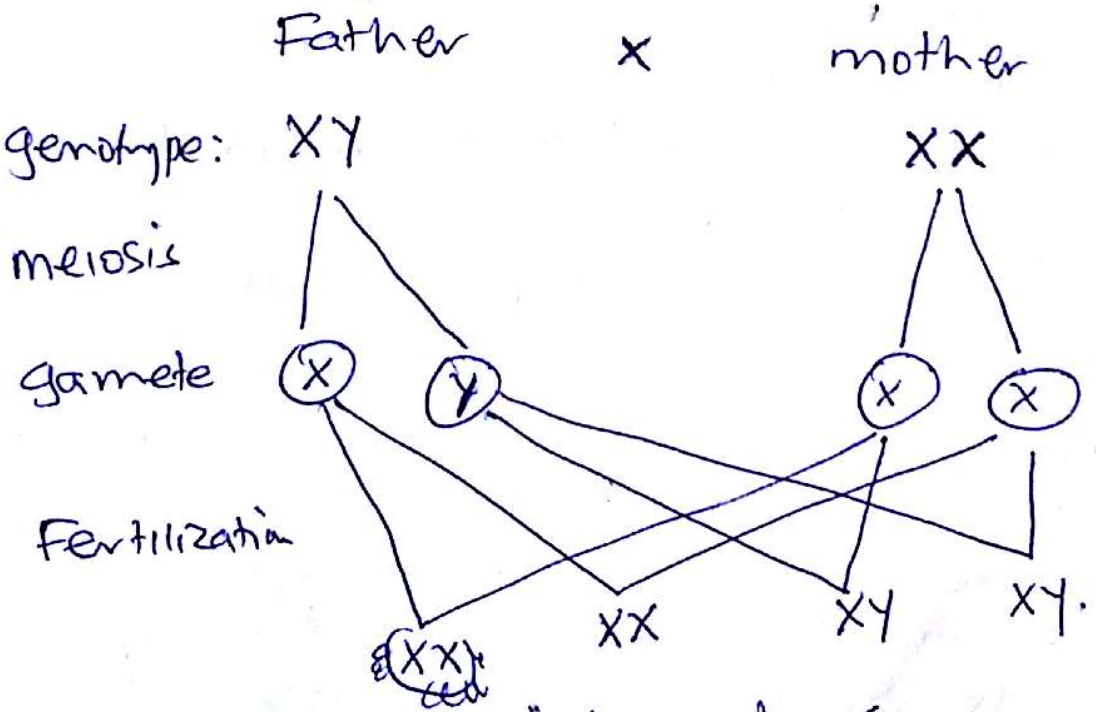
phenotypes: 3 with blood group B : 1 with blood group O.

How sex is determined in man

Man has 23 pairs of chromosomes i.e 46 chromosomes. Of the 23 pairs, one pair is a pair of chromosomes which determine sex. These are called sex chromosomes which is XY pair

- Chromosome Y determines male sex
- Chromosome X determines female sex.

All female gametes (ova) carry ~~X chromosome~~ one X chromosome, but for males, some sperm cells (male gametes) carry Y chromosom and others carry X chromosome. For this reason, the chance to produce a boy or girl is determined by which type of the sperm cell fertilizes the ovum.



2 girls and 2 boys.

XX pair determines female sex (are girls) while XY are boys.

In humans there are genes which are carried/transmited on the sex chromosomes. These genes are called sex linked genes while the character controlled by such genes are called sex linked characters.

Definition:

Sex linked characters are those characters controlled by genes which are transmited on sex chromosomes.

Examples of sex linked characters in man are

1. haemophilia: This is a disease condition where blood fails to clot after an injury, due to lack of clotting factors in blood.
2. Colour blindness.

These disease conditions are mutations as we saw earlier.

Crosses involving Sex linked Characters.

N.B: 1. Sex linked characters are controlled by recessive alleles

2. The alleles for sex linked characters are carried only on X chromosome, and non is carried on Y-chromosome

PTO.

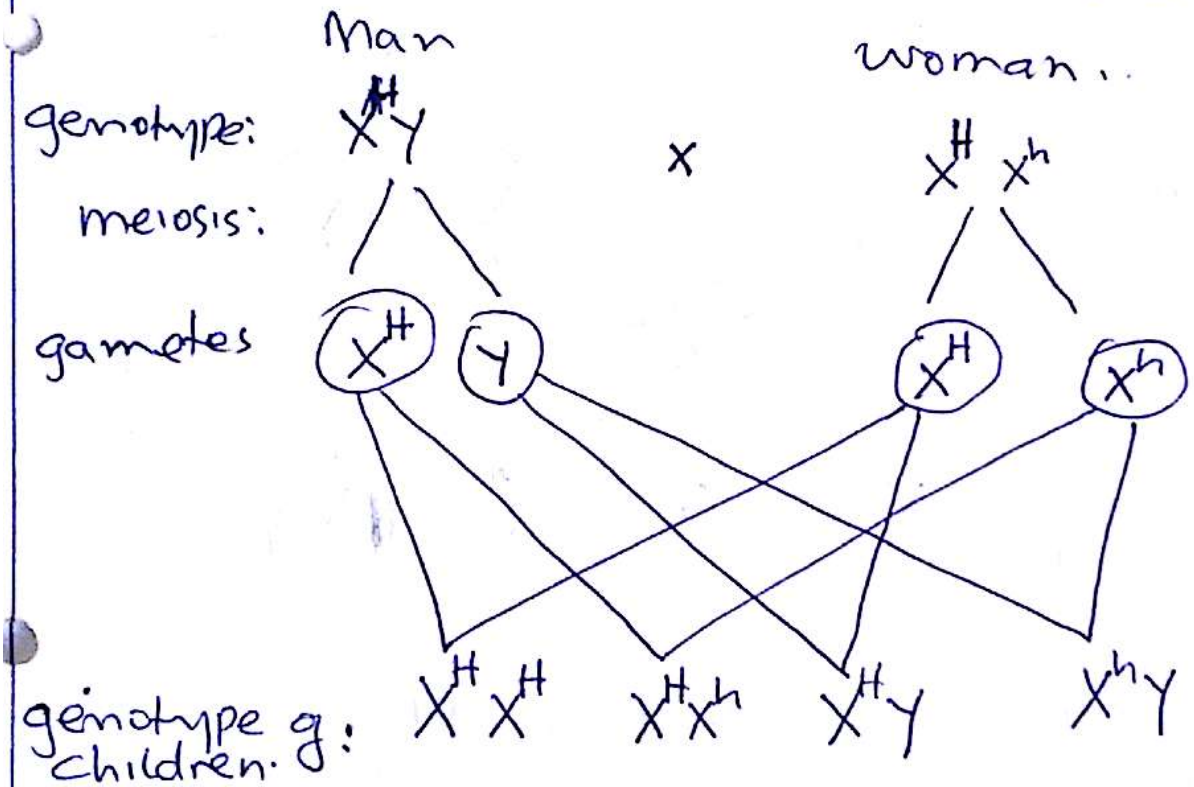
Example 1.

A woman who was a carrier for colour blindness was married to a normal man. What is the phenotype of their children?

Working.

Let allele for colourblindness be...h

Let the allele for normal condition be - - - - - - H.



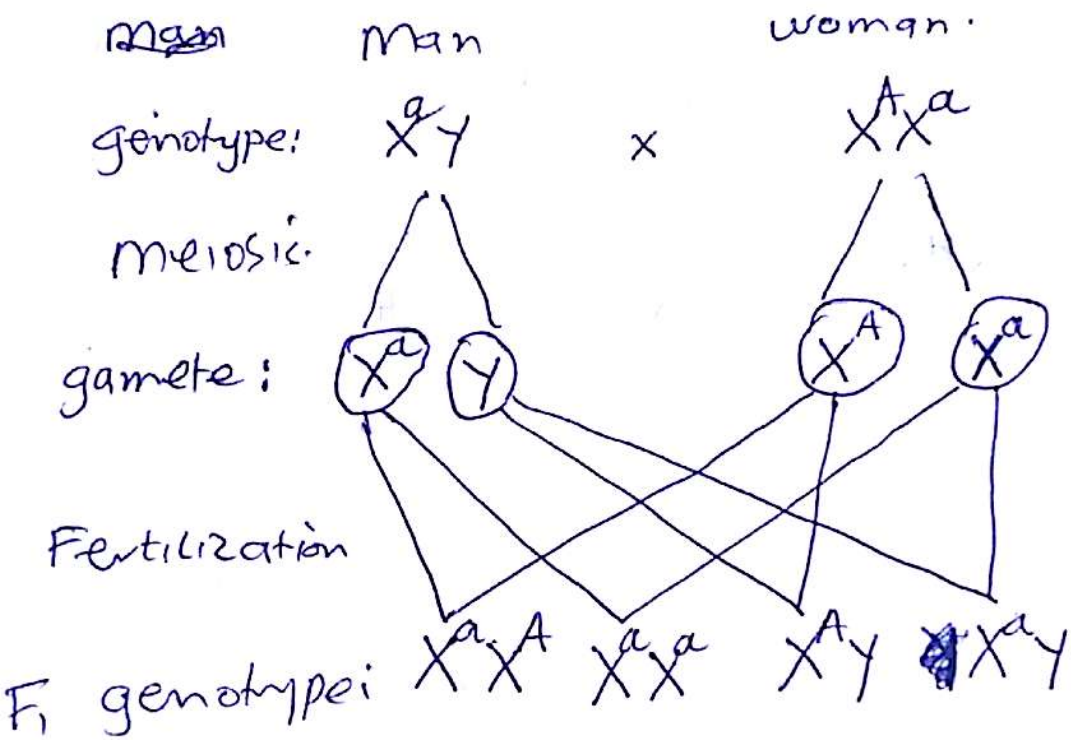
Phenotypes: 2 normal girls : 1 normal boy : 1 colourblind boy.

N.B: Females who are heterozygous are called carriers. However, they are phenotypically normal since they carry recessive allele.

~~2. A man with haemophilia mar~~

2. A colourblind man married a woman who is a carrier, what are the phenotypes of their children?

Let the allele for normal condition be A
Let the allele for colourblindness be a.



Phenotype: 1 normal girl : 1 colour blind girl : 1 normal boy : 1 colour blind boy.

ALBINISM (Albino character)

- Albinism is a genetic condition where a person lacks the skin pigment called melanin.
- It is controlled by a recessive gene which arises from genetic mutation.
- It is caused by having a double recessive gene for skin pigmentation. Therefore for one to be an albino, he must be homozygous recessive for the character.
- Homozygous dominant and heterozygous dominant individuals always have normal skin colour. Heterozygous are just carriers of the albino trait. Albinism is not a sex-linked character.

Example

Qn: What is the probability of children born having normal skin colour if a normal woman marries a man who is heterozygous for albinism?

Solution:

Let S represent allele for normal skin colour

Let s represent allele for albino

Man X Women.

Phenotype: Normal skin Normal skin

Genotype: Ss Ss

Gametes: S s S S

Offsprings: Ss Ss Ss Ss

Number of children with normal skin colour is 4.

Therefore the probability of children with normal skin colour;

$$= \text{Number of } \frac{\text{children with normal skin colour}}{\text{Total number of children possible}}$$

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

INHERITANCE OF SICKLE-CELL ANAEMIA.

Sickle-cell anaemia is an inborn disease and can occur in both male and female. It is not a sex-linked disease.

Sickle cell condition exists during low oxygen tension in the environment and in the blood stream.

A person suffering from sickle cell anaemia has a large proportion of his/her red blood cells sickle-shaped.

Under low oxygen tension, the red blood cells lose their normal biconcave shape and change to a sickle shape. In this shape, they are unable to carry oxygen.

Sickling of red blood cells is due to crystallisation of the abnormal haemoglobin under low oxygen tension. It is controlled by a recessive allele.

The disease is due to the presence of mutant haemoglobin in the red blood cells, affected.

- Normal haemoglobin is called Haemoglobin A abbreviated as HbA.
- Sickle cell haemoglobin is called Haemoglobin S, abbreviated as HbS.

- A person inherits only one of each of these from each parent.
- Most people are homozygous dominant for the normal haemoglobin and have genotypes HbA HbA
- Sickler people are homozygous for recessive mutant gene and therefore have the genotype HbS HbS
- Some people are heterozygous HbA HbS (carriers).
- The heterozygous carriers completely live normal lives and do not show the sickle cell anaemia. The allele HbA for normal haemoglobin is dominant over allele for abnormal HbS.

Characteristics of sickle cell anaemia

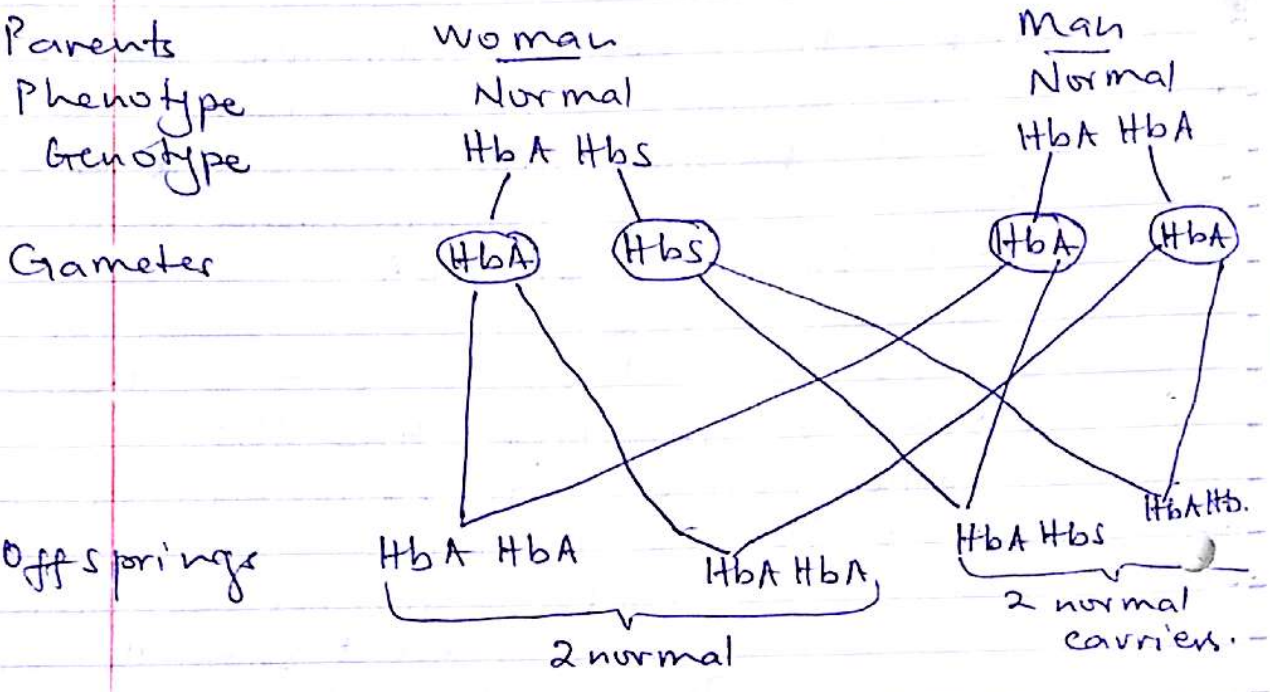
- A person has severe anaemia as sickle shaped red blood cells soon die off.
- Retarded physical growth.
- Having low rate of metabolism and hence less active.

Task:

The gene for normal production of haemoglobin is dominant to the mutant gene for sickle cell anaemia. If a woman heterozygous for sickle cell anaemia married a normal man. Illustrate using suitable symbols, The possible genotype and phenotype of their children

Let HbA represent allele for normal haemoglobin

Let HbS represent allele for Sickle cell haemoglobin.



Possible genotypes of children
2 HbA HbA ; 2 HbA Hbs

Phenotype of children: All normal.

MUTATIONS:

A mutation is a sudden irreversible change in genes or chromosomes of an organism.

Mutations due to change in chromosome number include;

(i) Darwin's syndrome (manpolism):
This is caused by addition of one extra chromosome leading to 47 chromosomes instead of the normal number of 46 in human body cells.

Symptoms include:
Mental retardation, reduced growth.
Reduced resistance to infection.

(ii) Klinefelter's syndrome
caused by addition of an extra X-sex chromosome leading to weak males with the genotype XXy. These males have the following characteristics.
- They are sterile males (produce no sperms)

- They possess female characteristics eg big breasts, soft voice.
- They have low intelligence.
- They possess small testes and little facial hair.

(iii) TURNER'S SYNDROME.

Caused by deletion or lack of an X-chromosome leading to a weak female with genotype XO. Such females have poorly developed sexual characteristics and are sterile. They normally do not survive pregnancy and its common in females producing pre maturely.

(iv) POLYPLOID

In this case the number of chromosomes may double or even triple. A polyploid is having extra whole set of chromosomes eg

$2n + n = 3n$ instead of $2n$ which is normal.