

# Genetics and Introductory Plant Breeding Techniques



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# Contents

1.	Cell Theory	1
2.	Cell Divisions	11
3.	Principles of Inheritance	21
4.	Mendelian Genetics	33
5.	Gene interactions and Gene actions	42
6.	Genetic Variation	50
7.	Heritability	59
8.	Mutation	66
9.	Introductory Plant and Animal Breeding	78
	References	87

# Preface

Biological properties provide fundamental structures that form the basis for the study of character transmission and inheritance patterns known as Genetics.

The science of Genetics has shown inter-relationship with many fields such as biology, biochemistry, Physiology, evolution, Anatomy, and practical Agriculture. Its practical approach is dependent on appropriate statistical, and field plot techniques with careful observation and documentation of both laboratory and field data. Genetics has its root in the epoch discovery of Gregor Mendel in 1866. His research findings eluded the scientific world until about fourteen years after his death. Several scientists have built on the formation made by Gregor Mendel.

However, the science of Genetics presents general biological implications which should never be lost because every biological material has interplay with the environment.

To accomplish this end, I have attempted to down play as much as possible a systematic historical approach to the subject and draw vivid examples from recent personal research work. This means that genetic ideas related in this book are developed along a logical sequence emanating from personal genetic studies of crops within the local environment. In addition to this heuristic approach the basic underlining principles of Mendelian



inheritance and Genetic breeding methods were adequately exploited. To explain the principles of Mendelian inheritance. Full use has been made of modern knowledge of cytology to which the first two chapters is largely devoted. On the other hand students majoring in basic biological sciences and biochemistry will find the chapters two to five highly relevant as it explains aspects of genetics that relate to the biochemical nature of gene and welfare of living organisms.

In all, the whole text is most appropriate for Agricultural students as it places emphasis on not only genetic principles but on application of the principles to plant and animal production in meeting human demands. Examples of inheritance as applied in plants and animals are thoroughly explained throughout the book.

Vivid illustrations made in the chapters form an integral part of the text and should be considered in context. Most of the old references in the book actually spurred me to writing this text. This is because present day students do not have access to recent relevant Genetics texts which are in most cases put under "reserve" sections in the Libraries.

Furthermore, most genetic conclusions in such "foreign texts" are vague to the imaginations of fresh Genetics and plant breeding students within our local environments such that the focus and practical application of knowledge is ensnared.

Questions and problems are major accessories attendant to Genetics. This book attempts problem solving. Therefore each chapter of this book confronts students with experimental questions that requires careful interpretations which in return arouse the interest of serious and zealous students in the study of genetics and breeding at advanced levels.

Aremu, C.O

June 2007.

# DEDICATION

To the students of Agriculture and Biological Sciences.

## ACKNOWLEDGEMENT

I am forever grateful unto God whose merciful hands I feel everyday. The author is also indebted to Profs. Fawole, I and Ariyo, O.J who laid the foundation of Genetics in me and took me through the path of practical application of Genetics to crop development and growth. Grateful, thanks are also due to my head of department. Dr. T.A. Adedayo and Dean of the Faculty of Agricultural Sciences Prof. I. A. Adetunji. They set the pace for hard work in academics.

I also acknowledge the works of my predecessors in genetics and plant breeding whose works form part of this book.

Backhome, Sola and Eriaanu. I am fulfilled in Christ Jesus through you. All others, you know yourselves, that you are there for me gives me great joy.

# Chapter 1

## THE CELL THEORY

### 1.0 Introduction

The study of the cell using a thin slice of bottled cork started in the year 1635 by an Englishman called Robert Hooke. He discovered for the first time a porous structure with individual cavity. Each of the cavity was called a cell and surrounded by a prominent wall called cell wall. Between 1838-1839, a German Botanist and a German Zoologist named Schleiden and Schwann founded the cell theory that plants and animals are cellular in nature.

Von Mohl and Nageli in 1858 identified two parts of a cell namely the cell wall and the protoplasm. The protoplasm consists of granular semi-fluid contents. Inside the protoplasm is a specialized body called the nucleus. The nucleus was discovered by Robert Brown in 1831 as a unit responsible for inheritance of characters.



## 1.1 Cell components and structure

Both plant and animal bodies are composed of structural and functional units called cells (fig. 1.1)

A cell is a unit of life made up of a mass of protoplasm in which a dense spherical or oval body called nucleus is embedded. The protoplasm of a plant cell is bounded by a protective distinct wall called cell-wall. Both the protoplasm and nucleus are living material while the cell-wall is non-living.

The living constituents of a cell are together called the protoplast. A plant cell therefore is made up of a protoplast and a cell-wall. The cell wall apart from its protective functions also serves to maintain shape and regulate the flow of materials in and out of the cell.

Cells are invisible to the naked eyes and in shapes and sizes some cells are spherical, oval, rectangular, polygonal or even elongated. The sizes vary from 0.01mm to 1mm. Virus cells are the smallest in size and followed by bacteria cell.

The cells of virus are so small that they defy microscopic view. However bacteria cells are visible under the microscope with the size ranging between 0.0001 and 0.001mm.

### 1.2.2 The protoplast

The protoplast is the physiological unit of the cell which performs specialized functions such functions include:

- a. Food synthesis
- b. Nutrition
- c. Growth
- d. Respiration
- f. Reproduction

The protoplast is differentiated into three distinct parts which are:

- i. Cytoplasm
- ii. Nucleus
- iii. Plastids



These distinct parts develop from pre-existing ones and are not newly formed.

### 1.2.3 The cytoplasm:

This is the liquid part of the cell containing various chemical compounds and vacuoles. The vacuoles consist of non-protoplasmic fluid filled cavities of varying sizes. As the cell grows and enlarges the small vacuoles fuse together to form a large central vacuole which occupies the major part of the cell-cavity. The fluid in the vacuole is called the cell sap. The vacuole performs the following functions.

1. Storage of water and organic compounds
2. Controlling amount of fluid within the cell sap thus maintaining turgidity of the cell and tissue.

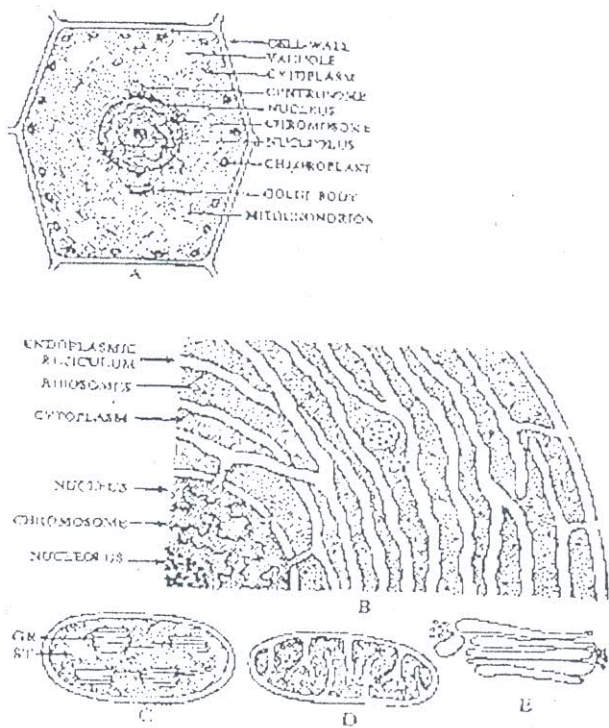


Fig 1.1 A typical Cell (Plant cell)

The cytoplasm is surrounded by a fluid delicate membrane known as the cell plasma membrane or ectoplasm. This layer controls the flow of substances in and out of the cell. Inside the cell sap are minute granules called microsomes. The fluid portion of the cytoplasm is known as hyaloplasm. The protoplasm is the living materials in the cell that form the physical basis of life. All plants and animals containing protoplasm are regarded as living organisms. All plant and animal cells cease to function when the protoplasm dies.

#### 1.2.4 Structure and nature of the protoplasm:

The protoplasm is a slimy gelly-like transparent fluid which contains fine granular materials. In the young cell, these materials fill the cell cavity, while in the mature cell, it appears as strands around the vacuole. The protoplasm content decreases and dries up following starvation of the plant or animal organism.

#### 1.2.5 Characteristics of protoplasm

- a. Reacts to external stimulus such as shocks, e.g. pin-pricks, variation in temperature or light, application of chemicals etc. The protoplasm contracts or expands during and after stimulations.
- b. It is semi-permeable: It allows selective substances to penetrate its body.
- c. It is under a slow but constant motion.
- d. The protoplasm exhibits motion. Movement is of different types which could be ciliary e.g. Fungi, algae rotation (clockwise or anti-clockwise) and circulation.

#### 1.2.6 Nucleus:

This is a specialized organ responsible for life in the cell. It varies in shape and type of cell. It is embedded in the cytoplasm of a cell. The nucleus is positioned centrally in a young cell and lies in the thin lining layer of the cytoplasm and may become flattened against the cell-wall. Nucleus is

present in all living cells both plant and animal. A nucleus cannot be newly formed but multiples by divisions of the pre-existing one.

### **Structure and Shape:**

Nucleus vary widely in shape from 1 $\mu$ m (micro) to 500 $\mu$ m. The usual size is between 14 to 25 $\mu$ m.

A nucleus is surrounded by a thin transparent membrane known as the nuclear membrane. This structure separates the nucleus from the surrounding cytoplasm. The shape of the nucleus is determined partly by the membrane. Within the nuclear membrane is the nuclear sap or nucleoplasm. This structure contains numerous fine threads loosely connected to form a network called Chromatin network or nuclear reticulum. This Chromatin network develops to form the Chromosome. The Chromosome is acidic in nature. There are two types of nucleic acids. They are De-oxyribonucleic acid (DNA) and ribonucleic acid (RNA). DNA is permanently located in the nucleus while RNA is located in the cytoplasm.

#### **a Functions of nucleus**

- i. It is responsible for life in all living cells
- ii. It is directly involved in reproduction both sexual and asexual.
- iii. It initiates cell division which is responsible for growth and development of living organisms.
- iv. It bears the hereditary material called the DNA.

#### **b. Genetic Properties of nucleic acids**

Both DNA and RNA have the following genetic properties.

- i. Specificity in action
- ii. Reproducibility,
- iii. Mutability
- iv. Stability

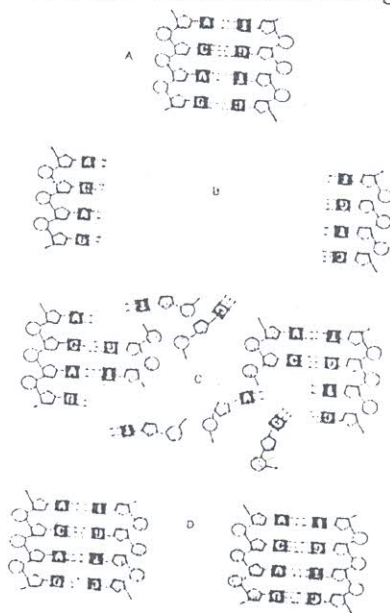
#### **b. Specific functions**

Both acids (DNA and RNA) are specific in action. This

property is independent on their specific structures. Character inheritance by offspring is associated by the properties of these acids. This accounts for why there is specificity in the synthesis of proteins and enzyme actions.

b. **Reproducibility**

Both acids are reproducible. The mechanism of reproduction is closely linked with the acid structures. Replication is facilitated in both acids by the ability of strong electro negative atoms in close association to form hydrogen bonds for as long as all the hydrogen atoms are attached to the carbon rings. However, replication of RNA is a lot more difficult than that of DNA. RNA molecule in the presence of enzyme RNA polymerase, build a complimentary strand. The complimentary strand then acts as a template to build a new strand, which is complimentary to itself and an exact copy of the original RNA-molecule. In the DNA, the double helical structure unwinds (in the presence of the DNA) to form strands. Each strand acts as a template to another strand called the complimentary strand. In sequence two strands containing a new and old strands coil-up into another double helix as in fig 1.2.



*Fig 1.2 The process of DNA replication*



- a. Schematic representation of DNA replication
- b. The two double helix separates
- c. The process continues as new bases are formed.
- d. New complimentary strand attaches to a template to form a new double helical DNA structure.

**e. Mutation Ability:**

The nucleic acids can undergo reversible changes which can be transmitted to the next generation. This is possible as the base pairing deviates from the normal pairing to abnormal type. This is extensively explained in Chapter 8. This change occurs very rarely. However, when it occurs during replication, it leads to wrong insertions (structural changes in chromosome).

**d. Stability**

The double helical structure of the DNA is very stable. The stability is enhanced by the hydrogen bond between the pairing bases of A-G; T-C. RNA is not as stable because it lacks de-oxyribose sugar. This confers a better genetic material quality to DNA than RNA. Experimental evidence by Louis (1980) shows that in organisms where both DNA and RNA are present; DNA is concerned with genetic information. However, in prokaryotes and viruses where only RNA is present, the RNA is concerned with transmission of genetic information.

### 1.2.6 Plastids

These are living protoplasmic bodies enclosed in the cytoplasm. Their average size is between  $4\mu$  to  $6\mu$ . Each plastid is bound by a double membrane. The ground substance in the plastid is called Stroma. Inside the stroma is a large number of granules called grana. The stroma is colourless while the granules are pigmented. Plastids are absent in blue-green algae, fungi and bacteria. There are three types of plastids.



- i. Leucoplasts
- ii. Chloroplasts
- iii. Chromoplasts

Each of this form can change to another form under different light intensity, e.g. leucoplasts when exposed to prolonged light, change to chloroplasts. While chloroplasts change into leucoplasts under continued absence of light. These pigments are responsible for fruit ripening e.g. tomato pepper, red apple etc.

Other cytoplasmic inclusions that are living are centrosomes, golgi bodies, mitochondria, lysosomes, endoplasmic reticulum and ribosomes.

The non-living inclusions are carbohydrates, starch, insulin, dextrin, glycogen, proteins, fats and oil, resins, latex, gums, alkaloids and organic acids.

### SUMMARY

All living organism are made up of cells. A cell is the smallest unit of life of all living organisms. The cell history started as far back as 1635 by Robert Hooke.

The living part of the cell is the protoplast. The nucleus is located inside the protoplast. The genes responsible for character transmission from generation to generation are located inside the nucleus. The protoplast performs all the physiological functions of the cell. The cytoplasm is the liquid part of the cell, containing chemicals. The plastids are sensitive to light.

## Questions

1.a Using a well annotated diagram, different between a plant and animal cell.

- b. The nucleus contains ..... Which is a .....
- c. The protoplast is responsible for all the ..... process in the body.
- d. The fluid in the vacuole is called .....
- e. The functions of the cell vacuole are ..... and .....
- f. The fluid portion of the cytoplasm is called .....

Q2 . Highlight four (4) features of the protoplasm.

- i. ....
- ii. ....
- iii. ....
- iv. ....

b. Differentiate between chloroplasts and chromoplasts.

.....

.....

.....

.....

c. List 5 each of living and non-living cytoplasmic contents in the cell

.....  
.....  
Q3. Itemise the major functions of the nucleus

- i. ....
- ii. ....
- iii. ....
- iv. ....

- b. The stroma is found in the ..... of a living cell
- ii. Differentiate between stroma and granule

# Chapter 2

## CELL DIVISIONS

### 2.0 Introduction

All cells actively divide to produce new tissues and organs. This is an essential attribute that differentiates living organisms from non-living. Plants and animals begin their existence as a single cell. Development produce physical effect called growth, which leads to formation of tissues and organs. Growth initiates the formation of new cells and enlargement of same. Cell division is a phase in the life cycle of every cell and begins immediately after fertilization and continues throughout the life of the organism. Cell growth and development involves five methods which are:

- a. Mitosis
- b. Meiosis
- c. Amitosis

- d. Budding
- e. Free cell formation

Cell division is composed of two parts: Nuclear division (Karyokinesis) and cytoplasmic division (cytokinesis). Karyokinesis comes before cytokinesis.

Mitosis and Meiosis are the mechanisms through which chromosome complements are maintained. The other three methods allow vegetative growth.

## 2.1 MITOSIS (GROWTH)

Before the onset of cell division, the nucleus is enlarged and the contents appear dense and granular. These granular contents later form the chromosomes. The genetic material packaged in the nucleus goes through a process of divisions. This series of cell divisions end in the production of two identical daughter cells. Cell division and enlargement give rise to growth. Before mitosis a cell is in the resting phase called interphase. At this stage chromosomes are stretched out and cannot be distinguished individually. At the onset of cell divisions, the granules are organized into discrete bodies which appear as the chromosomes (fig. 2.2).

There are four phases in mitosis:

- a. **Prophase:** The chromosomes are first seen as threads which are thin and tangled together at a later stage, the nuclear content progressively lose water and the chromosomes become shorter and thicker and distinct. The nuclear membrane and the nucleus disappear.
- b. **Metaphase:** Chromosomes appear thicker and prominent though shortened. Minute bodies called Centrioles appear at the opposite ends of the cell. From each end of the Centriole, radiates a web-like structure called spindle fibre. The chromosomes become attached to the spindle fibres by its centromere. Note that most plant cells do not have centrioles but spindle fibres. At this stage it is apparent that each chromosome consists of two parallel strands called Chromatids. These chromatids are produced by chromosome replication. The replications produce





## 2:2 Meiosis

This is nuclear divisions that result in the formation of haploid gametes. Meiosis is fundamental in sexual reproduction of both plants and animals. Four functional haploid gametes are formed in the male whereas only one functional gamete (Ovum) formed in the female.

There are two steps involved in Meiosis

1. Reductional division
2. Equational division

### 1. Reductional division:

This is called meiosis 1 and consist of four stages:- Prophase, metaphase, anaphase and Telephase.

**Prophase 1** :- This phase is divided into five stages which are: Leptotene, zygotene, pachytene, diplotene and diakinesis.

**Leptotene**:- Each Chromosome appear as thin long beaded threads.

**Zygotene**: Chromosomes appear as double strands. They are shortened and thick. Nucleolus appears and nuclear membrane remains intact. Homologous chromosome lie side by side (synapsis) i.e. pairing up to form bivalents

**Pachytene**: The bivalent chromosomes double up to form four chromatids called tetrads. The tetrads pair up and a pair fall apart so that each chromatid has a pairing partner in each region forming a cross shaped material called Chiasmata (Singular: Chiasma) though not very conspicuous.

**Diplotene**:- The Chiasmata appear very prominent and move towards the bivalent ends of the Chromatids. This stage is known as terminalization.

**Diakinesis**: - The bivalent shortens and thickens nuclear membrane disappear. This is an important stage as Chromosome number is easier to count.

**Metaphas 1**: - The tetrads (paired chromatids) align at the equatorial plane.

**Anaphase 1**: The paired Chromatids (bivalents) connected at their centromere separate to form dyads which move to the opposite poles of the cell. The two chromatids of each dyad spread away from each other

and move to the opposite pole and held at the poles by the Centromere.  
**Telophase:** haploid sets aggregate at each pole. This marks the end of Meiosis I. At the end of Meiosis I each daughter cell is halved.

## 2. Equational division

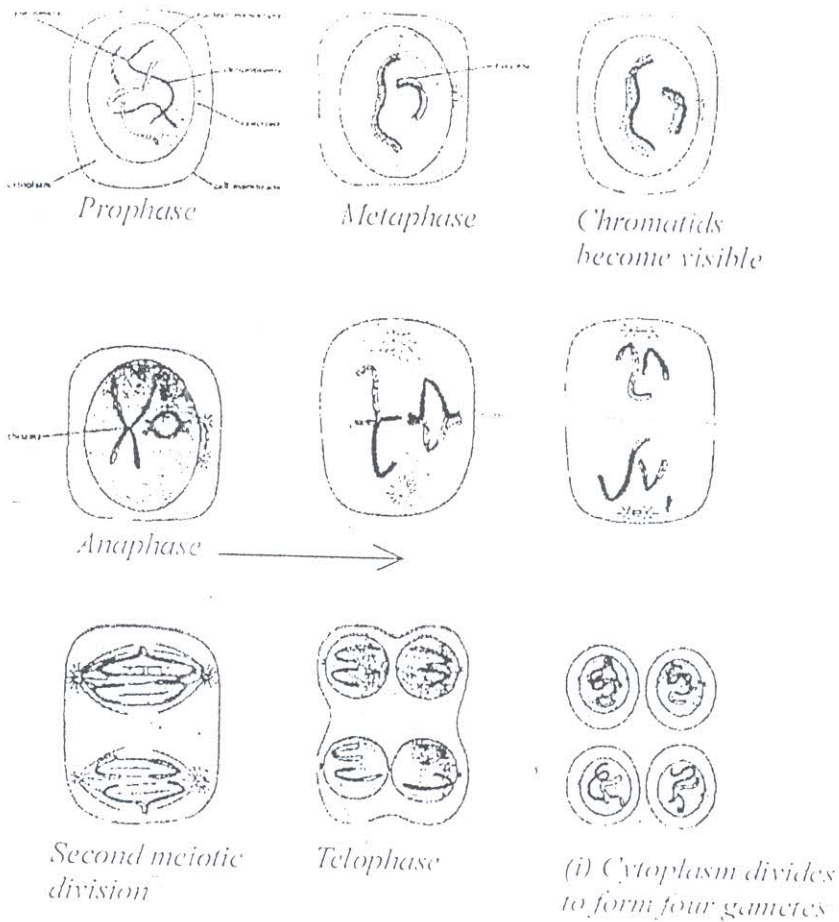
This is also known as Meiosis II: Meiosis II follows the stages in Mitosis having four stages.

- a. prophase II
- b. metaphase II
- c. anaphase II
- d. telephase II

**Prophase II:** - the dyads are still held by the centromere

**Metaphase II:** the centromere divides and the chromatids separate and are held at the plane by the spindle fibre each chromatid grows to a complete individual chromosome.

**Telophase II:** - Four nuclei formed each containing one member of each pair of Chromosomes. These are the nuclei of the Spermatids. These nuclei re-organize to form part of the head of the Sperm cell. This Meiosis II is a process that forms the secondary Spermatocyte. The general process of sperm-cell formation in Meiosis is called spermatogenesis.



*Fig 2:2 Meiosis showing gamete formation principles*

### 2:3 Gametogenesis

The general processes of sperm-cell formation are similar in all sexually reproducing plants and animals. In males four functional gametes, called sperms are formed from each primary spermatocyte. In females, after first meiotic division only one of the four daughter nuclei is functional and contains full cytoplasmic inclusions. The remaining three nuclei are abortive cells called polar bodies and contain little or no cytoplasmic materials.



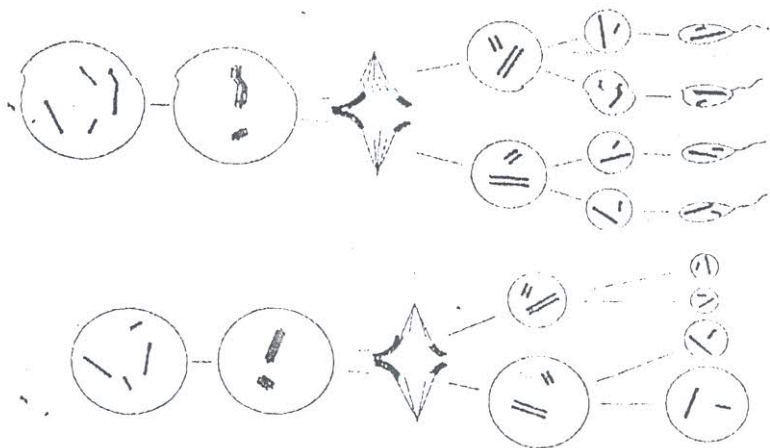


Fig 2:3 Gametogenesis in man

## 2:4 Summary differences between mitosis and meiosis

- Mitosis is a growth process in somatic body cells while Meiosis occurs in reproductive cells forming gametes and spores.
- Two identical daughter cells which are diploid are the resultant products of Mitosis, whereas, in Meiosis, four haploid gametes called tetrads are formed. I.e. Mitosis is equational while Meiosis is reductional.
- Meiosis keeps the Chromosome number constant from generation to generation.
- Pairing of homologous chromosomes occurs during the Zygotene stage in prophase of meiosis, but in mitosis no pairing occurs as the chromosomes divide longitudinally.
- Stages in meiotic divisions are prolonged and it last a longer than the stages in mitotic divisions.
- The centromere of the homologous chromosomes in metaphase stage in meiosis lie towards the opposite poles of the spindle fibre. While in mitosis, the centromeres are lined up at the equator.
- Chromosomes are prominent in all stages of meiosis than in mitosis.
- Chromosome strands in prophase stage of mitosis are double while in meiosis they appear as single threads.



- Meiosis is a remarkable process that allows exchange of genetic material. This is a prominent feature in the diplotene stage of prophase I in the first meiotic division (Meiosis I)
- Meiotic divisions result in the formation of haploid germ cells which provide basis for the segregation and independent assortment of genes.

### Summary

Somatic nuclear divisions (mitosis) results in the formation of two daughter cells, identical with each other and with the parent cell in chromosomal and genetic constitution. Meiotic divisions (reductional process) result in formation of haploid germ cells and provide basis for Mendelian genetics which explains the laws of segregation and independent assortment. Members of a pair of chromosomes are alike except for the sex chromosomes. The members of different pairs of chromosomes differ in constant structural details and are distinguishable from each other. Non sex linked chromosomes are called autosomes. Autosomes are also present in pairs. The diplotene stages of 1st meiotic division are very important and responsible for creating variability. Meiotic divisions are generally longer than mitotic divisions.

### Quest

Q1.

- i
- ii.
- iii.
- iv.
- v.

Q2

- 40
- 40
- 40

b.

c.

## Questions

Q1. Explain and indicate what the following terms signify:

- |                |                  |
|----------------|------------------|
| i. Anaphase    | vi. Nucleus      |
| ii. Diakinesis | vii. Diplotene   |
| iii. Meiosis   | viii. Tetrad     |
| iv. Spermatid  | ix. Zygotene     |
| v. Polar body  | x. Somatic cells |

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Q2. How many functional eggs are expected from  
40 primary oocytes  
40 secondary oocytes  
40 ootids.

b. What are the common factors in the processes of sperm cell and egg cell formation?

.....

.....

.....

Q3 What is Centromere?

.....

b. Explain the relationship between a Centromere and a Spindle Fibre.

.....

.....

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c. Differentiate between Chromatin and Chromomere.

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d. Write briefly on Homologous Chromosomes

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# Chapter 3

## PRINCIPLES OF INHERITANCE

### 3.0 Introduction

In the previous chapter it was explicitly clear that all living organism contain nucleus in their respective cells and that genes which carry chromosomes are embedded in the nucleus. The genes in the chromosomes are the genetic materials and not the chromosomes. These genetic materials are discrete units which cannot be seen with the naked eyes and are transmissible from generation to generation.

The question is what is the relationship between genes and chromosomes as it concerns character inheritance?

### 3.1 Genes and Chromosomes

Genes are discrete unit of heredity responsible for trait or character transmission. Genes are located within the chromosomes.

There are two types of chromosomes. Sex chromosomes and non sex chromosomes called autosomes. Autosomes provide basis for the inheritance of characteristics that are not sex-linked while sex-chromosomes are involved in sex-linked traits. Autosomes are in pairs and maintain their individual identity as in genes. Autosomes and sex-chromosomes carry genes. Let us substantiate the behaviour of this genetic material in the chromosome.

### 3.2 Evidence about the behaviour of Genetic materials

1. That genetic material is sparsely distributed in the chromosomes: Genes are located on different points called LOCUS on the chromosomes. This means that distance from one gene locus varies from Locus to locus on the same chromosome. This is evident in the space locations of three mutant genes scute echinus and cross veinles at different gene loci in *Drosophilla*. These 3 genes are linked. Their distances between the mutant respective genes were not equal, hence maximum cross over effect was experienced and this resulted in the recombinant phenotypes manifesting in the offsprings. It is through crossing over that recombination among linked genes occur.

2. That genetic factors are carried on the chromosomes

a. This evidence is made clear by the behaviour of genes and chromosomes at Meiosis during gametogenesis.

b. And also by the presence of sex-chromosomes and sex-linked characters.

The discovery of specific chromosomes associated with sex determination provides proof of the chromosomes theory of inheritance. The morphological differences in males and females are traceable to the differences in the sex chromosomes. This confirms that the genetic factors responsible for sex linked character differences are borne on the sex chromosomes.





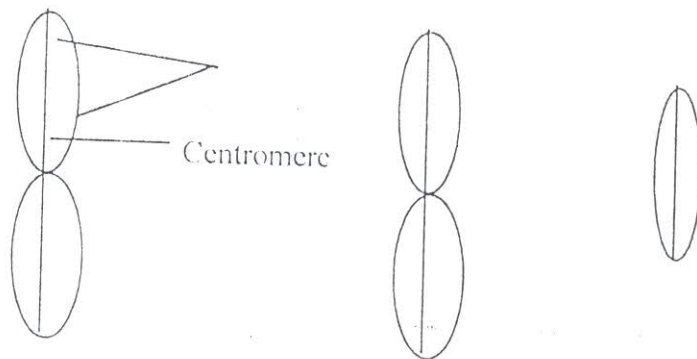


Fig. 3.1 Diagrammatic illustrations of centromere positioning.

### 3:4 Chromosome Number

The number of chromosome is constant for all individuals of a specie and varies from one specie to another for example

Man	= 46	chromosomes
Rabbit	= 44	chromosome
Rat	= 42	chromosomes
Peas	= 14	chromosome
Corn	= 20	chromosome
Tomatoes	= 24	chromosome

Chromosomes are in pairs except for sex chromosomes. Chromosome number of specie is addressed in pairs e.g. man has 23 pairs, rabbit 22, rat 21, peas 7, corn 10 and tomatoes 12.

The chromosome number found in species and specifically in somatic cells is referred to as the diploid number with the symbol  $2n$ . While the chromosome pairs found in gametes are referred to as the haploid number and has the symbol  $n$ .

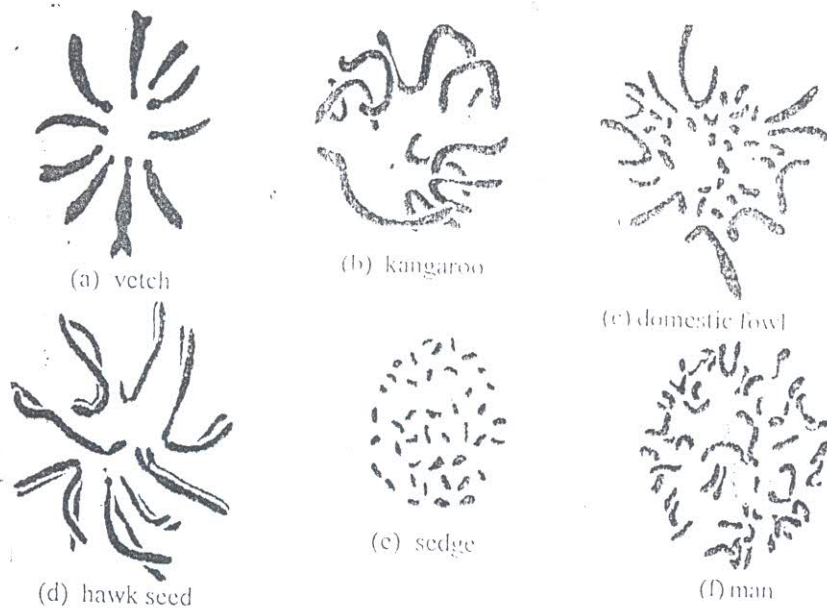


Fig 3:2 A giant chromosome

Table 3:3 Chromosomes of different species

Organism	Chromosomes In gametes (n)	Chromosomes in somatic cells (2n)	Pairs of chromosomes Somatic cell (n)
Man	23	46	23
Corn	10	20	10
Rabbit	22	44	22

### 3.5. Gene and Chromosome Peculiarities

- i. Genes and chromosomes are transmissible from generation to generation.
- ii. Genes transmitted in pairs are called alleles. This manifest in form of characters and are represented using symbols such as TT, Tt, tt.
- iii. Gene and chromosome transmission from parents to offsprings pass

through a medium known as the gametic cells.

- iv. During gamete formation there is random and independent assortment of alleles.
- v. Constant number of pair of chromosomes is present in each of the somatic cells of all individuals of specie.
- vi. Members of different pairs of chromosomes differ in structural details and can be distinguished from one another. However, members of a pair of chromosomes are alike except for the sex chromosomes.

### 3.6. Sex determination and Linkage

A cytologist McClung between 1901-903 detected a special chromosome concerned with sex determination at fertilization. In 1905 Miss Stevens and Wilson discovered different number of chromosome pairs in male and female insect belonging to the class Orthoptera. The female insect has an even chromosome number and the male has an odd number.

When the male chromosomes paired with the female, it resulted in a single representative in the male. According to McClung these male and female chromosomes are called accessory chromosomes but Miss Stevens called such chromosomes X-Chromosomes

In most plants and some lower organisms such as insects there is no morphological differences between the male and female individuals. In animals however, sexual differentiation is the rule. The only pair of chromosomes which shows differences between male and female animals is called sex chromosomes or heterosomes. All other chromosomes apart from those sex chromosomes are called autosomes. Those sex chromosomes are known as X and Y chromosomes. When an egg is fertilized by an X-bearing sperm, the zygote is female (XX) when it is fertilized by a sperm lacking the X chromosome the zygote is male, having only one X derived from the egg. The sex of the individual that develops from the fertilized egg is therefore determined at fertilization by a chance. In insects e.g. butterfly, the sex chromosomes are reversed i.e. the female having XY chromosome and the male having XX. In some insects e.g.



grasshoppers, one sex has one chromosome more than the other sex. The Y chromosome is absent and so the male has XO chromosome in grasshoppers, the female has 20 chromosomes made of 18 autosomes and one homologous pair of sex chromosome XX. On the other hand, the male has 19 chromosomes being made up of 18 autosomes and one sex-chromosome (X0)

Other types of chromosomal sex determination include:

1. Where both individuals (male and female) have a pair of sex chromosomes with the members being homologous in one sex and not in the other sex.

These types are:

a. Where the homologous sex-chromosomes are found in the female individual e.g. man. This is the XY chromosome system. Here, male sex chromosome pair is XY. In man, each normal somatic cell contains 46 chromosomes. Consisting of 22 autosomal pairs and one pair of sex-chromosomes and is represented thus:

Female	♀	$2n = 22 \text{ TT} + \text{XX}$ and
Male	♂	$2n = 22 \text{ TT} + \text{XY}$

In *Drosophila*, the somatic cell contains three autosomal pairs and one pair of sex-chromosomes. The female *drosophila* is represented as follows:

Female	♀	$2n = 3\text{AA} + \text{XX}$ and
Male	♂	$2n = 3\text{AA} + \text{XY}$

In *drosophilla* the genes determining male characteristics are carried on the autosomes and their phenotypic effect show on the XX chromosome and male characteristics appear in the presence of a single chromosome. In heterogametic individuals, the sex of the offspring is determined by the sexually differentiated chromosome.

### 3.7. Sex Linkage

Genes are borne on the chromosome. Genes carried on the sex chromosomes are said to be sex linked. This explains that characteristics dependent on genes that follow the pattern of the X chromosomes



inheritance are known as sex-linked characteristics and the controlling genes are sex-linked genes. The characters controlled by these genes are therefore inherited with sex. Sexually dimorphic organisms are therefore said to have sex-linked characters.

In insects e.g. *Drosophilla* eye colour is sex-linked. A true breeding red eyed female mated with a white-eyed male. The first filial generation ( $F_1$ ) had red eyes, white eye was therefore recessive. On selfing the  $F_1$ , Hunt Morgan (1910) discovered a ratio 3.1 of red eye to white eye. He later crossed a white-eyed male with some of the red-eyed females, the following result was obtained:

129 red-eyed female  
 132 red-eyed males  
 88 white-eyed female  
 86 white-eyed males

These gave a ratio of 1.1 female to male. This shows that white eyes can be carried over to the females when crossed.

In *Drosophilla*, the eye-colour gene is borne on the X-chromosome while the Y-chromosome is inert. The genotypic representation of the above is as follows where W superscript is on the sex-chromosome of XX.

Parent ♀  $X^w X^w$   
 ♂  $X^w Y^0$       Gametes:  $X^w$   $X^w$   $Y^0$

$F_1$   $X^w X^w$ ;  $X^w Y^0$  All red-eyed

On selfing:

Gametes  $X^w$   $X^w$   
 $X^w$   $Y^0$

$F_2$  using a checkerboard.

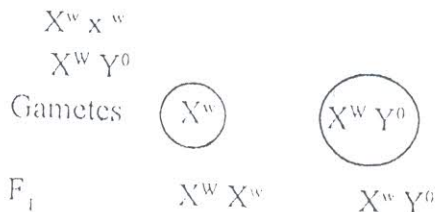
	W	Y
$X^w$	$X^w X^w$	$X^w Y^0$
$X^W$	$X^W X^w$	$X^W Y^0$

Fig. 3.4. Sex Linkage pattern in *Drosophilla*

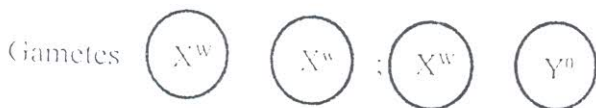
All females are phenotypically red-eyed; half are genotypically homozygous ( $X^W X^W$ ) while the other half is heterozygous ( $X^W X^w$ ). The males on the other hand, consist of half red-eyed and half white-eyed. In this result, the Mendelian expectation of 3:1 of red-eyed to white eyed  $F_2$  population was obtained. There is a little deviation with the sex ratio i.e. all females had red-eyes, males half red-eyes and half white eyes.

On the other hand where the crossing is reversed and a white eyed female crossed with a true breeding red eyed male, the  $F_1$  males will be all white-eyed and the females' red-eyes. The  $F_2$  will produce the following:

$F_2$  equal proportion of red-eyed male and female and equal proportion of white eyed male and female. The genotypic proportion will be as follows:



When crossed together:



F<sub>2</sub>

	W	Y <sup>0</sup>
X <sup>w</sup>	X <sup>w</sup> X <sup>w</sup>	X <sup>w</sup> Y <sup>0</sup>
X <sup>w</sup>	X <sup>w</sup> X <sup>w</sup>	X <sup>w</sup> Y <sup>0</sup>

where Female red-eye = X<sup>w</sup> X<sup>w</sup>      Male white-eye = X<sup>w</sup> Y<sup>0</sup>  
 Female white-eye = X<sup>w</sup> X<sup>w</sup>      Male white-eye = X<sup>w</sup> Y<sup>0</sup>

Fig. 3: shows equal red eye male to female

**Summary**

In sexually reproducing organisms life begins as a single cell formed from union of germs-cell (gametes) the fusion has the combined chromosome complements with twice the chromosome number of either gamete alone. Further growth and development of the zygote is based on mitotic divisions. Reproduction by the new adult is preceded again by reduction of chromosome number (meiosis). The fundamental element of the chromosome is a thread like structure called chromonema. The chemical composition of chromosomes are the deoxy-ribonucleic and ribonucleic acids (DNA and RNA) respectively. The mature germ cells (gametes) of sexually reproducing individuals contain only half the number of chromosomes. Gametes are haploid (n) in chromosome number and the somatic cells are diploid (2n). The sex differences within a specie is associated with a difference in chromosome number i.e. one sex may be diploid and the other haploid. In hymenoptera the Y chromosome is absent hence the male has XO chromosome.

## Questions

Q1 Differentiate between a gene and a chromosome

.....  
.....  
.....  
.....

b. Explain the following:

i. Sex-linked genes

.....  
.....  
.....  
.....

ii. Sex chromosomes

.....  
.....  
.....  
.....

c. The point of attachment of chromatids is called .....

d. Chromosome morphology is dependent upon ..... of the

Q2a Differentiate between Pericentric and Metacentric chromosomes.

.....

- .....  
.....  
.....
- b. Explain the following terms
- i. Centromere
  - ii. Accessory Chromosome
  - iii. Sex determination
- c. Genes and chromosomes are transmitted through a medium known.....
- d. Independent assortment of alleles to produce constant number of chromosome pairs occur during .....
- Q3 Discuss briefly sex linkage as related to insects.



# Chapter 4

## MENDELIAN GENETICS

### 4.0 Introduction

Biological individuals have patterns, limitations and characteristics that depend at least in part on the parents of an individual. Through experimentation geneticists have established certain rules that characterize the transmission of biological properties. In the early development of science of genetics, investigators realized that genetic systems need to be understood in relation to the environments in which the organism exists. The study of genetics leads to a profound understanding of the world of living-things and the application has provided ways in solving practical problems concerned with man. What is responsible for character transmission from generation to another is the concern of Geneticist and plant breeder. The foundation of modern knowledge of inheritance started in the eighteenth century by Johann Gregor Mendel. Prior to the discovery of Gregor Mendel a number of hypothesis and theories have been

developed to explain the basis of variation and inheritance. Among these theories are:

1. The theory of inheritance of acquired characteristics also known as Lamacks Hypothesis.
2. Wolff's theory of epigenesis.
3. Swammerdam's theory of preformation
4. Darwins hypothesis of pangensis
5. Weisman's theory of germplasm.

#### 4.1 Mendelian Experiments and choice of plant

The study of character inheritance was first carried out by an Austrian Monk called Johann Gregor Mendel between 1858 and 1866. He worked in Monastery garden by planting and crossing a flowering plant known as garden peas (*Pisium Sativum*). The work of Mendel gained acceptance and provided basis for the science of Genetics because of the following:

1. Mendel had a brilliant analytical mind.
2. He was meticulous at experimentation of analysis and interpretation of his work.
3. He was careful in the choice of parent plants in investigations and maximized the chances of obtaining meaningful results.
4. He was able to simplify and avoid complexities in the course of his work.
5. He was hardworking and painstaking
6. He was able to make meaningful inferences from his analysed result

Why the choice of garden pea by Gregor Mendel?

1. The plant morphology shows a number of contrasting traits.
2. The flower (pistillate) is constructed to exclude the pollen from other plant flowers.
3. The pea is an annual plant and fast growing.
4. It allows far easy controlled crossing (cross-pollination)
5. The plant is naturally self fertilizing and therefore represents true-breeding lines.

In all Gregor Mendel's success was tied to the simple and logical sequence of making crosses and the careful numerical counting of the resultant progenies which he kept and used the parent plants as reference's in making his scientific submissions.

The work of Mendel was not recognized and appreciated until 1900 (about fourteen years after his death) when other geneticists built on his finding.

### 4.3. Character inheritance: Monohybrid Inheritance

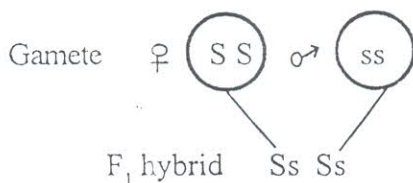
Mendel's first experiment assumed an inheritance theory known as law of segregation: This law explains that when gametes are formed the factors (genes) separate and are distributed as single units into each gamete. This will be explained during the practical illustrations of Mendel's work. The pairs of alternative character studied by Mendel were round versus wrinkled seeds.

Crossing plants containing seeds of pure breeding round seed with plants having smooth wrinkled seeds, the following results were obtained

Smooth rounded seeds are designated SS

Wrinkled seeds are designated ss

Parent:



All smooth and rounded phenotypes were gotten in the F<sub>1</sub> generation.

The F<sub>2</sub> generation will be:



The F<sub>2</sub> consist of two phenotypes  
 SS, Ss Ss = Smooth seeds



ss = Wrinkled seeds

The ratio of smooth to wrinkled seeds is 3:1

Fig 4:1 Mendelian ratio illustrating segregation pattern following crosses of smooth vs wrinkled seed coat colour of garden pea

#### 4.4 Result Analysis

There were presumptions following the garden pea experiments these are:

1. The parent pure-breeding pea: contain a pair of similar factors for each character i.e. a pair of alleles (called a gene) is responsible for a character (traits) e.g. smooth seeds and wrinkled seeds. These characters are represented using symbols. Smooth seeds represented by the symbol SS and ss for the wrinkled seeds. The symbols are used in genes to differentiate characters of an organism. Where the symbols are in capitals such character is said to be dominant and if otherwise such characters are said to be recessive. Characters represented by same symbols are said to be Homozygous and hence produce same gamete.
2. Crossing the two contrasting parent types will result in producing hybrids with dissimilar offsprings at some level e.g. SS parent and ss parent will produce offsprings with Ss genes. Where this occur such offspring is said to be heterogeneous as shown in fig. 4.1
3. At gamete formation, the two alleles of a character will separate such that each gamete contains only one allele for a monohybrid inheritance.
4. The crossing of the two characters produced hybrids with different outward appearance. This outward appearance is called phenotype. And the inward (genetic) constitution of the phenotype is referred to as the genotype. It is therefore evident that two different genotypes of SS and Ss have the same phenotype.
5. From this experiment the presumptions satisfied all the experimental observations and hence predications were made. These assumptions later formed basis for the two laws of inheritance known as:

Law of segregation and Law of Independent assortment.

The law of segregation holds for monohybrid experiment. Other kinds of crossing combinations can be made to further test these assumptions.

#### 4.5. Dihybrid inheritance: Law of Independent Assortment.

In dihybrid inheritance Gregor Mendel chose two contrasting characters from each parent. Smooth coat and yellow cotyledon as one parent and wrinkled seed coat with green cotyledons as the second parent. These parents were grown and their flowers crossed to raise the  $F_1$  hybrid. All the  $F_1$  progeny had round with yellow cotyledons. This confirmed the dominance of smooth, seed coat and yellow cotyledons over green-cotyledon.

The  $F_1$  seeds were planted out again and allowed to self fertilize. Four different classes of phenotypes were produced. These four classes are in the ratio of 9:3:3:1

This result showed that:

1. The parent types, smooth-yellow seeds and wrinkled-green seeds reappeared.
2. New hybrids different from the parent plants and seeds also appeared. These are smooth seed with green cotyledon and wrinkled seed with yellow cotyledons.

The ratios of appearance are as follows:

315 smooth seed coat and yellow cotyledons

101 wrinkled seed coat and yellow cotyledons

108 smooth seed coat and green cotyledons

32 wrinkled seed coat and green cotyledons.

The ratio of overall smooth seed coat to wrinkled seed coat is in the following proportion:

$$\text{Smooth seeds} = 315 + 108 = 423$$

$$\text{Wrinkled seeds} = 101 + 32 = 133$$

$$\text{Approximate ratio} = 3:1$$

$$\text{Seeds with Yellow cotyledons} = 315 + 101 = 416$$

$$\text{Seeds with Green cotyledons} = 108 + 32 = 140$$

$$\text{Approximate ratio} = 3:1$$



This shows that the segregation of the pair of factor (genes) which control seed coat texture is completely independent of the segregation of the pair of factors which control colour of the cotyledons. This experiment presupposed the second law of inheritance known as Law of independent Assortment. This is demonstrated as follows:

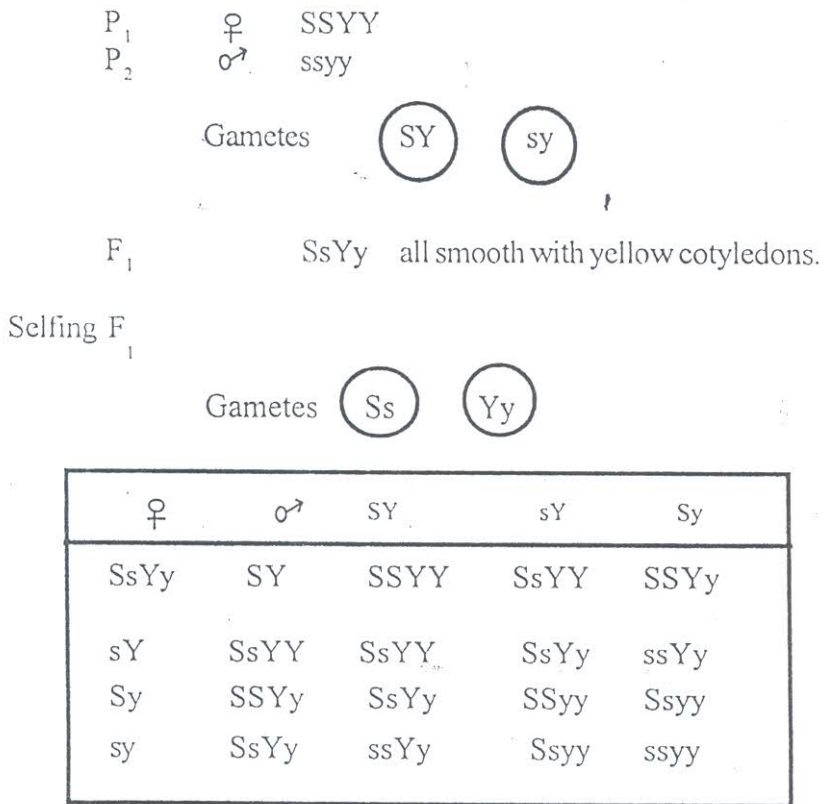


Fig. 4.2 the use of a check board showing independent assortment in peas of two contrasting characters.

The dihybrid character inheritance pattern is summarized in a table to show the different assortment pattern of the two characters involved.

Table I. Appearance of the two contrasting characters in a cross of smooth-seed coat and yellow cotyledons versus wrinkled seed coat and green cotyledons

Parent character	Character frequency		Phenotype ratio
	F <sub>1</sub>	F <sub>2</sub>	
1. Seed type: Smooth Vs wrinkled coat	All smooth	315 smooth 101 wrinkle	3: smooth 1: wrinkled
2. Colour of cotyledon Yellow vs. Green	All yellow	416: yellow 140: Green	3: yellow 1: Green
3. Seed type and cotyledon & Yellow Colour	All Smooth	416: smooth & yellow 140: smooth & green 140: Wrinkled & yellow 32: wrinkled & green 1:wr. & green	9:Sm. 3:Sm. & green 3:wr. & Yellow 1:wr. & green

Note: Ratio 9: 3:3 :1 is represented as follows

- 9 = smooth seed coat with yellow cotyledons
- 3 = smooth seed coat with green cotyledons
- 3 = wrinkled seed coat with yellow cotyledons
- 1 = wrinkled seed coat with green cotyledons.

## SUMMARY

The differences in genetic characters depend on particulate factors called genes. Genes are in pairs. During Gamete formation a member of a pair of genes are donated by each parent (Paternal and maternal parents) and separate without influencing each other. Mendelian genetics follows the law of inheritance. Monohybrid and dihybrid character inheritance are typical research work of Gregor Mendel. Plant type with contrasting characters is better used in the study of Mendelian Genetics. In hybrids one member of an allelic pair may be dominant over the other. Members of different pairs of alleles can assort into gametes independent of each other and recombine at random during fertilization.

## Questions

Q1a Highlight the characteristics of any choice of plant for genetic studies using Mendelian Genetics

.....  
.....  
.....

b. Using diagrammatic illustration define and explain

i. Law of independent assortment

ii. Law of segregation

2a. A true-breeding tall and sweet fruit orange was crossed with a dwarf sour fruit orange type. What type of progeny and in what proportion will the resultant progeny be, assuming independent assortment?

i.  $F_1$

.....  
.....  
.....

ii.  $F_2$

.....  
.....  
.....

iii. Back crosses  $F_1$  to the sweet fruit parent

.....  
.....  
.....

2b. by the analogy in 2a, can the law of segregation hold?

.....

.....

.....

.....

# Chapter 5

## GENE INTERACTIONS AND GENE ACTIONS

### 5.0 Introduction

Transmission of traits from parent to offspring involves the mechanisms of inheritance as earlier discussed in the previous chapters. We are certain that genetic materials packaged in chromosomes go through a complex but intelligible series of steps enhancing gene exchange before a new offspring emerges. We have also known that the principles of gene segregation and assortment lead to the emergence of hybrids with some traits having resemblance with the parents. The phenotype is a product of genotype and environment interaction. Features that differentiate individual phenotype show variations. The various gene interaction processes as affected by the environment determines type of phenotype produced by the offspring. These various interaction processes mediated by meiotic divisions which are controlled by the inheritance principles are responsible for variations in individual phenotype. Going by this principle we are



certain that passing parental features to the offspring is a function of Gene actions and interactions of which this chapter will extensively reveal.

### 5.1 Gene interaction

In some ways, the interaction between two different genes where one gene affects the expression of another is explained by the dominance phenomenon. Dominance refers to gene modification at a level where an allele expresses itself at the expense of the other. This does not reveal any interaction between alleles of genes. Segregation ratios as reported by Mendel are found when the genes involved do not interact. When two or more genes interact at some locus or different loci to determine the phenotype of the offspring such interaction is referred to as Gene interaction.

The normal 3:1 segregation ratio implies that genes involved do not interact. However, where deviation from the normal segregation ratio occurs it implies that a number of levels of gene interactions have taken place. Characters which show continuous variations as in Mendel's illustrations can be quantified and critically analyzed. Characters that show discontinuous variation are analyzed qualitatively. Characters with continuous variations are controlled by several genes and are said to be polygenic. Polygenic characters are highly susceptible to environmental modifications e.g. soil, temperature, humidity, sunlight etc. Such characters are not easily exploited in meaningful breeding programme. Examples of polygenic characters are height, body weight, length, litter size, number of branches etc.

There are different types of gene interactions with polygenic inheritance.

#### 5.2.1 Complementary gene action

Here, one dominant allele is present at two different Loci i.e. genes A and B are dominant and presented at Locus 1 and Locus 2 respectively. This type of interaction explains that the character is not expressed in any genotype not carrying the two alleles i.e. AAbb, Aabb, BBaa, Bbaa or aabb will not express the character. Complementary gene affects results

in a 9:7 dihybrid F<sub>2</sub> ratio. For example, the inheritance of maturity period in cowpea indicated two gene, A and B interaction at two different Loci such that when both genes are dominant the maturity date is intermediate between late-maturing and early-maturing dates. This intermediate maturity date is not expressed when either gene A or B is present. Some other notable examples are the inheritance of comb shape in domestic fowl. Two genes R and P are involved. When these two genes are in dominant form the comb shape is walnut type, but when only gene P is dominant, comb shape becomes pea-type and when R is dominant comb shape turns Rose-type and when both R and P shape are recessive, the comb becomes a single type.

### 5:2:2 Additive gene actions

This is similar to complementary gene action in that both genes affecting a character are in the dominant state. However in additive gene action, the affected gene character has more vigor which is expressed in increase in size.

Note that any genotype without the A or B gene will give no expression for instance characters with AaBb show more intense additive gene effect than a character with Aabb gene expression. A genotype with aabb gives no expression at all.

Additive gene action is recognized by a 9:6:1 dihybrid ratio. Another example is the inheritance of skin colour in man. A gene is responsible for skin pigmentation (melanin) while several other genes in other Loci are responsible for pigment accumulation on the skin. Intensity is therefore dependent on how many of the accumulating genes are involved.

### 5.2.3 Epistatic gene action

This is a form of gene interaction where genes at one locus show dominance over the genes at another locus. The interaction is purely non allelic. In this interaction the dominance of one factor over the other occur when the character is controlled by two genes rather than by alleles of a single



gene. These type of genes are also called masking genes. It produces a 12:3 dihybrid ratio

There are different interaction levels with epistatic gene actions:

- A. Duplicate epistasis
- B. Dominant epistasis
- C. Recessive epistasis

**A. Duplicate epistasis:** - This interaction occurs when both genes have similar expression i.e. a phenotype is only expressed as A and B genes from different loci produce same phenotype with  $Aabb$ ,  $aaBb$ ,  $Aabb$  and  $aaBB$ . Only the full recessive  $aabb$  has no expression and hence the dihybrid ratio of an  $AaBb$  cross is a 15:1 ratio. In any meaningful breeding programme, characters that are controlled by duplicate epistatic gene actions are not easily exploited to bring about successful hybridization. This is because the genes responsible for such characters are not easily identified especially with continuous variable traits where many genes are involved. This is the case with improvement of late maturing cowpea with wide canopy. In a cross of early maturing with reduced canopy and late maturing with wide canopy cowpea varieties it was discovered that days to flower, length of peduncle and number of seeds per pod were controlled by duplicate epistatic gene action. Therefore improvement of such cowpea crop will require continuous hybridization to achieve meaningful result.

There are cases where a ratio of 13:3 is produced in duplicate epistasis. This occurs when either of the two genes act to suppress or inhibit the expression of the other gene when the other gene is also expressed in the dominant form e.g. gene A is dominant but its expression is inhibited when B is also dominant. Therefore only  $AAbb$  or  $Aabb$  genotypes are expressed.

**B. Dominant epistasis:** - Here, Gene A effect dominates gene B effect and the character is expressed only when no dominant Allele is present i.e. the gene B can be expressed only in the  $aaBB$  or  $aaBb$  combination. But if in the homozygous recessive  $bb$  and in  $aabb$  combinations, the B gene is not expressed.

C. **Recessive epistasis**:- Unlike dominant epistatic gene action where gene B can only be expressed when A gene is not dominant, recessive epistasis brings about modification in gene A where gene B is present i.e. gene combinations of aaBB, aaBb or aabb genotypes will not be expressed unless gene A is present. This implies that the expression of AABB, AABb and AaBb are intensified because gene A is present either in the homozygous or heterozygous state and therefore give a ratio of 9:3:4. Epistatic recessive genes are also known as modifying genes. There are diverse examples of modifying genes. The most notable are those associated with sex determination. Examples of such are:  
Sex-influenced characters e.g. baldness development of male and female features milking in cows and human females. There are cases where many genes influence more than one character such cases are referred to pleiotropic gene effect. e.g. gene in sorghum results in both increase in lysine content of protein and shrinking of the endosperm. Pleiotropy and gene linkage may be confusing. A pleiotropic gene will not produce segregations which can be separated as in linked genes. A single pleiotropic gene will not produce a recombinant genotype and it is only when there is a single recombinant genotype that linked genes are present.

### 5.3 Gene Linkage

The exchange of genes from parents to form new combinations that eventually result into new phenotype is known as gene linkage. Genes that show linkage are from same chromosome. The expression of the new combinations of linked genes which has the tendency to remain together is called recombination. The various processes of segregation and independent assortment of members of homologous chromosome pairs produce new recombination of linked genes. This phenomenon is explained in the inheritance of colored and frizzled egg cells and white normal egg cells. According to early Genetics by Hutt 1933. Genes for colored frizzle denoted as fund F are in one homologue and gene I and F for white normal are in another homologue, such that the determination of progeny of the egg cells is by having same allele in chromosome combinations as in the Gametes of the parents.



### Linkage in the $F_2$ :

The Mendelian dihybrid ratio of 9:3:3:1 holds with equal combinations of gametes producing four possible genotypes AB, Ab, aB and ab.

However, where there is linkage of the segregating genes, there exist deviation from the expected 9: 3:3: 1 ratio. The magnitude of the deviation depends upon the strength and frequency of linkage.

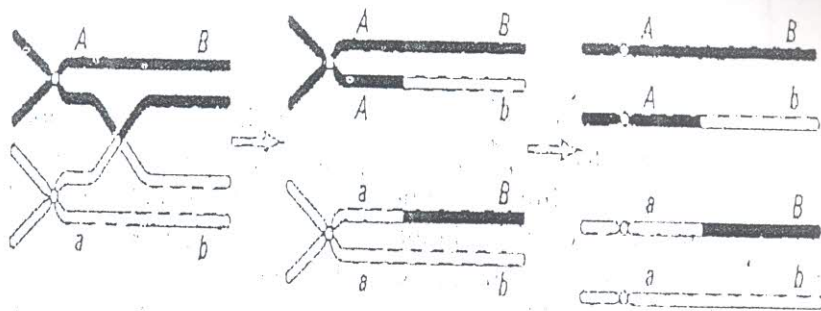
Test cross data are preferably used to estimate linkage values because the totals of recombination and non-recombination gamete types are read directly and more easily than using data from the  $F_2$

### 5.4 Crossing over:

At the diplotene stage of prophase during Meiotic I division, there is exchange of genetic materials. The whole process leads to recombination of linked genes restricted to alleles of same homologue. Therefore, recombination of linked genes through a process by which homologue chromosomes exchange genetic materials is termed crossing over. The necessary events that explain crossing over are as follows:

1. Crossing over characteristically occur in first meiotic division
2. Meiotic crossing over takes place during the time in the nuclear reproductive cycle when four chromatids are present for each pair of chromosomes.
3. When gene A and its allele are present in different members of a pair of homologous chromosome (fig. 5:1) the gene and its allele occupy corresponding places in the homologues.
4. To provide recombination between two different allelic pairs situated in the same chromosome pair, crossing over must occur between the loci where the genes are involved.





*Fig. 5.1 interchange of gene A and B during crossing over.*

Crossing over is a process that produces recombinations as in fig. 5.1 above A and B double strands is a new recombinant as well as A and B. The new segments a and B; a and b are called crossovers. These crossovers are actually the chromatids resulting from the interchanges. Therefore it can be categorically said that a crossover is recognized by a recombination.

## SUMMARY

Gene interaction is important as it provides basis for selection. The effects of the various genes may be complementary or additive while others may be modifying. The contributing effect of each individual gene can be determined but each determination is relative to their modifications by the environment. The influence of the environment on each gene differs. Characters subjected to environmental modification are somewhat not easily exploited in any meaningful breeding programme.

## Questions

Q1a Quantitative traits are controlled by ..... genes.

b. Complementary gene action is present in one of the following pairs of genes

AAbb

Aabb

AaBb

Aabb

c. The different interaction levels in Epistatic gene action are

.....and .....

Q2 What is the relationship between recombinant genes and crossing over?

b. What is the significance of the Diplotene stage in first meiotic division?

.....  
.....  
.....  
.....

Q3. What is the significance of the following in plant breeding?

i. Linkage

ii. Recombination

iii. Crossing over

iv. Locus

# Chapter 6

## GENETIC VARIATION

### 6.0 Introduction

Organisms are made up of components. These components are referred to as traits. Individuals are distinguished using traits or characters. It is this character performance that results into variation. Plant and animal breeders seek desirable or combinations of traits in existing populations. Desirable traits are sought within recommended cultivars, breeding lines, land races, exotic or related genotype, wild relatives, alien crop species etc. When desirable traits cannot be found in any of the existing germplasm sources, the breeder can create variation through artificial crossing known as hybridization or induced mutation. Characters between similar groups of organisms show variations that enable one group to be identified and differentiated from another. Genetic variations can be divided into two categories which are continuous and discontinuous both variations follow the laws of inheritance.



## 6.1. Sources of Genetic Variations

In the introductory note highlights on sources of desirable traits were given. It is therefore important to expose us to the various means by which genetic variations can be introduced to organisms. These various sources have led to the discovery of new phenotype called variants, which are consequently subjected to environmental influences. Genetic resource is the main stream of variation and of course precious to plant breeders. The realization of the importance of genetic resource led to the establishment of gene banks for the purpose of conserving genetic resources. Gene banks are important so as to:

1. Meet the needs of plant breeders: to provide genetic resources particularly of wild species, weed races, land races and to derive features for pest resistance, adaptation etc for continued progress and success in plant breeding.
2. Reduce the loss of genetic diversity amongst organisms. These losses may be as a result of land uses as relating to pesticide and fertilizer application continued land exploitation due to population pressure, change in topography, temperature, humidity etc.

*The various sources of Genetic variations are:*

- a. **Land races:** - These are genetically diverse populations selected under low-input agricultural conditions for yield stability and not for productivity or yield ability. Land races under intense cropping systems are not likely to perform as well as their cultivated counterparts but they are useful in plant breeding as they provide basis for direct selection for wide adaptation.
- b. **Commercial cultivars:** - This sources supply superior germplasm that can adapt to specific environment. The success of these genotypes is the assurance that they are the best gene combinations available. For example in current research programme by Aremu et al., (2005) it was discovered that a cowpea cultivar called Medino I cultivated in the Southern province of Cameroon was found adaptable to a transition

between humid and Guinea Savanna agro-ecology of Nigeria. Cultivars in this category would not be stored in gene banks because they usually can be obtained from commercial sources.

c **Breeding lines:** These are potential genotypes that are either incompletely evaluated or offer desirable traits but have other limitations. These lines can serve as parental materials in some breeding programmes. This is typical of two cowpea lines – Danilla and Ife brown. The former has large seed size with above average yield potential but with long maturity date. The latter has small seed size with moderate yield potential and reduced plant canopy in addition the early maturity period. These two can serve as parent stocks when breeding for large seed size with reduced canopy form so as to allow more crop stands.

4. **Plant introductions:** - Plants and animal diversification led to exploiting plant introduction method in establishing an old type in a new environment. Newly introduced crop or animal species may be used directly as new crops, new cultivars or even new germplasm for hybridization with another crop. Such introductions are more successful where similarities exist in soil, climate and other weather elements between the crop or animal origin and the new area of production. Irish potatoes is an example of a successful introduction from Irish to Jos Nigeria. However, not all introduced organisms are successful e.g. the introduction of *Pueraria lobata* into Southern U.S.A. in the early 1900s caused problems as it became a major weed.

5. **Hybrids:** These are gotten from inter-specific and inter-generic hybridization. This is a cross between wide diverse materials to produce desirable genes in new species. Though this method pose a major problem of incompatibility which eventually results into sterility but most hybrids especially vegetable crops have high vigor with high yield

6. **Mutations:** - These are changes in genetic materials that results in the production of new specie type capable of surviving under favorable



environments. It can have specific effects on a trait or have several inter-related effects. Mutation is a major source of genetic variation that deserves extensive discussion. Details will be given in the later part of the chapter.

## 6.2. Continuous and Discontinuous Variations

Both continuous and discontinuous variations arise in natural population. According to Darwin, variation is the mainstream of evolution. Variations are acted upon by nature so that the favorable ones are selected for and perpetrated in future generations while the unfavorable ones are selected against. Therefore, variations can be said to be affected by genetic and environmental factors. The effect of the environment on any genotype produces the phenotype. As earlier said both continuous and discontinuous variations follow the law of inheritance. In qualitative genetics, it is clear that dominant and recessive relationships are expressed and hence distinguishable phenotype are observed such as 3:1, 15:1, 9:7 etc. Where the character relationship involve many genes in different loci, with each gene having small individual effects, the inheritance pattern deviates from the Mendelian ratio as above. The study of variation would then involve appropriate statistics with continuous variables such as mean values of a population and the spread of such mean values leading to variances and standard deviations.

Most economic characters in plants and animals are quantitative e.g. yield, size, protein/oil content, maturity date, height, seedling vigor etc. Both quantitative and qualitative traits are expressed over a wide range of environmental conditions.

### 6.2.1 Qualitative traits

The segregation process determines the phenotypic values of qualitatively inherited traits. These traits are conditioned by a few genes on same locus with the traits expressed in clear dominance or recessive relationships. However, where there is recessive relationship, the genotype is faithfully expressed in the phenotype. It is noted that the environment

has little or no influence on most traits which are qualitatively inherited. There are different examples of crop species having qualitatively inherited traits. A typical example is seen in seed coat colour of cowpea *vigna unguiculata*. The coat colour is controlled by dominant gene at one gene locus. Another example is found in wheat seed colour. Other traits under qualitative inheritance are found in maize e.g. maize sugary endosperm having Su, su genes resulting in endosperm with high sugar content; Amylose endosperm -al,al used in manufacture of sweeteners and having high lysine level of amino acid essential for growing body cells. Qualitative traits are easily identified in plants. Qualitative traits with recessive genotypes enhance selection of the recessive and the use of such recessives as parents in subsequent generation to increase the frequency of emergence of desirable genotype. However, there is a caution, the initial F<sub>1</sub> and F<sub>2</sub> population should be large enough to ensure the presence of recessive individual selection. A recessive gene requires one generation of selection to be expressed in the homozygous phenotype. In practical terms, selection for a trait with dominant gene is more complicated and difficult.

### 6.2.2 Quantitative traits

This involve several genes having two or more genes on different loci interacting together to bring about quantitative inheritance. The individual genes involved have a small effect on the phenotype. The environment plays a major role in most of the traits which are quantitatively inherited. The variations as a result of impact of the environment on the genotype can be partitioned into genetic variation (Vg) environmental variation (Ve) and Genetic and environmental variation (Vgxe). Sexually propagated crop plants exhibit both genetic and environmental variations but vegetatively propagated crops are influenced mainly by environmental factors (Ve).

Among heterozygous plants, the portion of variations due to either environment or genotype can be difficult to identify. The study of the magnitude of variation as affected by the environment or genotype is known as heritability this term shall extensively be discussed in a later chapter.



Selecting plants for quantitatively inherited traits involves research in quantitative genetics. The aim of selection is to shift the population to a value that is more desirable than the mean value of the parent population. There must be phenotypic variation for any selected trait for a meaningful plant breeding programme and the variation must be genetic and not entirely due to environment. Selection considerations should therefore include response to selection, selection differential, selection intensity, and selection index and selection criteria.

- (i) **Selection response:** - This is the progress made by selection and is the difference between the mean values of the progeny of one generation and the mean of the next generation. This difference is called selection differential. For example the average length of peduncle of 500 plant stands of cowpea was 6cm and if 50 of these were selected as parents with an average peduncle length of 8cm the difference of 2cm is known as the selection differential.
- (ii) **Selection intensity:** - This is the number or proportion of individuals selected as parents for the next generation intensity as parents for the next generation. It is advisable to have high selection intensity and this will afford the opportunity of having large number of good genotypes (genotypes with desirable quantitative traits) than having few individuals.
- (iii) **Selection index:** - This is the setting of a standard for a trait such that such standard must be met before a trait is selected for. This standard is a minimum or maximum value level for which a trait must attain before it is selected for. Selection index is necessary because improving more than one trait can be difficult as some plants are superior for one trait but may be below average for another trait. Therefore when a minimum or maximum standard is set for each trait any plant failing to meet the desired standard will automatically be discarded.
- (iv) **Selection Criteria:** - Quantitative traits depend upon many genes that influence individual plant characteristic. It therefore means that only

the sum of these individual gene effect produce somewhat noticeable variation on the phenotype. To achieve these variation large population size is a criteria for achieving success in selection. Note that estimation of additive, dominant and epistatic gene actions are dependent on large population size. The implication is that where a large population size is not a criterion prior to selection, any selection at that period will not yield the desired results

## SUMMARY

Component of Genetic variations are subject to environmental influence. Gene banks serve as home for conserving genetic resources. Variations are divided into continuous and discontinuous types. The discontinuous variations are expressed in discrete terms variations such as length, weight, height etc can only be described by quantitative measurement. Effective manipulations of quantitative data require the use of appropriate statistical techniques. Quantitative traits depend upon the activity of multiple gene actions. A gene may have a major effect on a character and at the same time have a minor effect on another character. Gene interaction can be intergenic or intragenic. Of all the various gene actions the most important to plant breeders is additive gene actions. This is because traits with additive gene actions are sure to produce phenotype that will manifest in the next generation. This is of course a source of variation.



## Questions

Q1a. Differentiate between Quantitative and Qualitative traits

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b. What is a trait?

Q2a. Write briefly on plant introduction

b. What is the implication of not using a large population size in the study of gene actions?

c. The difference between the mean values of a progeny in a generation and the mean of the next generation is called

.....

Q3 Write briefly on:

i. Selection intensity

ii. Selection index

iii. Selection criteria

.....

.....

.....

.....

- b. Quantitative traits are influenced by .....  
actions.
- c. In plant breeding the effective manipulation of quantitative data  
require the use of .....

# Chapter 7

## HERITABILITY

### 7.0 Introduction

The most effective guide to selection is the computation of an index that combines standard bases for making a selection with selection criteria in which the various gene actions (additive, dominance, epistatic etc) determine the phenotype resulting from the quantitative traits.

In the last chapter, it was discovered that quantitative traits depend somewhat on collection of numerous genes with each gene having a small effect on the phenotype. The expression of these quantitative genes on the phenotype is influenced by the environment. This accounts for why phenotypic variation is partitioned into genetic, environmental and genetic by environmental components. Genetic and environmental variations can be partitioned and determined using heritability estimates.

## 7.1 Heritability estimates

Heritability is the ratio of genotype to phenotype variation. Depending on the type of gene behavior genotypic effects ( $V_g$ ) can be subdivided into three components which are:

Additive variance ( $V_a$ )

Dominance variance ( $V_d$ )

Epistatic variance ( $V_t$ )

Additive variance describes the difference between homozygous at any gene locus, while dominance describes the interaction of alleles at same gene locus (intra-genic interaction) and epistatic variation explains the interaction between nonallelic pairs (inter-genic interaction).

As mentioned earlier in chapter five genetic interactions especially additive gene effect is of practical relevance as it refers to variation that can be selected for and transferable. The estimation of character heritability in crops and animals, remain a vital subject in practical research. This involves precise experimental design and of course powerful statistical techniques.

Knowledge of heritability of selected traits is obvious in deciding what emphasis should be put into these traits in selection. Heritability estimates are subject to variations in themselves because they are affected by the amount of environmental fluctuations in the field in which they are studied. It is generally found that only a small fraction of the total variation in any generation with respect to a character is identifiable as genetic in its origin. This is shown as follows:

## 7.2 Calculation of heritability estimate.

Heritability is the ratio of genotypic variance to phenotypic variance. It is expressed as follows:

$$\text{Heritability } (H_{II}) = \frac{V_g}{VP} \times \frac{100}{1}$$

$V_g$  = total variance due to genotype



VP = total variance due to phenotype

In the early discussion, phenotypic variance is partitioned into three components which include genetic, environmental and genetic x environmental.

And expressed as:

$$VP = Vg + Ve + Vgxe.$$

$$\text{Heritability (Broad sense)} = \frac{Vg \times 100}{Vg + Ve + Vgxe}$$

This type of heritability that give the proportion of the total phenotypic variation due to all genetic factors are known as broad sense heritability. Genotypic effect can be divided into 3 components depending on type of gene interaction. (Table 2)

Table 2: Mean and variance components for number of branch in a Cross Danilla x Ife-brown

Component	Danilla	Ife-brown	Generation		Backcross	
	P <sub>1</sub>	P <sub>2</sub>	F <sub>1</sub>	F <sub>2</sub>	1	2
Mean	4	8	6	7	5	8
No of plants	85	147	110	320	215	200
Variance	3.4	2.0	2.1	10.6	7.2	9.0

The additive component describes the difference between homozygous at any locus while dominance describes the interaction of alleles at same gene locus and epistasis describes interaction of non allelic genes.

Additive gene action implies allelic performance that is regardless of other alleles at the same locus. Gene t, for example has the same relative value in homozygote tt as in heterozygous Tt.

In practical terms, genes that act in additive manner are preferred for selection as the superior genotype will breed true to type in the next generation provided the environment allows expression of the phenotype.

The first one gives a ratio of the genotypic variance as earlier given while

the second is the ratio of only the additive variance to the phenotype variance. This is known as narrow sense heritability and expressed as follows:

$$\text{Heritability (narrow sense)} = \frac{\text{Additive variation}}{\text{Phenotype variance}}$$

$$H_n = \frac{V_a}{V_a + V_d + V_e}$$

Using data on Table 2, heritability estimates can be calculated. Components of variance in  $F_2$  and back cross generation is given as follows:

$$\begin{aligned} \frac{VF_2 = V_a + V_d + V_e}{V_{B1} + V_{B2} = V_a + 2V_d + 2V_e} \\ \text{Environmental variance (Ve)} &= \frac{VP_1 + 2VP_2 + 2VF_1}{3} \\ &= \frac{3.4 + 2(2.0) + 2}{2.1} \\ &= \frac{3.444 + 0 + 4.2}{3} = 11.6 \\ V_e &= 3.86. \end{aligned}$$

Additive variance is given as:

$$\begin{aligned} V_a &= 2VF_2 - (V_{B1} + V_{B2}) \\ V_a &= 2(10.6) - 7.2 + 9.0 \\ &= 21.2 - 16.2 \\ V_a &= 5.0 \end{aligned}$$

Dominance variance is obtained as

$$V_d = \frac{(V_{B1} + V_{B2}) - V_{F2} - (V_{P1} + V_{P2} + F_1)}{3}$$



$$\begin{aligned}
 &= (7.2 + 9.0) - 10.6 - (3.4 + 2.0 + 2.1) \\
 &= 16.2 - 10.6 - 7.5 \\
 V_d &= -1.9
 \end{aligned}$$

From here broad sense and narrow sense heritability estimate can be calculated.

$$H_B = \frac{\text{Genotypic variance} \times 100}{\text{Phenotypic variance}}$$

And

Genotypic variance = Additive variance + dominance variance

Phenotypic variance = Additive + genotypic + environmental variances.

Therefore,

$$H_B = \frac{5.0 + (-1.9)}{5.0 + (-1.9) + 3.86} \times \frac{100}{1}$$

$$H_B = \frac{3.1}{6.96} \times \frac{100}{1}$$

$$= 44.54\%$$

$$H_B = 44.54\%$$

Narrow sense heritability:

$$H_n = \frac{\text{Additive variance}}{\text{Phenotypic variance}}$$

$$= \frac{5.0}{6.96} \times \frac{100}{1}$$

$$H_n = 71.84\%$$

### 7.3 Uses of heritability estimate

Heritability estimates are measures that confer reliability of selection. The selected traits are sure to produce phenotypes that will breed true to type in the next generation. This applies mainly to the use of narrow sense heritability estimates ( $H_n$ ).

The reliability in selection is a hope to breeders as it is a major source of genetic variation which measures the importance of heredity relative to environment and unpredictable interactions. If the heritability value of a trait is high, it implies that such trait is subject to effective selection. The aim of selection is to shift the population to a value that is more desirable than the mean value of the parent population.

For plant breeding to be effective there must be phenotypic variation for the selected characters, and some of the variation must be genetic and not entirely due to the environment.

#### SUMMARY

The most important tool available to breeders is selection parameters. Effective selection is possible with the use of heritability estimates. Knowledge of heritability of traits determines the emphasis to be put on traits in selection. Additive, dominance and environmental variances are important components that determine the value of heritability. Heritability is the proportion of observed variability due to genetic and environmental factors. These factors are known as variability due to additive gene effects. The ratio of additivity determines if heritability is in the broad sense ( $H_b$ ) or narrow sense ( $H_n$ ). Highly heritable traits are easily subjected to effective selection.



## Questions

1 Differentiate between:

a Additive and Dominance components.

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.....

b. Phenotypic and genotypic variations.

.....

.....

2a. Environmental variation can be portioned and used to determine heritability. True or false

b. Define the following

- i. Broad sense heritability
- ii. Narrow sense heritability
- iii. Variance component.

Q3.

Component	P1	P2	F1	F2	Bc <sub>1</sub>	Bc <sub>2</sub>
Mean	5	8	7	6	5	8
No of plants	36	99	73	210	130	112
Variance	4.0	6.0	3.1	5.2	7.4	8.5

a. From the above table calculate:

- i. Environmental variance
- ii. Additive variance
- iii. Dominance variance



# Chapter 8

## MUTATION

### 8.0 Introduction

Mutation is the raw material for evolution. It is also a tool for geneticist to study the structure and functions of genes. We know that genetic materials are carried on the chromosomes. The efficiency of genetic material depends on each part of the structure. Therefore any change either in the base sequence or in the length of the polynucleotide chain or even in the positioning of DNA molecule means change in the information contained. This change will produce form, which may be abnormal or defective. These changes can occur under natural, spontaneous or induced conditions in the environment.

Mutation occurs in somatic tissues as well as in the reproductive cells of organisms. In such cases the mutant organism is genotypically and phenotypically a deviant of normal tissue. In higher plants and animals, if the reproductive cells are not affected, the mutant trait is not passed on to the next generation and genetic test cannot be carried out.

## 8.1 GENERAL FEATURES OF MUTATION

Mutations are sudden, heritable changes in the structure number and chemical properties of the genetic material. It is an established fact that the basic unit of inheritance is the gene, these genes have occasional distortions which eventually result into production of new phenotypes. The genes of these new phenotypes are passed on their descendants. Mutations can be dominant or recessive. The study of dominant mutation requires no special techniques because such mutations express themselves even in the heterozygote. If a mutation proves to be a dominant type, then it must have been present in the generation in which it first appeared. Recessive mutations can be carried for many generations as a hidden material and will show up only when two heterozygote are crossed. However, the detection of recessive autonomic mutations requires special breeding projects as such mutations are expressed only in the homozygous state. The type of recessive mutations can be easily identified from recessives that are already present in the heterozygote state. However sex linked recessive mutations can be detected directly in organisms such as man.

Some genes mutate at much higher rates than other genes. In some instances back mutation do occur (a reversal in the mutant gene to a normal or wild type). However, the frequencies of this occurrence vary from gene to gene.

## 8.2 TYPES OF MUTATION

The different types of mutations are

- i. Gene Mutations
- ii. Chromosomal Mutations

### 8.2.1. Gene Mutations

These are changes in individual genes that may occur during the production of gametes or in the formation of somatic cells. We all know







Gene mutations especially in gametes are heritable and persist in subsequent generations.

On the whole, genes are stable structures because DNA is a stable chemical until when subjected and exposed to mutagens to which eventually lead to gene mutations. Most gene mutations produce observable effects which in most cases are lethal.

### Types of Gene Mutation

Gene mutations are in most cases harmful to the phenotype. This is not surprising because any change in an organism is likely to upset the physiology of such. The various types of such mutations are:

Lethal genes: - these results in the death of the organism, such lethal mutations are frequent as the organisms involved are new and cannot adapt to the environment. There are two types of lethal genes.

- a. Dominant lethal: This type of mutation results in the death of the organism immediately after the reproductive stage.
- b. Recessive lethal: This type does not show up in the next filial generation unless in a heterozygous condition. Recessive mutation cannot be identified in the first mutation generation ( $M_1$ ) but can show up in homozygous state at the  $M_2$  or later mutation generations. e.g. The abnormal haemoglobin.
- c. Conditional lethal: This mutation affects the nutritional properties of the organism. The organism may fail to survive or propagate on low nutrition medium-but grows on appropriate supplemented medium. Another conditional lethal includes temperature sensitive lethal mutations. These occur when some mutants are temperature sensitive. This mutation renders essential genes inactive under high temperature but become active under low temperature or vice versa. I.e. at high temperature, the mutant genes become active and otherwise at low temperature. Various means may lead to breakage and disruption of the normal structure. Such means are physical, chemical and sometimes natural.

## 8.2.2. Chromosome Mutations

These are gross or minor change in chromosome quantity or structure in the different types of chromosome mutation are:

- a. Changes in chromosome structure
- b. Changes in chromosome number

### Changes in chromosome structure

These are mutations associated with breakage and rearrangement of the chromosome. Crossing over is associated with breaks in chromatids if the broken ends fail to rejoin as expected structural changes do occur. Chromosome changes are desirable as they may lead to somatic abnormalities or failure of zygote. This cause sterility, the different structural changes are:

- a. Substitution
- b. Deletion
- c. Insertion
- d. Duplication
- e. Inversion
- f. Translocation

**a. Chromosome Substitution:** This occur when a segment of an normal chromosome length is replaced with another segment of a "foreign" chromosome type, the new segment may not contain the gene as in the broken segment

**b. Deletion:** This occurs when segment of the chromosome is detached from the normal structure and not replaced, such that the detached structure remains incomplete (fig 8:2) gene.

**c. Insertion:** This is the addition of a segment to an existing normal complete chromosome structure. Insertion may result into duplication or substitution. As in fig 8:2D with abd genes inserted into chromosome A.

**d. Duplication:** When a nucleus is found to have additional material to that found in the normal chromosomal complement. The extra part of



chromosome on a normal complete segment is known as duplication. With duplications an allele may be present three or more times within a nucleus. The chromosome segment gained may be inserted into various positions in a homologous or non homologous chromosome (fig 8:2E)

c. **Inversion:** This is a kind of aberration in which a chromosome segment exists in reverse relationship to the rest of its chromosome. This occur when a normal chromosome breaks from two points followed by rejoining of ends in a manner opposite from the original chromosome to form new partners (Fig 8.2F)

f. **Translocation:** This is an aberration in which a fragment of one chromosome becomes attached and interchanges with a non homologous chromosome. Here a chromosome break is followed by a new kind of union among broken ends of chromosome to form a new chromosome structure (Fig 8.2G) where i, ii and iii are non homologous chromosome. The various structural aberrations can be illustrated as follows:

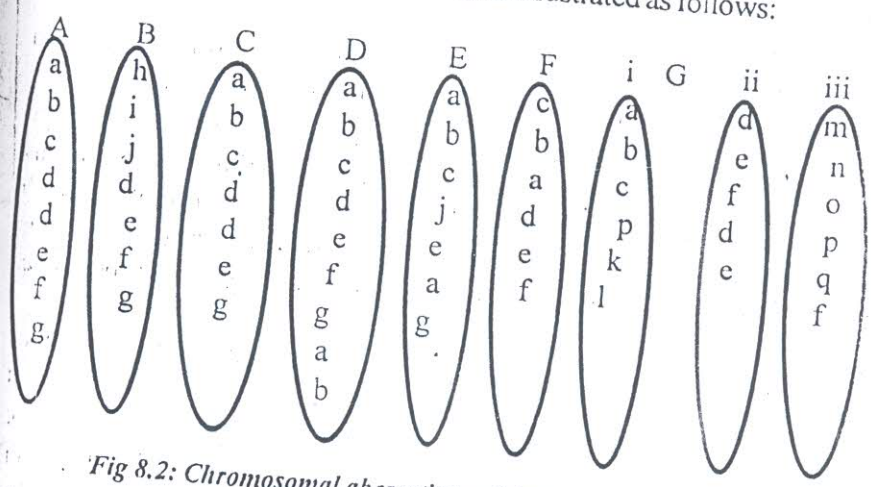


Fig 8.2: Chromosomal aberrations of different structures.

### 8.3 Changes in Chromosome Number

These are aberrations leading to increase or decrease in chromosome or multiples of chromosome number of organisms. Changes in chromosome number can be in form of presence or absence of parts of



chromosomes, or of whole chromosome or of whole sets of chromosomes.  
Aberration in chromosomes number include

Aneuploidy

Euploidy

Polyploidy

**Aneuploidy:** This refers to organisms nuclei containing incomplete or excess genome of the basic number of chromosome. An organism may lack one chromosome of a diploid complement and called monosomic ( $2n-1$ ) where an organism lack 2 extra chromosomes of a diploid complement that are different members of the genome it is called double monosomic ( $2n-1-1$ ) and nullisomic when a diploid lacks 2 times the chromosome of a diploid genome.

A trisomic has two complete genomes plus a single extra chromosome. The various genome and chromosome number aberrations are detailed in Table 8.1.

Trisomy is found in man where there occurs an extra chromosome 21 in the genome. This chromosome number 21 in the human karyotype causes the **Down's syndrome**. The symptoms of this disorder are characterized by facial features with resemblance to the Mongolian race known as mongolism. Affected children have round slightly flat face and head with small deep eyes. They have retarded mental growth, the frequency of this syndrome increases with increase in age of mothers the disease is heritable.

**Euploidy:** These are aberrations in which the total chromosome number are complete genomes e.g. monoploid ( $n$ ) where each chromosome is represented only once in a nuclei. Monoploids especially in plants are usually smaller and less vigorous then their diploid prototypes. However they can be exploited by plant breeders to produce diploid genomes by doubling the chromosomes of the monoploid. The doubling produces homozygote individuals that are **pure lines**. However monoploid plants are sterile because the chromosomes have no regular pairing partners. Triploids have three complete genomes per nucleus. Triploids are formed when a diploid gamete fuse with a monoploid (haploid) gamete. Triploid

are unstable in sexual reproduction. This is because during meiosis the Centromere of the three homologous chromosomes cannot orientate to give its equivalent at the two poles of the spindle fibre. The consequence of triploids is sterility.

Other forms of euploids involve doubling the genomic numbers to form polyploidy. Diploid plants ( $2n$ ) are usually fertile. Whereas, crosses involving different genomic numbers such as  $n$ ,  $2n+1$ ,  $2n+2$ , etc. can be sterile.

Polyploids have more than two copies of a genome. Autopolyploids have three or more copies of the same genome. Other polyploids with three or more genomes are called Allopolyploids. An example of allopolyploid is autotetraploid with  $2n = 32 = 4x$ . Here, there are 8 chromosomes in each genome of  $n$  e.g. Alfalfa. Bread wheat is an allohexaploid with  $2n = 42 = 6x$ .

Polyploids are usually sterile; the following table explains the basic chromosome number aberration.

**Table 8.1: Chromosomal aberrations as affecting diploid and genome number complements.**

Aberration Name	Formular	Chromosome Complement Where B, A, C and D are non homologous
<b>ANEUPLOIDY</b>		
Monosomic	$2n-1$	{BAC}[BAC]
Trisomic	$2n+1$	[BACD][BACD][B]
Tetrasomic	$2n+1$	[BACD][BACD][B][B]
Double trisomic	$2n+1+1$	[BACD][BACD][BC]
<b>EUPLOIDY</b>		
Monoploid	$n$	[BACD]
Diploid	$2n$	[BACD][BACD]
Triploid	$3n$	[BACD][BACD][BACD]
Autotetraploid	$4n$	[BACD][BACD][BACD]



[BACD]

Allotetraploid

4n

[BACD] [BACD] [B'A'C'D]

[B'A'C'D]

Polyploids are differentiated as autopolyploids and allopolyploids.

Autopolyploids are those in which the multiple genomes are identical or nearly identical. This include Autotetraploids autohexaploid, autoheptaploid etc.

Allopolyploids are those in which the genomes that make up the multiple set are not alike. This include Allotetraploid, allohexaploid etc.

### Effects of Polyploids

Polyploids are more vigorous than diploids. The triploids especially show gigantic growth of morphological parts in crop plants and show mongolism in man.

The aspect of producing increased size and vigor in plants has been exploited by plant breeders to produce economic plants of superior value. This is evident in maize, vegetables and apples.

Another major effect though negative is that it often reduces fertility. And therefore can not be propagated sexually to improve crop plants. Polyploids facilitate gene transfer synthesis of new crops; broaden genetic base and development of commercial cultivars.

### 8.4 Origin of polyploids and other chromosomal aberrations

The major sources of gene and chromosome aberrations are physical, chemical and natural agents.

The agents employed in both physical and chemical means of inducing mutations are: Physical means: This involves exposure of organisms to radioactive rays such as x-rays, gamma rays and Beta rays. These rays are ionizing radiations X-rays are widely used as they are less hazardous.

Chemical mutagens include N-methyl-N-nitro-N-trosoguanidine (ethyl methansulphate) Sodium-azide, diethyl sulphate.



## SUMMARY

Mutations are spontaneous changes in genes and chromosomes that result in alterations in the characteristics of the organisms. The rate of changes in genes is constant. Most mutations produce recessive genes. Major mutations are lethal to the organism while minor mutations are common occurrence and may not be detected. These minor mutations are called isoalleles. Mutations are often reversible, however the rates in the two different directions are often different. Mutation rates can be accelerated by the use of mutagens which can be chemical or physical. Structural changes in chromosomes provide basis for genetic engineering.

## Questions

Why is mutation important in plant breeding?

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.....

What is the pairing pattern in the following bases?

A =

G =

C =

T =

A =

C =

G =

T =

Q2. Explain the following terms:

- i Protein
- ii Polypeptides
- iii Bases
- iv Nucleic acids
- v Template
- vi Nucleotid

b. What is a gene?

c. ....

d. ....

e. ....

8. Differentiate between  
polyploidy and aneuploidy  
inversion and translocation

.....  
.....  
.....

9. a. A condition where an organism fails to survive under limited environmental temperature is known as

.....

b. Recessive lethals can only show up in ..... generation in ..... Condition.

c. Down's syndrome is caused by ..... type of mutation under ..... aberration.



# Chapter 9

## INTRODUCTORY PLANT AND ANIMAL BREEDING

### 9.0 Introduction to Plant Breeding

The science aspect of plant breeding is the manipulation of the genetic potential of plants to form a new crop type desirable to man. This involves application of field experimental and statistical techniques that would eventually produce phenotypes different from the original parents. Achievable success is enhanced by the ability to identify parents with desirable traits which can combine by hybridization and further make effective selection from the off springs of the hybridized parents.

Without the knowledge of Genetics and to some extent, the botany and morphogenesis of organisms there could be no understanding of the basic steps to breeding. For example in animals, gametes carry half (haploid) the hereditary component from the male parent even as pollens also carry half the hereditary component of the productive cells. The hybridization of parent with haploid gametes is expected to increase genetic variability

subsequent selection. Hybridization for crop and animal improvement was scarcely utilized until the early nineteenth century. Despite advances towards techniques for purposeful and routine hybridization of plants, progress in plant breeding depended upon the ability to handle progeny following hybridization. In all, the perspective in breeding is to create variability prior to earlier steps in breeding. Wild types in organisms were undoubtedly unappealing in terms of size, vigor, maturity period, quality, taste, etc. Considerable improvement techniques were therefore needed to transform such plants into desirable forms in relation to value, taste, quality, quantity, maturity time etc. According to Arnold (1985) all crops were developed by humans through conscious selections. For progress to occur in plant and animals, deliberate breeding programmes should be considered so as to introduce variability.

#### 11. Sources of Genetic Variability in Plants

The various sources of variation have been discussed in chapter 6. There is an important source yet to be discussed. This other source is Domestication:

Prior to crop domestication, early farmers suffered a great deal of crop failure as well as low yield as a result of the characteristic performance of wild plants. The areas of concern in wild plant growth are in

Seed Dormancy

Seed Size

Shattering Types

Delayed Maturity Period

Wide Plant Canopy

**Seed Dormancy:** There is need for modification before plants can be economically and agriculturally accepted. Dormancy is a mechanism that hampers seed germination and ensure seed survival even under unfavorable environmental conditions. Indefinite dormancy might lead to the loss of such seeds in the subsequent future and hence lead to extinction of a very uncommon seed type.



**Seed Size:** Small seeded plants are in most cases not preferred to large seeds. It is an established fact that growth of large seeded plants has more vigor than small seeded types. Selection can be said to favor large seeds for planting. If seed size were genetically controlled plant progress through breeding will occur.

**Shattering Types:** The feature that distinguished a wild plant from its domesticated counterpart is the ability to disperse seed at maturity. Wild rice and soybean shatter their seeds while on field prior to harvesting. This led to continuous harvesting and as such tedious and time consuming. The genetic modification of the shattering tendency has led to plants retaining seeds to maturity and harvesting.

**Delayed Maturity Period:** Wild crop relatives have history of long maturity date, until late 80s most tuber and cereal crops had records of late maturity dates of up to 3 years from date of planting to maturity. This of course led to delay in development of new crop type because research periods that would yield results were unnecessarily prolonged. Typical examples are wild types of rice, oil palm, cassava, beans, yam, etc.

**Wide Canopy Type:** Wild plants are naturally extensively branched and rooted. The reason for this could be that the growth habit which is not controlled is to allow for the various plant part especially root to search for water.

## 9.2. Crop Domestication

Domestication of plant should not be confused with crop cultivation. Domestication is an evolutionary change, whereas cultivation refers to human deliberate efforts to nurture the plant to suit human needs. Domestication exposes wild plants to thorough cultural management practices in the environment with an overall effect on the plant genotype, thereby subjecting the genotype to genetic changes which are desirable to human needs and the environment associated with it. Note that wild plants may be cultivated and not domesticated. Domesticated plants are dependent on humans for survival. Breeders and scientist were only able to domesticate wild species where natural variables existed. The evidence



of domestication of diverse crops in different areas suggests that advances in plant breeding were not mere accidents. However early domestication is associated with unconscious selection.

Plants that were and are still domesticated include self and cross fertilizing types. This will be treated in the late part of the chapter.

### 9.3. Reproductive Systems and Plant Breeding Methods

The pattern of breeding methods appropriate for particular species is determined to a large extent by the reproductive system of the species. The aim of the plant breeder is to create superior crop cultivars or varieties depending on the mode of reproduction. With reference to propagated crops, a cultivar is any crop genotype with sufficient characteristic value and with an identity name accepted and used within the locality of the cultivar.

In self-pollinated crops a cultivar is a particular homozygous genotype which is referred to as a pure-line. In cross-pollinated crops a cultivar is not typified on the basis of any one plant but sometimes by a particular plant population which of course is composed of genetically distinct individuals. From the aforementioned, we have been able to identify three reproductive systems found in crop species. These are:

1. Vegetatively propagated crops.

2. Cross pollinated crops

3. Self-pollinated crops

Asexually and sexually propagated crops are improved upon using the same breeding methods. The breeding methods that have proved successful with asexually and cross pollinated crop species are:

Mass selection.

Backcross

Progeny testing

Hybridization

Mutation breeding

The breeding methods most suitable for self-pollinated crop species are:

Mass Selection

Pedigree Method

Pure-line Method

Bulk Method

Backcrossing Method

**Mass Selection:** This breeding method is based on phenotypic appearances such that meet human needs. The application and uses of mass selection is as follows:

1. It serves as a means of improvement of a new crop being investigated.
2. It is used to preserve the identity of an established cultivar or a cultivar yet to be released.
3. It serves as a means for assessing resistance quantitatively such that the desirable segregates are selected from the resistant population and the undesirable genotypes are discarded. This is better achieved when the  $F_2$  segregating populations are:

The purpose of mass selection is population improvement in both cross and self pollinated crop species. It permits a large pool of germplasm to be manipulated and carried along. In actual practice, the processes of mass selection and pedigree selection may be combined. Pedigree selection may be utilized in the early segregating generations to exploit the major genetic differences and eliminate obvious undesirable types. For example  $F_2$  plants can be pedigree selected on the basis of  $F_3$  line performance. After the desirable types are selected, the best  $F_3$  or  $F_4$  lines may be bulked and carried on by mass selection until homozygosity is reached. At this time pedigree selection is resumed to isolate the superior genotypes.

4. Mass Selection is most effective for additive generations because it has been predictably effective for traits with little environmental interactions.
5. It is practiced directly on the trait for which improvement is sought. The effectiveness of the technique depends upon the heritability of the trait. Where low heritability estimates are recorded against some traits, mass selection is said to have limited success with such trait and may be repeated. Repeated selection is known as recurrent mass selection.

**Backcross Method:** This is a cross of an  $F_1$  plant with one of its parents; this method is used for transferring simple identifiable characters from one



cultivar or line to another. It is found useful in improvement of self-pollinated crops and inbred lines of cross-pollinated crops. Characters controlled by single genes or not more than three genes and are visually identified among the progeny are most suitable for transfer. The backcross method is not effective for transfer of quantitatively inherited traits involving more than three genes. Where several genes are involved larger plant populations are necessary.

The backcross method is based on the fact that a heterozygous  $F_1$  progeny is backcrossed to a homozygous parent and the resultant offspring will be homozygous for the genotype of the recurrent parent. This is achieved when repeated backcrossing with the recurrent parent leads to recovery of the parent (recurrent). The main advantage of the Backcross method is its predictability in that the final offspring is homozygous with resemblance to the recurrent parent.

Problems associated with backcross method for cross-pollinated crops are that backcrossing of such crops is equivalent to selfing and thus results in a decline in vigor. A rapid loss of vigor normally occurs when cross-pollinated and heterozygous crops are selfed. The loss of vigor following the backcross in cross-pollinating crops may be overcome by the use of large populations so as to effectively make selections from the large bulking and thus handle the effect of inbreeding.

**Pedigree Method:** This method is used to sort desirable genotypes from segregating progeny. Individual plants are selected visually on the basis of their generational (ancestral) records as well as their phenotypic appearance. It is assumed that the best genotype will be derived from the superior plants. Hence, the progeny of each plant are handled separately. This can be exemplified as follows: Selection is made first from the  $F_3$  or  $F_4$  generated from the  $F_2$  or  $F_3$  respectively. Note that segregation is fully manifesting in the  $F_2$  generation and hence the basis for the use of  $F_2$  as a selection opportunity. Following the initial selection, plants are reselected in each subsequent generation until genetic homozygous is reached and plants assume homozygous stage phenotypically. In pedigree method it is of practical importance to identify and tag parent offspring (progeny)



relationship so as to trace each progeny to its original  $F_2$  source in any future generations

**Pure-line Method:** This method produces genetically pure plants resulting from continued selfing of self-pollinated crops. It also involves the doubling of chromosome of a monoploid to give rise to diploids which are of course homozygous for all the gene pairs in the organism. Pure line breeding procedures require that individual plants are selected from genetically variable populations e.g. wild types or land races which constitute an area under crop/plant introduction. The first step in pure line breeding is to select a large number of homozygous plants from the parent heterozygous populations. The second step is to plant out the seeds of the selected homozygous in progeny rows for observation. The progeny with uniform phenotype performance having desirable traits are selected for and advanced in the next step. The selections are continued until acceptable phenotypes with potential for superiority are maintained. Pure line breeding can be used as a preliminary breeding method following pedigree bulking-pure-line selections.

**Bulk Method:** This is planting of genetically diverse selections made in the next generation until homozygous lines are eventually obtained. This is to say that from the large plant population grown an  $F_2$  generation is planted in a plot large enough to accommodate hundreds of plants. The seeds are eventually planted out again until single plant selections are made. Bulk breeding takes advantage of selection pressure and attempts to increase the frequency of superior genotypes by eliminating inferior types. This continues until the end of segregation and at which time single plant selections are made for evaluation. The bulk breeding method is used for small grain cereals (rice, beans, maize, soybeans, millet, sorghum etc.) The advantage of selection pressure is that it allows natural selections and places emphases on character performance as related to population and productivity. It can be said that, bulk breeding places emphasis on plant ability to survive in competitive environment.

## SUMMARY

The objective of plant breeding is to create superior crop cultivars. Breeding method for any crop type- asexually, self and cross pollinated crop type largely depend on genetic structure which is governed by natural or artificial method of pollination.

No matter the breeding method employed the ultimate goal is to create variability which may arise from qualitative or quantitative genes. Mass selection is achieved by identifying and marking desirable plants as they developed and grow and by visual observation, desirable plants are harvested at maturity and seeded again and again until there is no more variation and the majority of plants selected are retained in mass selection. This breeding method last for about five years.

In pure-line breeding a new crop type is formed from the progeny of a single pure-line and forms basis for other breeding systems. The use of pedigree method produces new crop type after generations of bulking or mass selection and crop selection using records of lines of descent. Backcrossing and mutation methods are popular breeding methods in crop improvement of cross pollinating crop species.

## Questions

1. Outline the breeding methods most appropriate for the flowering plants

- a. Asexual plant
- b. Self-pollinating plant
- c. Cross-pollinating plant

2. List 5 crop examples in each plant type

A	B
i.	i.
ii.	ii
iii	iii
iv	iv
v	v

- C
- i.
  - ii.
  - iii.
  - iv.
  - v.

3. Identify 3 major sources of genetic variation
- a.
  - b.
  - c.
4. Differentiate between
- i Mass selection and bulk selection method
  - ii Write concisely on:
    - a. Selection
    - b. Breeding method



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