GENETICS

Genetics is the scientific study of heredity and variations between organisms while inheritance describes how the similarities are transferred from the parent to the offspring. The similarities are in form of characteristics such as skin colour, intelligence, height and many others.

Mendel was the first scientist to study genetics and inheritance.

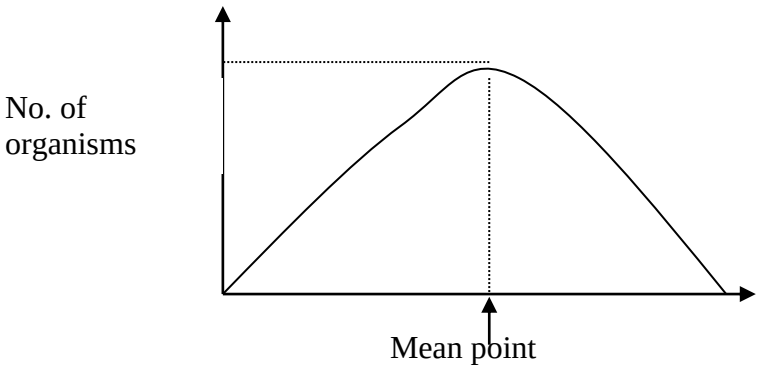
Categories of variation

There are two types of genetic variations.

1. Continuous variations.

These are variations that show a gradual change in individuals without a clear-cut division between the two extremes. It results into formation of intermediates. Such variations include height, intelligence, skin colour, yield in plants, etc. In such variations, organisms are usually very many around the mean/average point.

Graphic illustration of continuous variation



2. Discontinuous variation.

This is a variation, which shows a clear-cut difference between the two extremes without intermediates. This results into expression of only two phenotypes. Examples of discontinuous variations include, tongue rolling, blood groups, sex, etc.

Causes of variation

Some variations are inherited and are called inherited variations while others are occupied as a result of the environment hence called environmental variations.

Examples of inherited variations are blood groups, eye colour, albinism, hair, etc.

Examples of environmental variations are knowledge, etc.

Environmental factors that cause variations

- ✓ Diet
- ✓ Pathogens
- ✓ Altitude
- ✓ Light

Factors that cause inherited variations

- ✓ Mutation
- ✓ Crossing over
- ✓ Fertilization

Terms used in genetics.

1. **Chromosome**. These are thread-like structures bearing genes and located in the nucleus.
2. **Chromatid**. This is half of a chromosome split longitudinally.
3. **Bivalent**. This is a pair of homologous chromosomes.
4. **Gene**. This is a unit of the hereditable material found on the chromosome and responsible for controlling a particular trait/character.
5. **Allele**. This is the alternative form of the same gene. most genes are made up of two alleles. Alleles of the same gene are represented by the same letter but the dominant allele is represented by a capital letter and the recessive allele by a small letter in the case of dominant-recessive characters
6. **Diploid**. This is a description of a cell, which has a whole set of chromosomes.
7. **Haploid**. This refers to a cell with half the set of chromosomes.
8. **Genotype**. This refers to the genetic composition of an organism.
9. **Phenotype**. This is the physical appearance or the outward expression of an individual.
10. **Dominant gene/dominant allele**. This is a description of a gene /allele whose effect is seen in the phenotype of the heterozygous individual. The effect of the dominant gene/allele is seen in the phenotype even in the presence of another gene/allele.
11. **Recessive**. This is a description of a gene whose effect is not phenotypically expressed in the heterozygous state. The effect of a recessive gene/allele is not seen in the presence of another (dominant) gene/allele.
12. **Homozygous**. This refers to a gene with two identical alleles for example if T represents the gene for height where tallness is dominant to shortness then the allele for tallness is T and that for shortness is t. an individual with TT is said to be homozygous tall and tt is said to be homozygous short.
13. **Homozygous dominant**. This is where both alleles of a gene determine a dominant character.
14. **Homozygous recessive**. This is where both alleles of a gene determine a recessive character.
15. **Heterozygous**. This refers to a gene with two different alleles for example if T represents the allele for tallness and t for shortness then Tt is the heterozygous state of this gene.

16. **Hybrid**. This is an offspring produced by parents of two different pure lines.
17. **Incomplete dominance**. This is a condition where neither of the genes is dominant over the other.
18. **Gametes**. These are reproductive cells.
19. **Fertilization**. This is the fusion of the male and female gametes to form a zygote.
20. **Monohybrid inheritance**. This is a type of inheritance, which involves studying a single pair of contrasting characteristics.
21. **Dihybrid inheritance**. This is a type of inheritance, which involves studying two pairs of contrasting characteristics at ago
22. **Test cross**

    This is a type of back cross which involves crossing an offspring having a dominant character with its recessive parent in order to determine the test of that offspring.
23. **Back cross**

    This is the mating of an offspring with one of its parents.

MENDEL'S EXPERIMENT

For his experiment he collected one of the varieties of garden peas (*pisum sativum*) with contrasting features such as one variety was producing tall plants when stems are about 200cm and another short plant with stems of 25cm. He crossed these plants for his experiments.

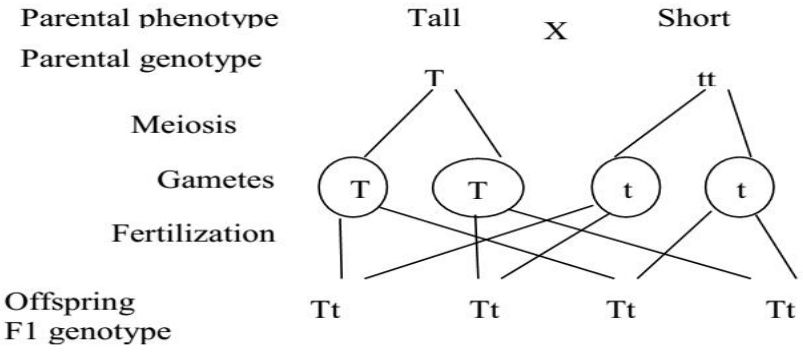
He crossed pure tall pea plants with pure short pea plants and all the off springs were tall (F1 generation)

Tallness was the dominant character and shortness the recessive character.

The dominant character is represented using a capital letter while the recessive character is represented using a small letter.

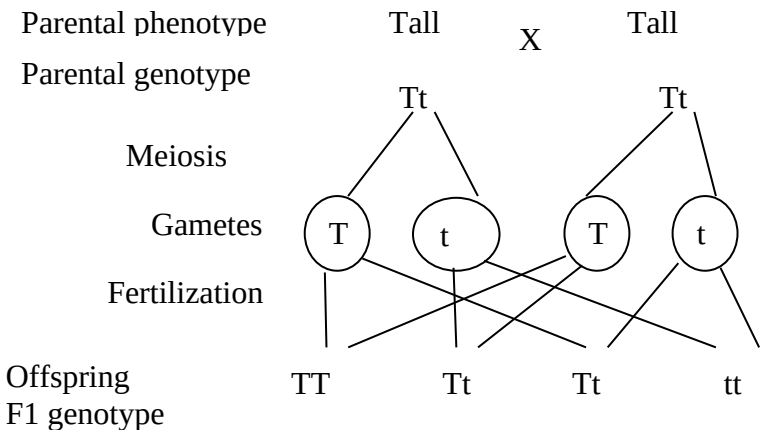
Let the gene for tallness be T

Let the gene for shortness be t



Offspring phenotype: All tall

Mendel then selfed the plants of the F1 generation and obtained an F2 generation with tall and short plants in a ratio of 3:1



Genotypic ratio; TT:Tt:tt = 1:2:1
Phenotypic ratio; 3 tall : 1 short

Mendel's conclusions

Mendel suggested the following to explain his results.

1. Gametes like pollen grains and ovules of the garden peas carry characters determining factors through which resemblance is past on from one generation to the next.
2. A character like height of the garden pea is controlled by a pair of genes. These separate during formation of gametes and only one goes into each gamete. This means that only half of the usual number of genes is present in the gametes. However the normal number is restored at fertilization by the fusion of the two gametes
3. He named a gene determining a dominant character as a dominant gene and one determining a recessive character as a recessive gene. In his representation dominant genes were given capital letters and recessive genes were given small letters.

Mendel's laws of inheritance

From his observations, Mendel put up two laws of inheritance.

First law: The law of segregation.

This law states that the character of an organism is determined by a pair of alleles. Only one allele of such a pair is carried in a gamete.

Second law: The law of independent assortment.

This states that each of the alleles in a pair may combine with another allele from another pair randomly.

Conclusions from Mendel's' crosses.

1. A character can be transmitted from parent to offspring independent of other characters.
2. Genes occur as a pair of alleles.
3. Only one allele of the same gene is carried in a single gamete.

MONOHYBRID INHERITANCE

Inheritance is the passing over of characteristics of the parents to their off springs. Monohybrid inheritance involves the study of how one character is inherited from the parents to the off springs. Mendel carried out several experiments on peas to study monohybrid inheritance.

Mendel chose garden peas for his experiments because of the following reasons:

1. They grow very fast and produce results in a very short period of time.
2. They are relatively small and can be grown on a small plot for study purposes.
3. Some of their characters are controlled by single genes, which make it easy to study them.
4. They have characteristics, which show clear-cut differences without intermediates like tall and short, green and yellow cotyledons, etc.

He therefore concluded that their reproduction can be manipulated by pollination.

Questions:

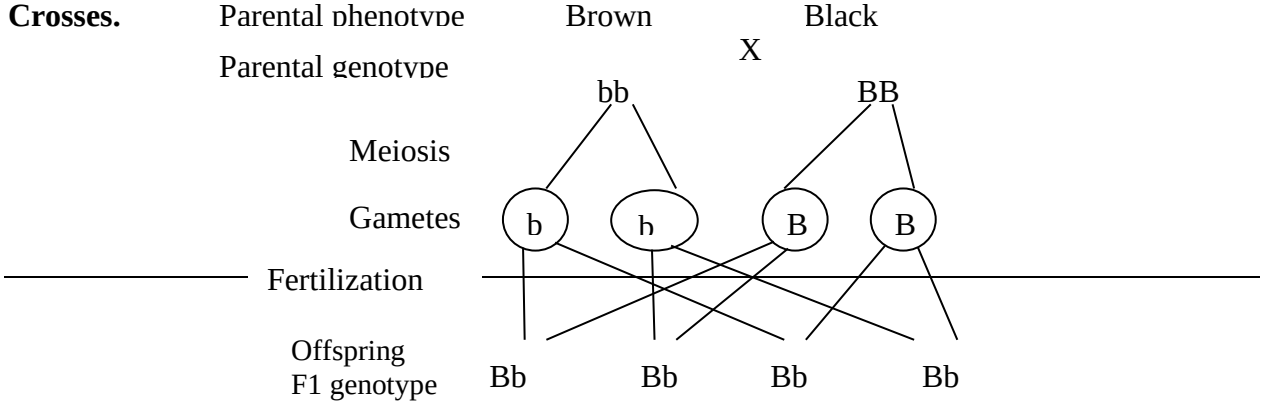
What would be the offsprings for a cross between homozygous black and homozygous brown. Take B for black and b for brown.

Let the gene for black fur be represented by B and that for brown b.

Note.

1. It is one gene controlling a character, which is fur colour. For this reason we use the same letter
2. Black colour is dominant that is why we use (B) and brown is recessive (b)
3. The term pure-breeding is used to mean homozygous for that particular gene.

Crosses.

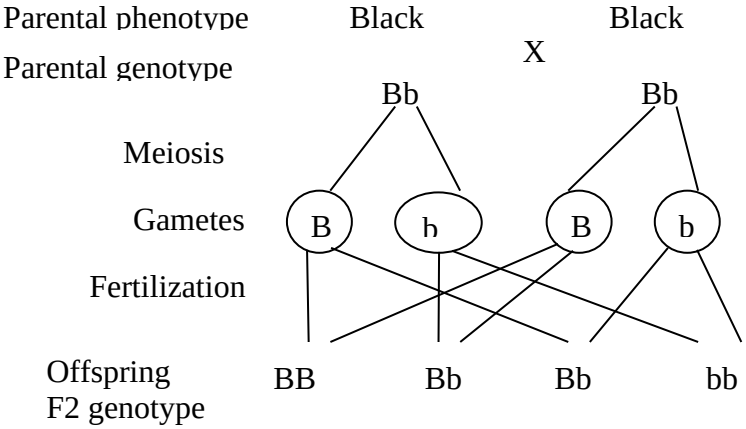


Offspring genotype: all Bb (heterozygous)

Offspring phenotype: all black.

They are all black because black is dominant to brown and it shows up in the heterozygous state.

Consider selfing of F1 (crossing two offsprings of F1 above).



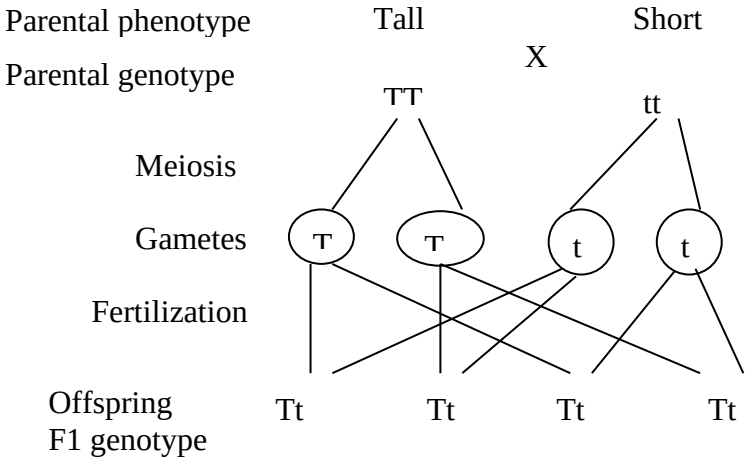
F2 phenotypic ratio. 3 black : 1 brown

3 : 1

Example ii

Consider a gene for height in garden peas. Tallness is dominant over shortness.

Let the gene for tallness be T and that for shortness t. show the cross between pure-breeding tall pea and a pure-breeding short pea.



F1 phenotype. All offsprings are tall.

Selfing of F1 produces F2 with a phenotypic ratio of 3 tall to 1 brown. (3:1)

Monohybrid inheritance in human beings

1. Albinism

This is a condition in human beings where the individual fail to produce skin pigments called melanin.

Albinos have;

- ✓ Light skin
- ✓ White hair
- ✓ Pink eyes
- ✓ They are sensitive to bright light

Albinism is caused by a recessive gene.

Example

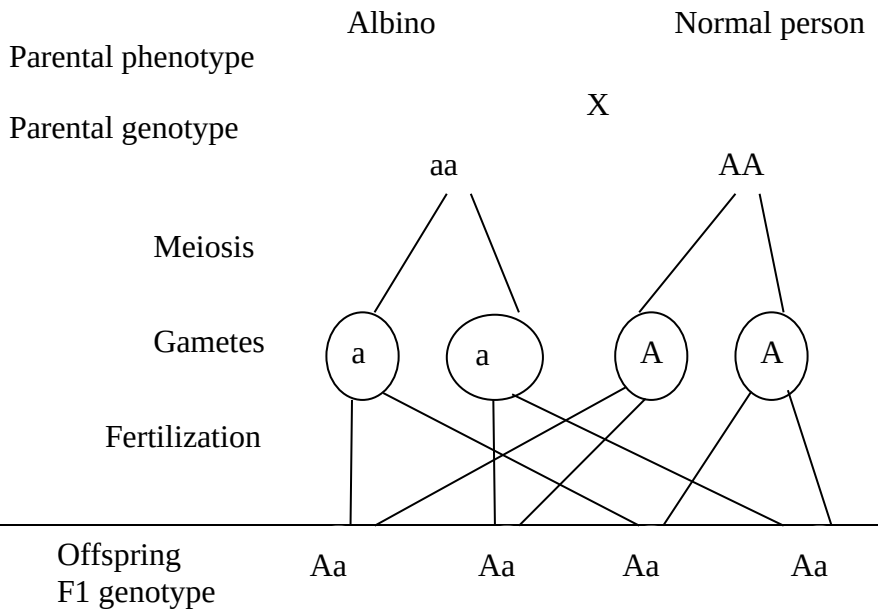
Let A be the allele for normal skin colour

Let a be the allele for no skin colour

Genotype	Phenotype
AA	Normal skin colour
Aa	Carrier for albinism
Aa	albino

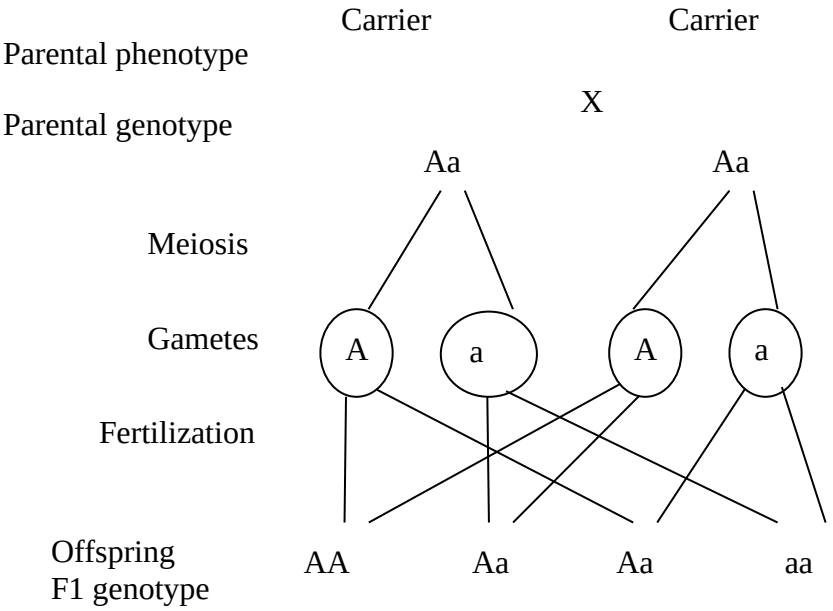
QUESTIONS:

1. What would be the offsprings if an albino marries a normal person?



All the offsprings will be carriers of albinism

2. What would be the offsprings when 2 individuals who are carriers of albinism get married?



Genotypic ratio; 1 normal : 2 carrier: 1 albino

1:2:1

Phenotypic ratio; 3:1

BACK CROSS OR TEST CROSS

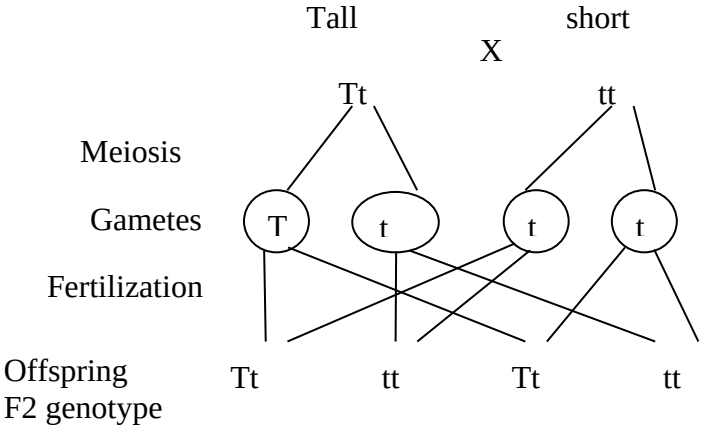
A test cross is used to distinguish between homozygous and heterozygous dominant forms. This is when an F1 individual with the phenotype of the dominant parent is crossed with the recessive parent to determine the phenotype of the parent.

If the F1 is homozygous dominant, all the offsprings will show the dominant character.

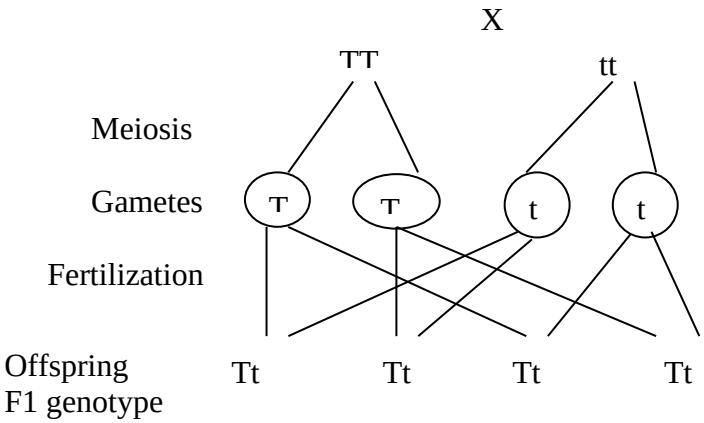
If the F1 individuals are heterozygous, a 1:1 ratio of dominant or recessive characters is obtained. E.g.

let T represent the allele for tallness

let t represent the allele for shortness



Two offsprings will be heterozygous tall and 2 will be homozygous short.



Heterozygous tall

QUESTION:

The fruit fly (drosophila melangaster) usually has wings twice as long as its abdomen but some drosophila have very short or vestigial wings. A long winged drosophila (male) was crossed with a vestigial winged female drosophila and all the F1 offsprings were long winged. The long winged F1 generation were then mated.

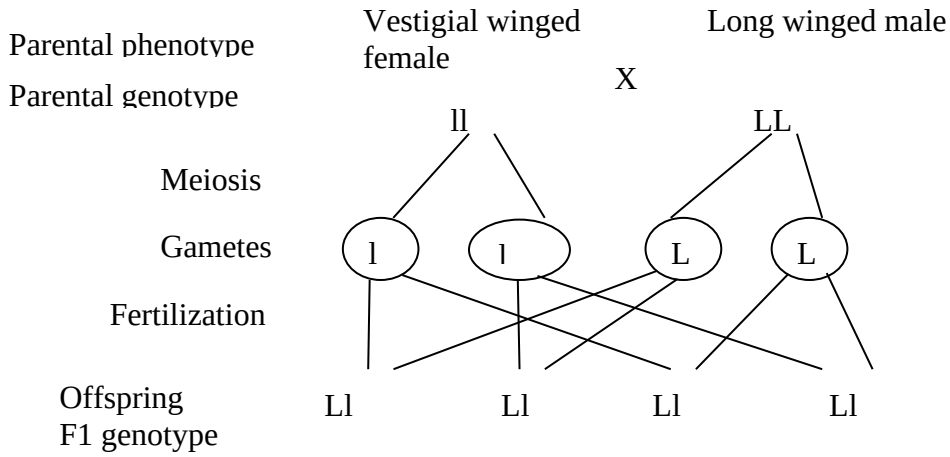
i) How can the cross be represented diagrammatically
ii) State the phenotypes of the offsprings in the F2 generation and state their genotypic ratio.
iii) What is the percentage of the vestigial winged drosophila flies in the the F2 generation.
iv) A drosophila is normally used in experiments on heredity, why do you think it is suitable for such experiments.

Solution:

Let the gene for long wing be L and that of vestigous wing l

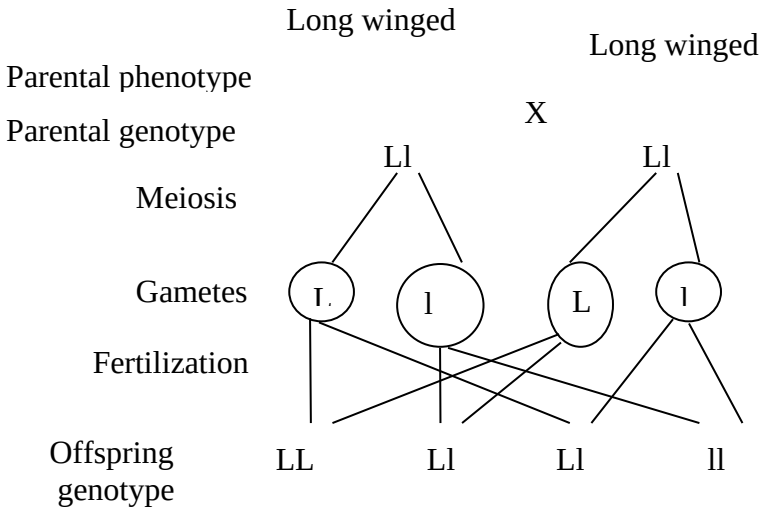
The long winged female can be LL or Ll because long winged is dominant to short winged.

i)



F1 phenotype. All long winged.

ii)



One of the offsprings will be homozygous long winged

Two of them will be heterozygous long winged

One of them will be homozygous short winged or vestigial winged

Genotypic ratio 1:2:1

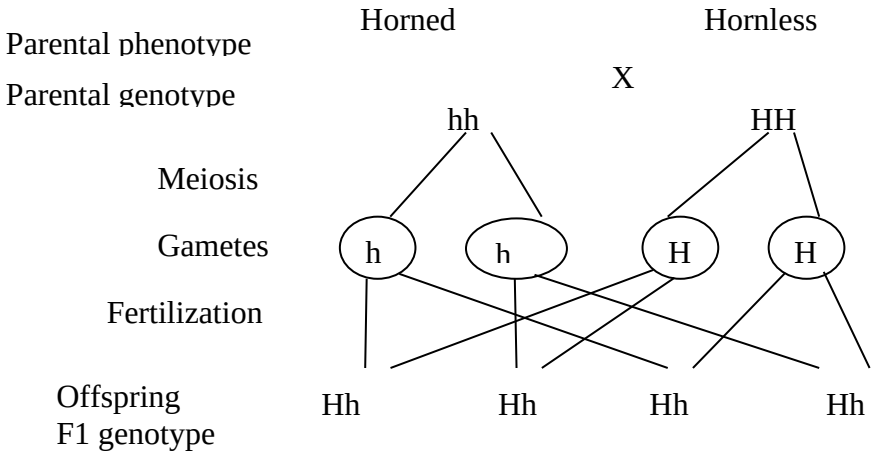
iii) ¼ x100=25%

iv) It's because they have contrasting characters and have short life span and show clear cut differences.

In cattle, the gene for hornless condition is dominant over one for horns. A hornless cow was mated with a horned bull. Using genetic symbols, show the possible phenotype and genotype of the F1 offspring.

Let h represent the allele for horned bull.

Let H represent the allele for hornless bull

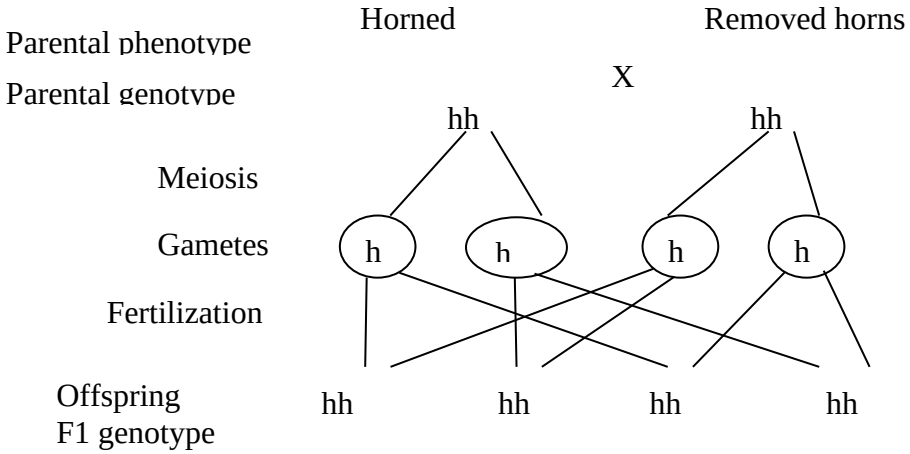


All were horned cows.

A bull whose horns were removed was mated to a horned cow. Show the possible genotypes and phenotypes of the F1 offsprings. Give a reason for your answer.

Let h represent the allele for horned bull.

Let H represent the allele for hornless bull



All are horned

Because the bull with cut off horns still has the genes for horned and cutting off the horns doesn't change the genes.

SEX DETERMINATION IN HUMAN BEINGS

There are 23 pairs of chromosomes in each cell of the human body. One pair determines the sex of the individual and they are called sex chromosomes.

In the human female, sex chromosomes are homologous (XX) so females produce one type of gamete which is X.

In the human male, sex chromosomes are not homologous and they are heterozygous (XY). However, the Y chromosomes do not carry any genes, they are empty hence it is the X or Y chromosome produced by man that determines the sex of the offsprings. When the ovum is fertilized by an X sperm, a female baby XX is born.

When it is fertilized by a Y sperm, a male baby is born.

Hence it is the male which determines the sex of a human baby.

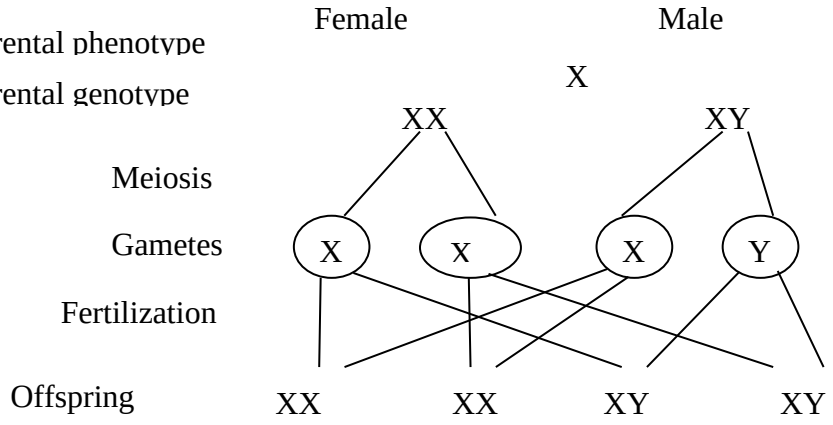
The Y sperms are more active and persistent than the X sperms. This increases the chances of an ovum to be fertilized by a Y sperm. So to every 100 girls, 120 boys are born but XY baby boys are not so tough as the XX baby girls due to this; more boys than girls die at the time of birth.

QUESTION;

What would be the offsprings when a male mates with the female.

State the genotypic ratio of the offspring.

v)



Genotypic ratio 1:1

SEX LINKED TRAITS/CHARACTERS

These are traits or genes associated with the sex of the individual. These characters are carried on the sex chromosomes and are controlled or determined by the genes on those chromosomes. Such characters appear in a recessive form hence are very common in males than in females. Such characters include;

- ✓ Colour blindness

- ✓ Haemophilia (bleeder disease)
- ✓ Sickle cell anaemia
- ✓ Baldness
- ✓ Etc.

Inheritance of colour blindness

Colour blindness is a defect of the eyes caused by a recessive gene on the X chromosome.

Example

Let B be the allele for normal colour vision

Let b be the allele for colour blindness

Genotype	Phenotype
X^BX^B	Normal female
X^BX^b	Carrier female
X^bX^b	Colour blind female
X^BY	Normal male
X^bY	Colour blind male

QUESTION:

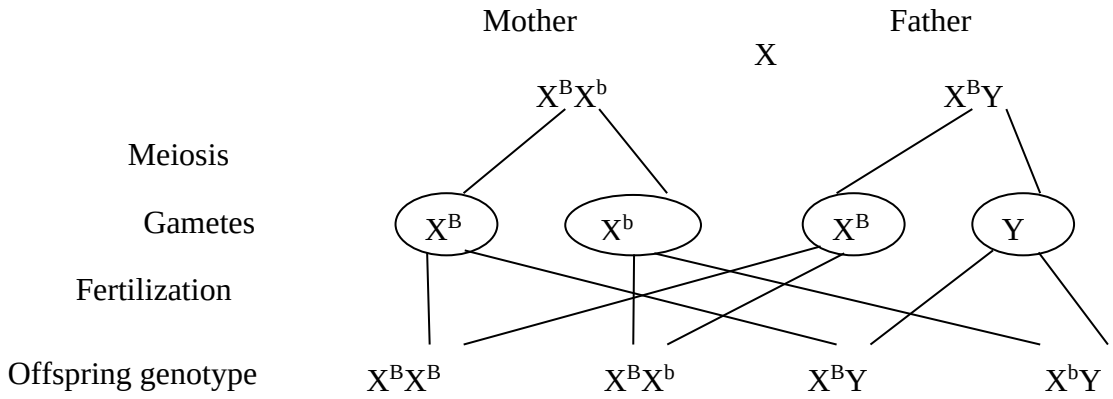
1. i) what would be the offsprings when a carrier female for colour blindness marries a male with normal colour vision.

   ii) write the genotypic ratio of the offsprings and make a comment of their condition.

Solution:

let B represent the allele for normal colour vision

let b represent the allele for colour blindness.



Genotypic ratio 2:1:1

2 will be normal girl (female)

1 will be normal boy (male)

1 will be carrier girl (female)

1 will be colour blind boy (male)

2. What would be the offspring if a colour blind woman marries a normal man.

Solution:

Inheritance of haemophilia (bleeder disease)

It is a disease in which blood takes a long time to clot at a wound. It is also known as the bleeder's disease. This disease is caused by a recessive gene which is carried on the X chromosome.

Let H be the allele for normal blood clotting

Let b be the allele for haemophilia

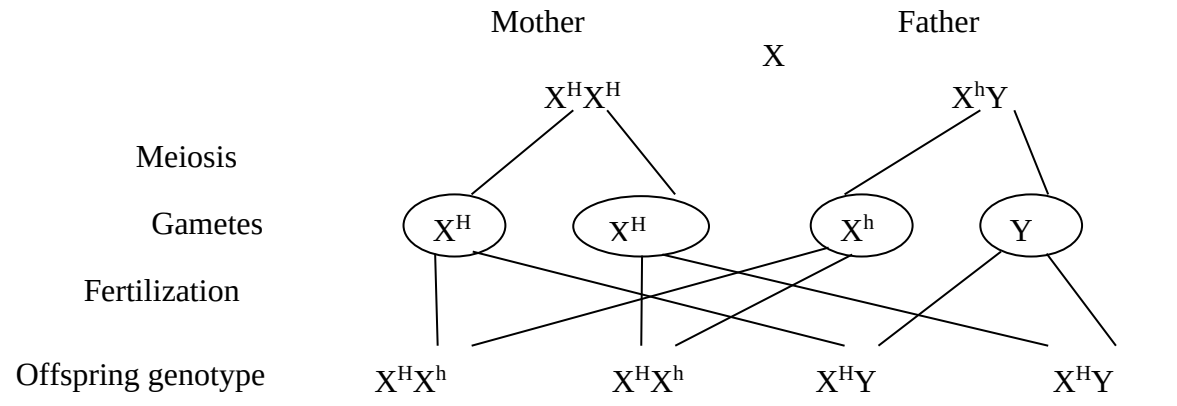
Genotype	Phenotype
X^HX^H	Normal female
X^HX^h	Carrier female
X^hX^h	Haemophiliac female
X^HY	Normal male
X^hY	Haemophiliac male

QUESTION:

What would be the offsprings if a normal woman marries a haemophiliac man?

let H represent the allele for normal blood clotting

let h represent the allele for haemophilia



2 carrier females: 2 normal males

Sex limited traits

These are characteristics that only show in one sex e.g. secondary sexual characteristics, hairy pinna, etc.

Sickle cell anaemia

It is due to a mutation of a gene. A person suffering from sickle cell anaemia has a defective type of haemoglobin. ***It is caused by a recessive gene.***

When the concentration of oxygen is low in blood, the red blood cells assume the shape of a sickle. Because of this, the red blood cells cannot absorb oxygen properly.

This is a hereditary disease and can be passed on to the children by the parents in their gametes.

Sickle cell anaemia has a fatal effect on people who are homozygous for this mutated gene.

People who are heterozygous i.e. they have mutated and non-mutated genes have normal red blood cells.

Example:

Let B represent the allele for normal RBC

Let b represent the allele for sickle shaped RBC

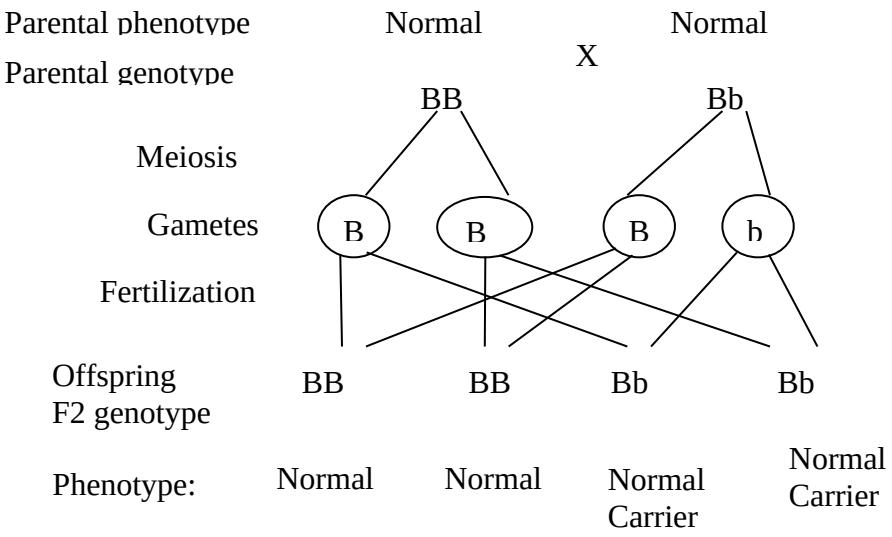
Genotype	Phenotype
BB	Normal RBC
Bb	Normal but carrier
Bb	Sickle shaped RBC

QUESTION:

1. ***A normal male married a carrier female for sickle cell anaemia. Determine the phenotype and genotype of the children.***

let B represent the allele for normal RBC

let b represent the allele for sickle cell



A normal male whose mother had sickle cell anaemia married a carrier female. What percentage of their children had sickle cell anaemia?

EXCEPTIONS TO MENDELIAN INHERITANCE

The following do not conform to the process of inheritance as illustrated by Mendel.

1. Linkage
2. Incomplete dominance.
3. Co-dominance
4. Multiple alleles.

CO-DOMINANCE

This is a condition where genes determining a particular character all show up such that the phenotype of the offspring is a mixture of that of the parents***. It mainly occurs in animals.***

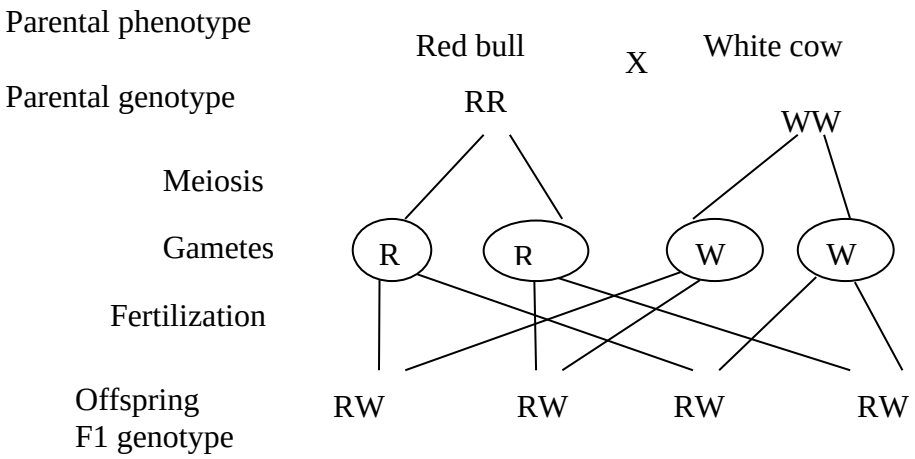
It is where in the heterozygous state neither allele is completely dominant over the other i.e. the 2 alleles are co-dominant. This results in the phenotype intermediate between the parent's appearance.

Question:

In animals, what will be the offsprings when a red bull is crossed with a white cow.

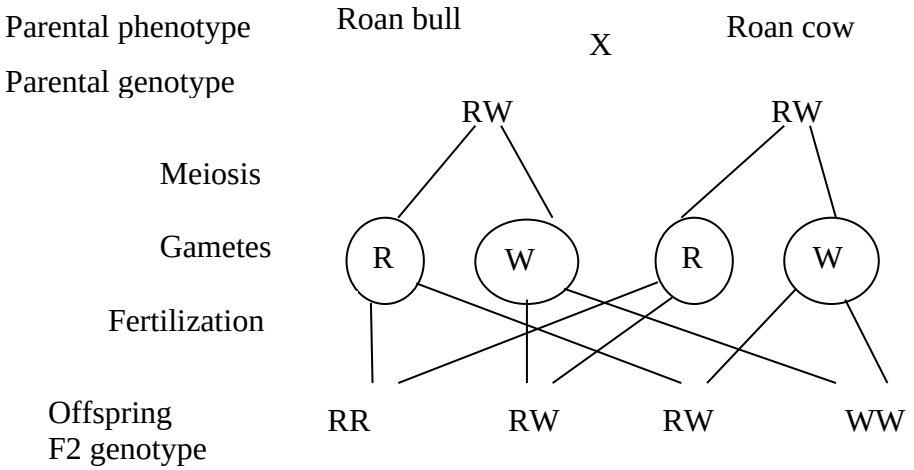
Let R be the allele for red bull

Let W be the allele for white cow



F1 phenotype: all the offsprings will be roan.

what would be the offsprings in the 2nd generation



F2 phenotype. 1 red, 2 roan and 1 white.

INCOMPLETE DOMINANCE

This is a condition in the heterozygous where neither of the alleles is dominant over the other and the phenotype of the offspring is an intermediate between that of the parents. ***It mainly occurs in plants.***

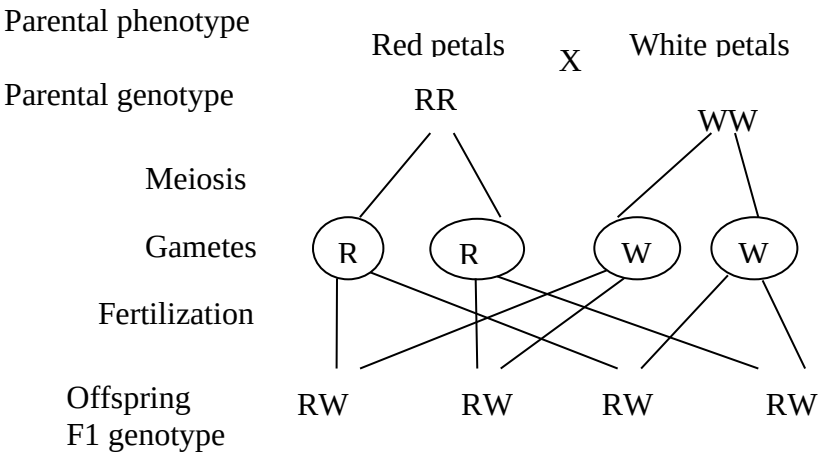
E.g. in plants, when a red flowered plant is crossed with a white flowered plant, the offspring produced pink and white flowers in a ratio of 1:2:1 respectively.

Example 1.

Consider petal colour in flowers.

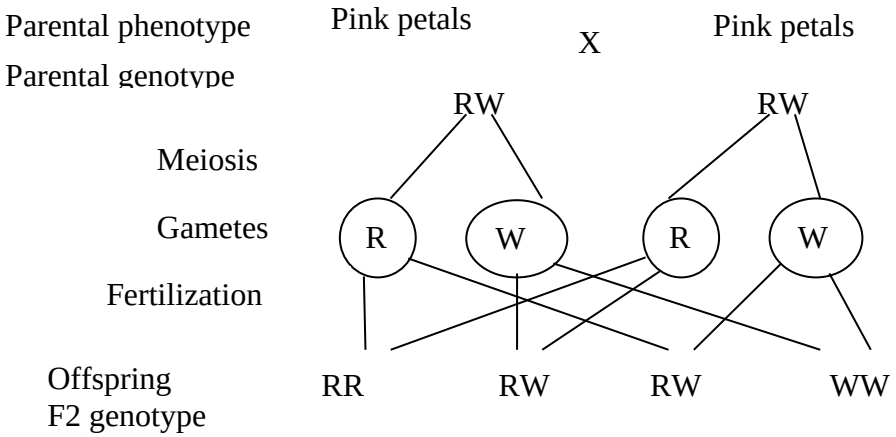
Let the gene for red petal flowers be R.

let the gene for white flowers be W



F1 phenotype: all pink petals.

Selfing F1. (Cross between offspring in F1)



F2 phenotype. 1 red, 2 pink and 1 white.

Phenotypic ratio; 1 red: 2 pink: 1 white. (1:2:1)

MULTIPLE ALLELES

This is where one character is determined by more than two alleles. This implies that a single gene contains more than two alleles. An example is blood group inheritance.

Inheritance of blood groups

The gene controlling blood groups is made up of three different alleles (multiple alleles). These alleles are A, B and O. The inheritance of blood groups is also an example of co-dominance. There are 4 blood groups that is group A, B, AB and O. the alleles for blood groups are

represented as I^A, I^B and I^O. I^O is recessive to I^A and I^B . I^A and I^B are co-dominant. An individual inherits two of these alleles one from each parent. The table below shows the possible blood groups that can arise from the different genotypes.

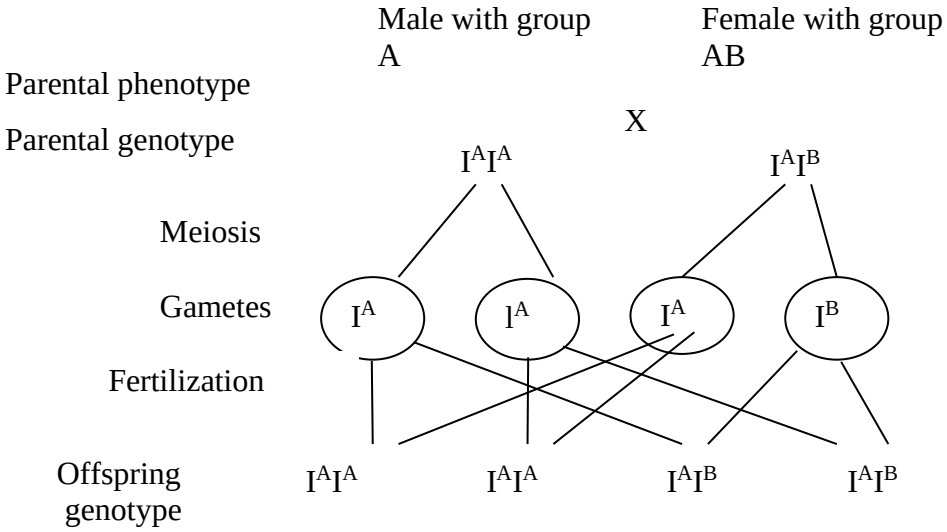
Genotype (alleles)	Blood group (phenotype)
I^AI^O	A
I^AI^A	A
I^BI^O	B
I^BI^B	B
I^AI^B	AB
I^OI^O	O

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

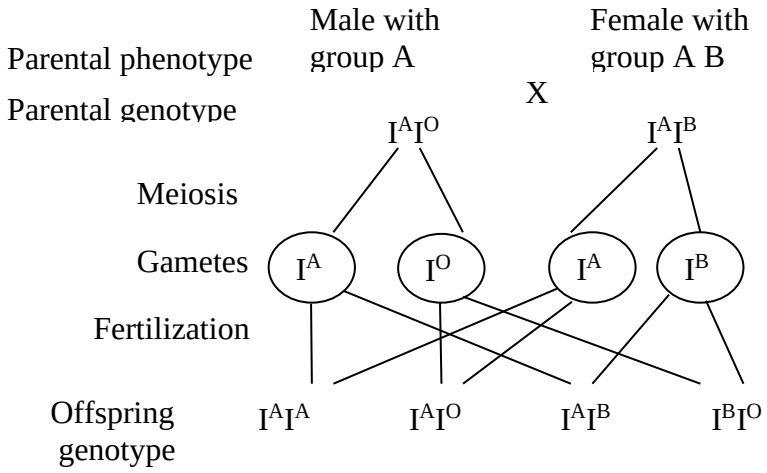
The man can have two possible genotypes, i.e. I^AI^O and I^AI^A. This is because allele I^A is dominant to allele I^O.

Considering the case where the man is I^AI^A



Offspring phenotype. 2 blood group A and 2 blood group AB

Considering the case where the man is I^AI^O



Offspring phenotype. 2 have blood group A, 1 has blood group AB and 1 has blood group B

Application of genetics

1. The study of genetics encourages breeding of animals with good characteristics to improve livestock.
2. It helps to eliminate or reduce harmful characteristics through the study of genetics.
3. Through genetic counseling and advice individuals may be advised on the possibility of their off springs.
4. It helps in prediction of offspring from two mating individuals and solves problems like fraternal uncertainty.

MUTATION

This is a sudden/spontaneous change in the structure and composition of a gene or chromosome.

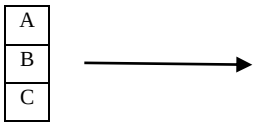
Types of mutation

1. Chromosome mutation: this is a sudden change in the structure of a chromosome.
2. Gene mutation

Types of chromosome mutation

i) Deletion:

This is when a piece of chromosome is broken off and lost therefore the chromosome becomes shorter than the original one.



ii) Inversion:

A piece of the chromosome breaks and joins on a different side of the same chromosome.

iii) Duplication:

A chromosome gains a piece from another chromosome of the same type and becomes longer.

iv) Translocation:

A piece of chromosome breaks and joins to another chromosome of different type.

Gene mutation:

This is a sudden change in the structure of a gene.

Types of gene mutation

Deletion

Duplication

Substitution: (this is a condition where a part of a gene is replaced by another of a different type).

Causes of mutations.

Mutations are caused by substances generally referred to as **mutagens**. These include;

1. High temperatures.

2. Chemicals such as mustard gas, colchine and caffeine.
3. High-energy particles such as alpha and beta particles.
4. High-energy radiations such as x-rays, gamma rays and ultra violet radiations.

Note; most mutations are disadvantageous and recessive. They are rare but persistent in the population.

EVOLUTION

Evolution is the process by which more complex forms of organisms arise from simpler forms over a long period of time. Or

This is a gradual process by which organisms change from simple to complex forms over a period of time.

As the environment changes, organisms also undergo changes to suit themselves to the changing environment. This results into evolution within the organisms.

ORIGIN OF LIFE

The origin of life is not exactly known. However some theories have been put forward to explain the origin of life. These are:

1. **Special creation theory:**

All living things were created by God.

2. **Steady state theory:**

It suggests that life has no origin and it has been in existence.

3. **Spontaneous generation theory:**

It suggests that life arose from non-living matter.

4. **Cosmozoan theory:**

   It suggests that life arose from another planet of the universe and arrived on earth by some means.

5. **Biochemical evolution theory:**

It suggests that inorganic molecules i.e. DNA and chromosomes and other protein molecules were organized into a basic unit of life called a cell.

It is the most accepted theory of the origin of life. The simple life (cell) gradually underwent numerous changes along different lines to form the present diversity of complex organisms.

This confirms that all the present organisms despite of their differences arose from the same ancestors, a process called ***evolution.***

THEORIES OF EVOLUTION

These explain the mechanism of how evolution has taken place over a period of time. There are two theories put forward to explain how evolution takes place.

1. Lamarck's theory (Lamarckism)
2. Darwin's theory (Darwinism)

LAMARCKIAN EVOLUTION

This was put forward by a biologist called Lamarck.

It was based on the following principles;

- ✓ Influence of environmental factors.
- ✓ Use and disuse of parts of the body.
- ✓ Inheritance of acquired characters.

Lamarck suggested that evolution was as a result of changes that organisms acquired during their lifetime. These changes were then passed on to their offspring. It was believed that ancestors of present day giraffes had short necks but as food became scarce, they stretched their necks in order to get foliage leaves at the top of short trees. This caused their necks to elongate. This character was passed on to their offspring. Lamarck put up the law of use and disuse. *He suggested that the disuse of any character would result in its disappearance and the use of any character would lead to its development.*

N.B: however, Lamarck's theory was proved to be wrong by genetic evidence that acquired characters cannot be inherited.

DARWIN'S THEORY OF EVOLUTION

Charles Darwin is another biologist who proposed a theory to explain how evolution takes place. Darwin suggested that evolution occurs by **natural selection.**

NATURAL SELECTION

This is the process by which organisms that are better adapted to the environment survive to reproduce while those less adapted fail to do so and become extinct. Or

This is a process by which nature selects for the best adapted organisms and selects against the less adapted ones.

When the environment changes, it affects organisms and those, which possess characters that enable them to survive in the changing environment survive while those less adapted, die over a long period of time. This occurs because organisms possess variations (differences between them).

The survival of the best adapted and removal of the less adapted is known as ***survival for the fittest.***

Through his studies, Darwin made the following observations.

1. Organisms produce very many offsprings.
2. The population of organisms generally remains constant despite of the large number of offsprings produced. This is due to competition between the members of the species for environmental resources such as food, space, shelter, and mates.
3. Offsprings tend to resemble their parents in some characters. This is due to inheritance of characters or genes from parents.
4. There is variation among organisms of the same population. This is due to both genetic and environmental factors.

From the above observations, Darwin suggested that there must be a struggle for existence where by the fit individuals (better adapted) survive and the unfit ones die (survival for the fittest). Over a very long period of time these organisms can change into a different species.

EVIDENCE OF EVOLUTION

There are several evidences put forward to support the theory of evolution. These include;

- ✓ Comparative anatomy
- ✓ Comparative embryology
- ✓ Paleontology
- ✓ Taxonomy
- ✓ Comparative biochemistry
- ✓ Geographical distribution of organisms

1. Paleontology

This is the study of fossils. Fossils are remains of organisms that lived in the past and were preserved in rocks. Fossil studies show that organisms that lived in the past had some

resemblance to the present day organisms. This shows that they had a common ancestry. The differences between them shows that evolution has occurred in the present day organisms.

2. Comparative embryology.

The study of the development of the zygote shows that organisms had a common ancestor. In all vertebrates for example the zygote develops a tail in the early stages and it is surrounded by membranes (amnion and allantois).

3. Cell biology.

The study of cells shows similarities between organisms. For example all cells of multicellular organisms have a nucleus, mitochondria and other organelles. This shows that the organisms had a common ancestry. The differences e.g. chloroplasts in plant cells shows that evolution took place

4. Comparative anatomy.

When anatomical structures of organisms are studied, they show similarities and differences. Similarities indicate that the organisms had a common ancestor while the differences show that they have evolved. For example all vertebrates have a pentadactyl limb but the limb has been modified in the different vertebrates and it performs different functions.

Homologous structures

These are structures from the common ancestral origin that serve different functions e.g the pentadactyl limb composed of five digits like in the horse for running, monkeys for grasping, human beings for handling and bats for flying.

This type of evolution is called ***divergent evolution*** which is the type of evolution where by organisms with common ancestors have developed structures that perform different functions because of change in the environment they live in.

When structures are further compared, it is observed that some of them differ but serve the same functions. Such structures are known as ***analogous structures.***

Thus ***analogous structures are structures from different ancestral origin but serve the same functions***. Such evolution is called convergent evolution which is a type of evolution where by different organs with different ancestral origins perform the same function. This is because of the similar environments they live in e.g. wings of birds and wings of insects.

5. Adaptive radiation:

When two populations of the same species are separated geographically. The organisms adapt themselves to the environment in which they live. This causes them to differ in some way thus evolution.

6. Classification.

The classification of organisms is based on resemblance in organisms. This indicates that organisms in a given group have a common ancestor.

7. Comparative biochemistry.

The study of chemical composition and functioning between living organisms shows that they have a common ancestor for example all organisms have DNA, they have enzymes made out of protein, etc.

8. Geographical distribution:

Distribution of plants and animals in different parts of the world indicates evolution. i.e. different environment look different. However some organisms in different geographical location are similar meaning that they had a common ancestor.