# S5 BIOLOGY CONTINUATION 31/MAY/2021

## GENE INTERACTIONS.

Sometimes a single characteristic is controlled by the alleles of two or more genes interacting with one another. A characteristic which is controlled by more than one gene is known as polygenic character and its transmission is called polygenic inheritance. These include,

- Gene complex/simple gene interactions/ complementary genes.
- Epistasis.
- Pleiotropy

There are other many situations when genes or alleles interact to control phenotypic characteristics of organisms they include,

- Incomplete dominance.
- Multiple alleles.
- Lethal genes.

## GENE COMPLEX/ COMPLEMENTARY GENES.

This is a condition where a single characteristic is controlled by the interaction of two or more genes occupying different gene loci on different chromosomes. It is also referred to as simple gene interaction. Example of gene complex is the inheritance of shapes of the comb in poultry (Domestic fowl).

There are two genes located at different gene loci on different chromosomes. One gene has a dominant allele P and a recessive allele p. whereas the other gene has a dominant allele R and a recessive allele r. The two genes interact and give rise to four distinct phenotypes (comb shapes in poultry) and these,

- Pea comb.
- Rose comb.
- Walnut.
- A single.

- Pea comb is determined when atleast its one dominant allele P is present, in absence of the dominant allele R, other alleles being recessive in the genotype. Possible genotypes for pea comb, PPrr or Pprr.

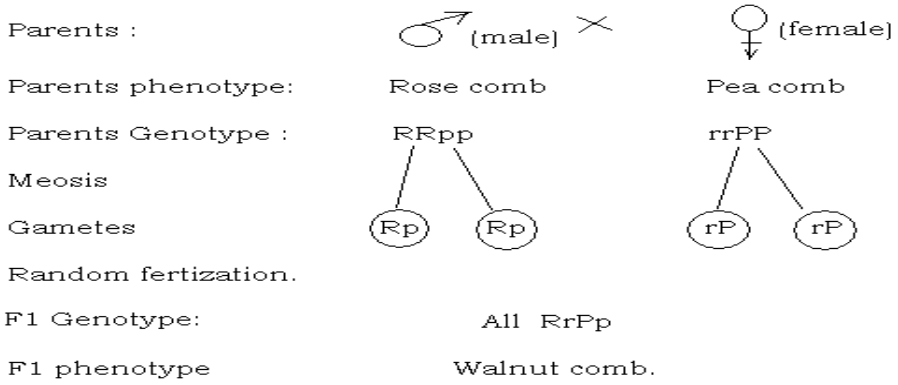
- Rose comb arises when atleast its dominant allele R is present, in absence of the other dominant allele P, other alleles being recessive in the genotype. Possible genotypes for the Rose comb, ppRR, or ppRr.

- Walnut comb is determined if atleast both dominant alleles P and R are present in the genotype. Possible genotype for the walnut comb, PPRR, PpRR, PPRr or PpRr.

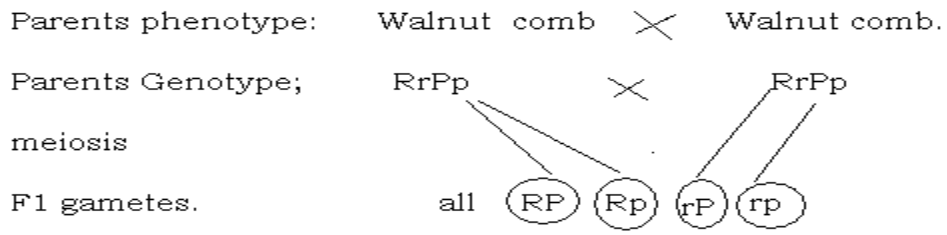
- A single comb is determined only when both alleles exist in their homozygous recessive state. A possible genotype for the single comb type is, pprr.

***Let,***

R represents an allele for rose type comb
P represents the allele for pea type comb.




**SELFING FI OFFSPRINGS.**




Random fertilization of the F1 gametes, F2 genotypes and phenotypes as shown by the punnet square below.

Male gametes

| | | RP | Rp | rP | rp |
|---|---|---|---|---|---|
| Female Gametes | RP | RRPP walnut | RRPp walnut | RrPP walnut | RrPp walnut |
| | Rp | RRPp walnut | RRpp Rose comb | RrPp walnut | Rrpp Rose comb |
| | rP | RrPP Walnut | RRPp Walnut | rrPP Pea comb | rrPp Pea comb |
| | rp | RrPp Walnut | Rrpp Rose comb | rrPp Pea comb | Rrpp Single |

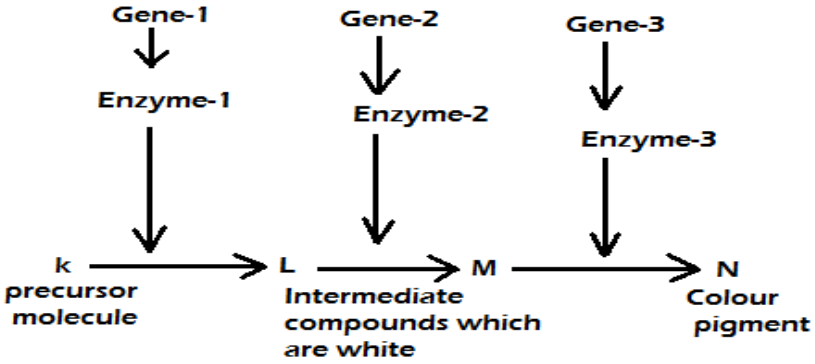
The $F_2$ phenotypes;
9 walnut type combs (R - P)
3 rose type comb (R – pp)
3 pea type comb (rr – P)
1 single (rrpp)

## EPISTASIS

This is a condition where the presence of one gene suppresses the effect of another gene at another gene locus. The term “epi” means over, while “hypo” means under. Epistatic genes are the ones suppressing the effects of others and also called inhibiting genes. While the gene, whose effects are suppressed is called hypostatic genes. In addition, epistatic and hypostatic genes occur at different gene loci on homologous chromosomes. Epistasis does not always result in the blending of features to produce intermediates. It may instead create entirely new features. It can also result into variety of phenotypic ratios depending on the genotype of the mating pairs.

### EXPLANATION OF EPISTASIS.

Epistasis arises when different genes control production of different enzymes that catalyse series of bio-chemical reactions that determine expression of a single character in an individual. Production of each enzyme depends on specific gene. For example, consider the gene pathway shown below for the synthesis of sweet pea plant pigment.




Production of enzyme-1, enzyme-2 and enzyme-3 are controlled by specific gene-1, gene-2 and gene-3 respectively. Compounds L and M are white intermediate compounds. Compound N is a coloured end product pigment.

Gene-1 initiates production of enzyme-1 which catalyses conversion of precursor molecule to the intermediate compound L while gene-2 stimulates production of enzyme-2 which catalyses production of enzyme-2 which catalyses conversion of L to another intermediate compound M. Then finally enzyme-3 catalyses convertion of M to to final coloured pigment N. Production of enzyme-3 is controlled by gene-3.

If gene-2 mutates or fail to stimulate production of enzyme-2, compound M would not be formed and final coloured pigment N will not be formed. Intermediate compound L will accumulate and gene-3 will have no effect on the phenotype. In this case gene-2 is epistatic while gene-3 is the hypostatic.

**TYPES OF EPISTASIS.**

- Supplementary gene interactions.
- Complementary gene interactions.
- Dominant gene epistasis.

**SUPPLEMENTARY GENE INTERACTIONS.**

This is where a particular gene will have no effect on a phenotype on their own but do so in combination with another different gene. For example in the inheritance of fur colour in mice.

• In the Inheritance of fur colour in mice. There are three possible phenotypes, Agouti (grey), Black fur and Albino (white fur). They are controlled by a pair of genes occupying different loci. The Epistatic gene determines the presence of colour and has two alleles, the dominant allele determines coloured (C) and its recessive allele c, that controls white colour (albino). The hypostatic gene that controls the nature of the colour, has a dominant allele (A) that controls grey colour or agouti and the recessive allele that controls black colour.

The dominant allele (A) for grey (Agouti) colour or recessive allele (a) for black color only express them selves when they are accompanied by the dominant allele (C) that controls coloured fur in the genotype.

Albino conditions appear in mice when the alleles controlling coloured fur are homozygous recessive even when the alleles controlling agouti and black fur are present in the genotype.

**Phenotypes.Possible Genotypes.**

| | |
|---|---|
| (i) Agouti (grey) | AaCc, AACc or AaCC. |
| (ii) Black | aaCc or aaCC. |
| (ii) Albino | AAcc, Aacc or aacc. |

Using the above ways in which the above alleles of the two genes interact,

(a) Determine the phenotype ratios of the following crosses
(i) AaCc X AaCc. (ii) AaCc X Aacc.
Assuming no linkage.

• Another example of such epistasis is provided by colour differences in onion bulb, fur colour in mice. Skin pigmentation in humans (albinism) and comb shape in poultry.

In onion bulbs, the red colour is obtained if atleast both dominant allele C and R are present in the genotype. The colour is yellow if dominant allele C is only present without the dominant allele R in the genotype and white colour obtained if recessive allele c is present in homozygous

recessive condition without its dominant allele C, either allele R or r being present in the genotype. This indicates that the dominant allele C and recessive allele c are epistatic.

**PHENOTYPES AND SOME POSSIBLE GENOTYPES OF THE ONION BULB**

| **Phenotypes:** | **Possible genotypes:** |
|---|---|
| Red | CCRR , CCRr , CCRR or CcRr |
| Yellow. | CCrr or Ccrr |
| White | ccRR, ccRr, ccrr. |

**COMPLEMENTARY GENE EPISTASIS.**

Is where presence of one gene affects another gene at another gene locus in such away that when the two alleles of the genes are atleast dominant, they interact and produce a single identical and specific phenotype and in absence of dominant allele of alteast one gene, its alleles being homozygous recessive, the phenotype is inhibited.

For example, flower colour in sweet pea plant is determined by two genes with their dominant and recessive alleles (R, r and W, w). If atleast one dominant allele of one gene is present in the genotype, it determimnes purple colour of the flower while homozygous recessive state of alleles of any one gene determines white colour in flowers.

Consider two plants producing purple flowers, each having the genotype RrWw are crossed. What will be phenotype ratio of the resulting offsprings. Assuming that each allele is located on its own chromosome.

Parent,s phenotype : Heterozygous Purple flower producing plant X Heterozygous purple flower producing plant.

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Parent, Genotype : RrWw RrWw.

Meiosis.

Gametes : all RW , Rw , rW , rw

Random fussion of gametes shown by the purnett square.

| Female Gametes. | Male gametes | | | |
|---|---|---|---|---|
| | RW | Rw | rW | rw |
| RW | RRWW<br>Purple | RRWw<br>Purple | RrWW<br>Purple | RrWw<br>Purple. |

| | | | | |
|---|---|---|---|---|
| Rw | RRWw<br><br>Purple | RRww<br><br>White | RrWw<br><br>Purple | Rrww<br><br>White. |
| rW | RrWW<br><br>Purple | RrWw<br><br>Purple. | rrWW<br><br>White. | rrWw<br><br>White. |
| rw | RrWw<br><br>Purple. | Rrww<br><br>White. | rrWw<br><br>White. | Rrww<br><br>White. |

Phenotype ratio of the offsprings;
Purple flowers producing plants = 9.
White flowers producing Plants. = 7
9 purple : 7 white flowers = 9 : 7.

- Determine possible genotypes of parents which when crossed will produce all offsprings with purple flowers.
- What will be the phenotype ratio of the F2 offsprings when RrWw is crossed with RRww.

When two white flowered varieties were crossed, all the F1 offsprings were purple flowers. The Selfing of the F1 purple offsprings produced purple and white flowered plants in the ratio of 9 purple : 7 white flowered plants. This result arises because,

- This single characteristic is controlled by two genes at different gene loci on different chromosomes.
- One gene determines production of a Colourless pigment precursor.
- The other gene controls the conversion of the precursor into a purple pigment.
- When one dominant allele of either of the two genes is absent in the genotype, it results into white flowers, this is because either no precursor was formed or the precursor was formed but not converted to purple pigments.

In the original cross, the purple flowers were the product of white flowered strains, where one allele was dominant for the production of a Colourless pigment, whereas the other allele was dominant for conversion of the precursor into purple pigment.

In **dominant gene epistasis**, the presence of atleast two dominant genes at different gene loci, will inhibit production of the phenotype while in a homozygous recessive state of one of the genes, a specific phenotype is produced. The dominant gene is epistatic while the recessive one is hypostatic.

For example, In white leghorn fowl, plumage colour is controlled by two sets of genes including the following, **W** (white) dominant over **w** (coloured) **B** (black) dominant over **b** (brown). The Heterozygous $F_1$ genotype **WwBb** is white while wwBB, wwBb are black and wwbb is brown.

**PLEIOTROPY.**

This is the condition in which a single gene controls two or more unrelated characteristics. It arises when the gene codes for an enzyme which affects more than one phenotype. In pleiotropy a single gene affects several phenotypic traits. If it affects a vital function of the body it may become lethal.

Examples of pleiotropy include,

- A mutation in certain gene for chloride ion secretion in epithelial cells gives rise to phenotype known as cystic fibrosis. The patients have problems with breathing and digestion.
- Sickle cell anaemia.
- Coat colour in mice.

**ADVANTGES OF STUYDYING GENETICS**

(i) Enable humans to choose partners with good characteristics for reproduction.
(ii) Used in legal profession to determine the paternity of a child.
(iii) enables elimination of harmful and fatal characteristics diseases from human population
(iv) Enables farmers to produced crops and breed animals with desired qualities such as increased crop yields, diseases resistance and drought resistance.

used in techniques of artificial insemination or artificial breeding where the closely related varieties of organisms are crossed so that their characteristics become combined in one individual

**EXERCISE.**

**1.** Flower colour in sweet pea plant is determined by two allelomorphic pairs of genes (R, r and W, w). If atleast one dominant gene from each allelomorphic pair is present, it determines purple colour of the flowers, all other genotypes where atleast one dominant allele is absent determine white colour in flowers.

(a) Explain each one of the following results,

(i) A cross between white flower producing plants, produced all offsprings with purple flowers.
(ii) A cross between a white flower producing plant and purple flower producing plant, produced offsprings producing white and purple flowers in the ration of 1 : 1.

(b)If two plants producing purple flowers, each having the genotype RrWw are crossed. State the phenotype ratio of the resulting offsprings, assuming the genes are linked.

**2.** In white leghorn fowl, plumage colour is controlled by two sets of genes including the following,

**W** (white) dominant over **w** (coloured)
**B** (black) dominant over **b** (brown).

The Heterozygous $F_1$ genotype **WwBb** is white. Account for this type of gene interaction and show the phenotypic ratio of the $F_2$ generation when the heterozygous white $F_1$ offsprings are selfed. Assuming no linkage.

**3.** The banding pattern of the snail *Cepea nemoralis* is controlled by two unlinked genes. The dominant allele B gives unbanded shells while the allele b gives banded shell. The dominant allele M gives midibanded shells while the allele m gives fine banded shells.

(a)(i) State the type of interaction shown by the genes.
(ii) How does allele B affect the gene M or m.
(b)How does allele B affect the genes M or m.
(c)A snail with an unbanded shell of the genotype BBMM was mated with one having a fine banded shell. Using genetic symbols show the phenotypic ratio of the F2 generation.

**4**. (a) List down any four features of epistasis.
(b) In an animal species, individuals that are homozygous for gene A or its allele die. Another independent gene B in the homozygous state, blocks this lethal effect, otherwise gene B has no other effect on the organism.
Work out the expected phenotypic ratio of the viable offsprings in a cross of individuals of AaBb and AaBB genotypes.

**5**. Maize cobs may have purple or red grains. This character is controlled by a single pair of alleles.The dominant allele **R** gives red colour. The colour appearance is affected by another gene.
(a) In an experiment, a heterozygous plant is crossed with a maize plant homozygous for allele **r**. State genotypes of these two plants.

(b) Grain colour is affected by a second pair of alleles. The presence of dominant allele E allows purple or red colour to develop but in a homozygous recessive **(ee)** no colour will develop despite the presence of alleles **R** or **r** and the grain will be white.
(i) When a plant of genotype RREE is crossed with plant of genotype rree. What will be the phenotypes of the offsprings.
(ii) What phenotypes of the offsprings will be produced when the offsprings in a (i) above interbreed.
State the phenotypic ratio.
(iii) What genotypes if allowed to self fertilize would produce pure breeding lines containing white grains.

## MUTATION.

**Mutation** is the sudden change in the amount or the structure of the DNA on the chromosome of an organism.

Mutations produces a change in the genotype of the daughter cells and may result in the change of the phenotype or in appearance of new characteristics of organism in a population, mutations which occur in gamete cells are inherited whereas as those occurring in somatic cells can not be inherited but appear in daughter cells produced by mitosis

Mutation has some general properties (characteristics) these are:-

i. It is spontaneous, occurs on its own
ii. Most mutations are disadvantageous to organism but some are advantagious.
iii. There occurrence is not common but when it occurs, it becomes persistent
iv. They occur gradually.
v. Their occurrence is very sudden
vi. They occur randomly in nature
vii. Environment has less influence over them.

Mutations are of two categories.

**(i) Chromosome mutation**: Is the sudden change in the amount or arrangement of DNA on the chromosome.

**(ii) Gene mutation ( point mutation)**
Is a change in the structure of DNA at a single locus on a chromosome.

### CHROMOSOME MUTATION

A change in the amount or arrangement of DNA on the chromosome can arise due to changes in the number or structure of chromosomes. These changes may involve the following aspects:

- Changes in the whole sets of chromosomes (Polyploidy)
- changes in the number of the chromosomes (Aneuploidy)
- Changes in the chromosome structure.

### POLYPLOIDY (EUPLOIDY)

This is a condition where a diploid cell of an organism has an additional whole set of chromosomes. The cell contains multiples of the haploid number of chromosomes such cells are termed as polyploids. Where three sets of chromosomes are present, the organisms is said to be triploid (3n), cells with four whole sets of chromosomes are (4n), five whole sets are pentaploids (5n), etc.

**CAUSES OF POLYPLOIDY/HOW POLYPLOIDY ARISES.**

● Failure of spindle fibres to form during prophase I of meiosis. This can be induced by a chemical colchicines. In this case all the homologous chromosomes fail to be separated during Anaphase I of meiosis. A diploid gamete is formed usually an ovum, and when this gamete fuses with another normal haploid one usually the sperm, a tetraploid (3n) is formed. Self fertilization of diploid gametes forms a tetraploid (4n).

● During mitosis, chromosome duplication and DNA replication occur during interphase but the cytoplasm fail to cleave during cytokinesis, resulting into formation of a tetraploid cell (4n) with a large nucleus. The tetraploid cell then undergoes normal mitotic division to produce tetraploid (4n) daughter cells. These tetraploid will have larger size because of increased size of their cytoplasm.

● Mating may take place between two genetically unrelated or related species of organisms to produce sterile hybrid whose chromosome number becomes doubled to form a fertile tetraploid which only reproduces when selfed.

● Polyploidy can also occur when whole set of chromosome double after fertilization.

Tetraploid organisms (4n) have two complete sets of homologous chromosomes and the organism is fertile. In the other hand, a triploid (3n) does not have two complete sets of chromosomes and cannot form complete homologous pairing during the gamete formation by meiosis and such organisms are sterile.

Polyploidy is much more common in plants than in animals. This is because a lot of errors occur during gamete formation by meiosis. However most plants are capable of propagating themselves vegetatively (Asexual reproducing). In animals polyploidy is also associated with sterility but in plants it is associated with hybrid vigour like increased yields, resistance to diseases and drought where as the polyploid plants can be propagated vegetatively unlike the animals.

So, Polyploidy in plants is often associated with advantageous features such as :

Increased size, hardness and resistance to diseases. This is called hybrid vigor. Most domestic plants are polyploids, producing large fruits, large storage organs, flowers and leaves, triploid tomatoes, produce more vitamin C. Polyploidy plants include most angiosperms, wheat, coffee, banana, sugar cane, apples e.t.c

There are 2 types of polyploidy
- autopolyploidy
- allopolyploidy

**AUTOPOLYPLOIDY**

Is the type of polyploidy where by the whole sets of chromosomes added in the cell arises from sets of chromosomes of organisms of the same species. The number of chromosomes in an autopolyploidy is always an exact multiple of its haploid number.

Autopolyploids are most likely to have arisen by spontaneous doubling following the failure of spindle fibres to form or to function correctly at meiosis.

An Autopolyploidy organism is fertile if they have an even number of chromosomes sets. Autopolyploid can be induced by chemical called colchicine. It inhibits spindle formation and so prevents chromosomes from separating during Anaphase I of meiosis.

Endomitosis is a type of polyploidy which occurs in animals. It involves chromosome replication without cell division e.g giant chromosome in the salivary glands of drosophila and tetraploid in the human liver.

**ALLOPOLYPLOIDY**

Is where the whole sets of chromosomes added in the cell arise fromsets of chromosomes from more than one different species of organisms.

The sets of chromosomes from more than one different species are then not homologous, and the plants (the polyploids) are usually sterile. But if mitosis occurs in the polyploid cells, both sets of chromosomes double and pairing of chromosomes in meiosis is possible and organisms may become fertile. The example of natural allopolyploid occurred in the origins of modern bread wheat.

Allopolyploidy does not occur in animals because there are fewer instances of cross breeding between animals of different species.

**ANEUPLOIDY**

Is a condition in which Diploid or haploid daughter cells have an extra chromosome (2n+1), or less by one or more chromosomes (n-1) and the other chromosome missing eg (n-1) or (2n -1).

Aneuploidy arises from failure of a pair or pairs of homologous chromosomes to segregate (separate) during anaphase I of meiosis so that the gamete cells produced contain either one extra chromosome i.e. n+1 or one chromosome less i.e. n-1. This is called Non-disjunction which is often lethal. It may also arise when part of the chromosome is deleted or duplicated, or broken and inverted in rejoining, or broken off and added to a different chromosome.

Non-disjunction can result into serious consequences in humans, which include the following,

- Down’s syndrome. (Mongolism).
- Klinefelter’s syndrome.
- Turner’s syndrome.

**1. Downs syndrome (mongolism), Trisomy 21.**

This is the condition where diploid cells of an organism have an extra chromosome on 21st pair of chromosomes, in human the individual will posses 47 chromosomes (2n+1). The cause of this condition is the non-disjunction that occurs at the 21st pair of chromosomes during meiosis. The homologous pair of chromosomes fails to segregate during anaphase I of meiosis and the gamete produced possesses 24 chromosomes (n+1). The fusion of this gamete with a normal one (n) with 23 chromosomes results in offspring having 47 (2n+1) chromosomes. This condition seems more common in ovum than sperm. The presence of three same chromosomes in the cell is known as trisomy. This is the case of trisomy involving autosome. The dawn's syndrome in children has disabilities such as:

- a short stocky body and thick neck and the characteristics fold of skin over the inner corner of the face similar to those which produce a superficial Mongolian appearance.
- protruding tongue
- Heart defects.
- Coarse, straight hair.
- Severe mental retardation.
- Reduced resistance to disease, this results into risk of infections particularly respiratory and ear infections.
- Congenital hearing abnormalities
- Low IQ
- A Short life expectancy.
- Intestinal problems and leukaemia are common.

Non – disjunction that occurs in other pairs of chromosomes, normally result in foetus aborting or the child dying soon after birth.

**2. Klinefelter's syndrome (Trisomy 23)**

This is a condition where there is an extra sex chromosome. This is another trisomy of sex chromosomes. The extra chromosome arises due to non-disjunction on the 23rd pair of chromosomes during meiosis called sex chromosomes. This can occur during spermatogenesis or oogenesis. Upon fertilisation, zygotes or individuals with the following genotypes can arise,

• XXX.

-These are females.

- Slightly taller than the ordinary woman.
- Behavioural abnormalities and learning difficulties occur.
- Promiscuity is evident.

• XXY and XXXY.

- These are males.
- Are sterile.
- They show some female secondary sexual characteristics.
- Mentally retarded.
- Little breasts may develop.
- Little facial hair/lack beards.

- Higher than normal secretion of FSH.

• XYY.
- These are males.
- Are fertile males.
- May have a high propensity for violence.
- Relative taller than average.

• YO.
- Zygote do not develop because many genes are missing.

**3. Turner's syndrome**

This is where the cell of a female person is missing one sex chromosome (X chromosome).i.e. 2n-1, their genetic constitution is X0, and this is an example of monosomy. It occurs due to non-disjunction of the homologous pair of sex chromosomes. Such individuals do not survive birth, but when born, they show the following features,

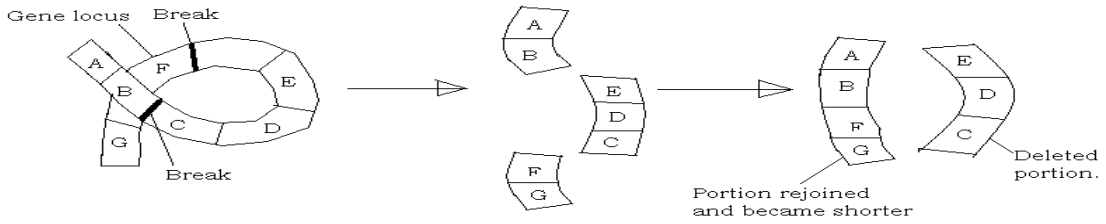
- are phenotypically females,
- sexually immature,
- physically very short,
- Their nipples are closer together.
- Small uterus.
- The hair line at the back of the head is lower than normal.
- Webbed neck.
- Puffy fingers.

**CHANGES IN CHROMOSOME STRUCTURE**

Several mistakes may occur during the crossing over process in meiosis. This lead to chromosome mutations, the changes in the chromosome structure occurs by anyone of the following ways.

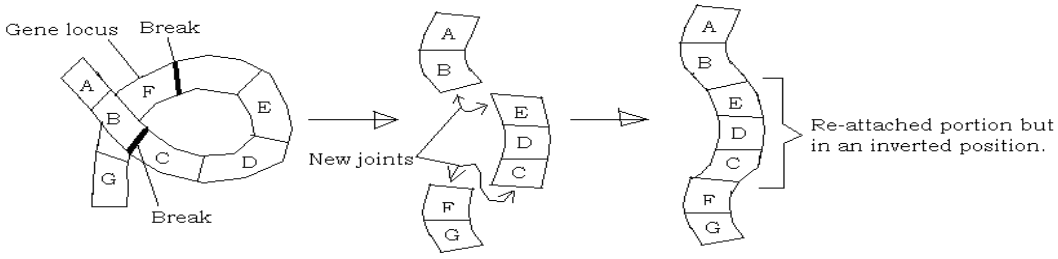
**i) Deletion**

A portion of the x-some is broken and lost, resulting into shortening of chromosome and loss of genes. This condition is often lethal.

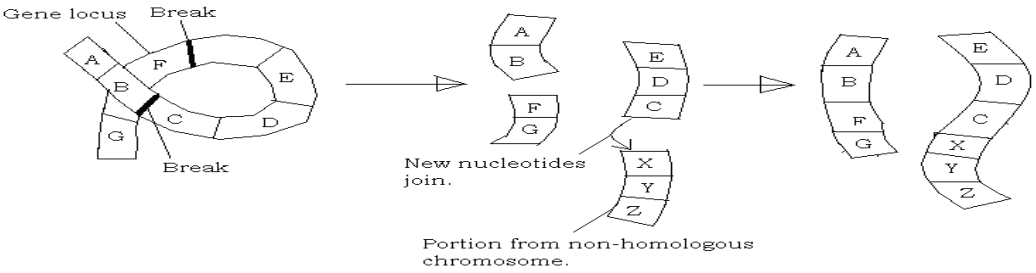


**ii). Inversion**

A portion of a chromosome becomes deleted, but becomes re-attached on the same chromosome in an inverted position. The sequence of genes (nucleotide base sequence) is reversed, the genotypes remain the same but the phenotypes may be altered.

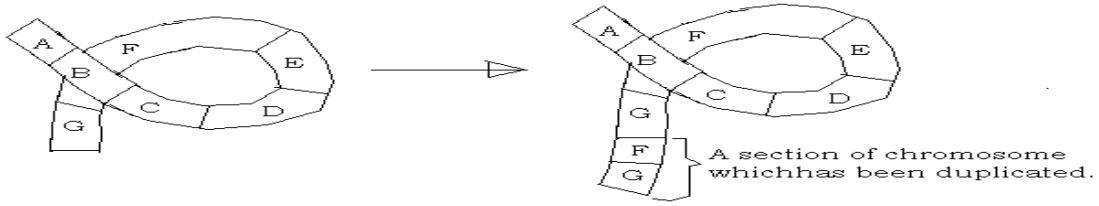



**iii). Translocation** A portion of chromosome becomes deleted and rejoins at a different point on the same chromosome or with a different chromosome.




**iv) Duplication**

A portion of chromosome is doubled, resulting in repetition of a gene sequence a different genetic constitution from the rest results, this is called a genetic mosaic.




**GENE MUTATION.**

A change in the structure of DNA which occurs at a single locus on a chromosome is called a gene mutation or point mutation

Agene mutation is the result of a change in the nucleotide sequence of the DNA molecule in a particular region of the chromosome, such a change in the base sequence of the gene is transmitted to messenger RNA during transcription and may result in a change in the amino acid sequence of the polypeptide chain produced from it during translation at the ribosomes.

There are a variety of forms of gene mutation involving the following.

**i) Duplication**
A portion of a nucleotide chain of a DNA becomes repeated .

**ii. Insertion (addition)**
A portion of a nucleotide base sequence becomes inserted in the chain.

**iii. Deletion**
A portion of a nucleotide chain is removed from the sequence.

**iv. Inversion**
A nucleotide sequence becomes separated from the chain. It rejoins in its original position only inverted. The nucleotide sequence of this portion is then reversed.

**v. Substitution**
One of the nucleotides is replaced by another which has a different nitrogenous base.
A slight change in a single base in the genetic code is the cause of sickle cell anemia in humans is an example of base substitution gene mutation, affecting base in one of the genes involved in the production of abnormal haemoglobin.called haemoglobin S that leads to **sickle cell anaemia**.

The haemoglobin is made of long polypeptides of alpha (δ) and Beta (β) chains. The mistake occurs in beta polypeptide chains.

**THE EFFECTS/CONSEQUENCES OF GENE MUTATIONS.**

Sometimes mistakes arise when DNA replicates. There are several ways in which errors can occur.

- One base sequence may be replaced by another.
- A portion of a nucleotide chain may be broken and lost.
- An extra portion of nucleotide chain may be added.
- A portion of a nucleotide base sequence becomes inserted in the chain.
- Nucleotide base sequence may become reversed.

When these errors occur, the new DNA is not an exact copy of the original. Such changes in the structure of the DNA is called gene mutation.

When a gene mutates, the changes in the sequence of the base in the DNA causes a complementary changes in the sequence in codons of messenger RNA. The altered codon may be translated as non-sense, causing synthesis of a polypeptide with one or more amino acids missing.

Alternatively the codons may be translated as mis-sense in which case another aminoacids is substituted in or added to the polypeptide chain. Protein molecules built from such polypeptides

are usually defective and can not carry out their normal functions. Production of abnormal haemoglobins and in born errors of metabolism are examples of some the consequences of such gene mutations.

Inborn errors of metabolism is due to in-ability to synthesise specific enzymes or sythesise enzymes which can not catalyse certain essential metabolic reactions. A number of human diseases can be attributed to the in-ability to sythesise specific enzymes, such human diseases include,

- Phenylketonuria.
- Alkaptonuria.
- Galactosaemia.

**CAUSES OF MUTATION.**

Any agent which causes mutation is called a mutagen. Most forms of high energy radiations are capable of altering the structure of DNA and thereby causing mutations this include ultra–violet light, x–rays and gamma rays. High energy particles and neutrons are even more dangerous mutagens.

A number of chemicals such as colchicines, formaldehydes, nitrous acid and mustard gas, cause mutations. Colchicine inhibits spindle formation and so causes polyploidy.

A natural mutation rate is greatly increased, in species of organisms with shorter life cycle and therefore has more frequent Meiosis. And the chance of occurrence of mutation is increased during gamete formation.