COURSE GUIDE

# ANP309
# GENETICS AND BREEDING

**Course Team** Professor G.O. Okagbare (Writer) – NOUN

**NATIONAL OPEN UNIVERSITY OF NIGERIA**

National Open University of Nigeria
**Headquarters**
University Village
Plot 91, Cadastral Zone,
Nnamdi Azikiwe Express way
Jabi, Abuja

Lagos Office
14/16 Ahmadu Bello Way
Victoria Island, Lagos

e-mail: centralinfo@noun.edu.ng
website: www.nou.edu.ng

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## Introduction

Genetics and Breeding is a two- credit unit course designed for students offering Agriculture and Agriculture- related courses at the National Open University of Nigeria. This course involves the study of basic genetic principles and applying these principles to crop and animal improvement.

## What you will Learn in this Course

Genetics and Breeding introduces you to the rudiments of genetics and breeding. This Course Guide tells you what the course is all about, what course materials you will be using and gives you guidance in respect of TMA (Tutor-Marked Assignment) which will be made available in the assignment file. Please attend tutorial sessions.

## Course Aim

The course aim is to provide students with basic knowledge of genetics and breeding of crops and animals.

## Course Objectives

To achieve the aims set out, the course has a set of objectives which are set out as specific objectives under each unit. You should read these objectives before you study the unit. After going through this course you should be able to:

- define the term "cell" and state the relationship between cells and tissues
- draw and label the different parts of the cell and differentiate between plant and animal cell
- list the different types of cell, their sizes, components and functions
- enumerate and state the functions of the different chemical components of the cell
- name the types of nucleic acids and describe the structure of DNA and RNA
- describe the process of cell division and explain the various stages of cell division
- explain the historical background of the principle of inheritance
- state the Laws of inheritance and explain the principles governing inheritance of various traits in plants and animals
- define the various terms used to describe observed variations in characters conditioned by genes
- discuss the causes of mutation of genes and its significance

- explain the different methods used in breeding self-pollinating, cross-pollinating and asexually propagated plants
- state the advantages and limitations of the different methods of plant breeding
- state the aims of animal improvement programmes and explain the various systems of animal breeding.
- define the term "selection" and explain the various methods of selection
- define artificial insemination, describe the process and explain the benefits as well as limitations of artificial insemination.

## Working through this Course

This course involves that you devote a lot of time to read and study the contents. Each unit contains self assessment exercises for this course and at certain points in the course you would be required to submit assignments for assessment purposes.

At the end of this course, there is a final examination. You are advised to attend the tutorial sessions where you would have the opportunity of comparing knowledge with your colleagues.

## Course Materials

You will be provided with the following materials:

- Course Guide
- Study Units
- References
- Assignments
- Presentation Schedule

## Study Units

This course consists of 5 modules which are subdivided into 13 units. They are as follows:

**Module 1 Cell Organisation**

Unit 1 Historical Background and Cell Structure
Unit 2 Types of Cells
Unit 3 Cell Components and their Functions

## Text Books and References

Banerjee, G.C. (2005). *A Textbook of Animal Husbandry*, 8th Edition. New Delhi: Oxford & Ibh.

George, Acquaah (2007). *Principles of Plant Genetics and Breeding.* United Kingdom: Blackwell.

Payne, W. J. A. and Wilson, R.T. (1999). *An Introduction to Animal Husbandry in the Tropics,* 5th Edition. Germany: Wiley-VCH.

Roberts, M.B.V. (1980). *Biology: A Functional Approach*, 4th Edition. Hong Kong: ELBS and Nelson.

Simmonds, N.W. and Smatt, J. (1999). *Principles of Crop Improvement,* 2nd Edition. United Kingdom: Blackwell Science.

Sinha, U. and Sinha, S. (1982). *Cytogenetics, Plant Breeding and Evolution,* 2nd Edition. New Delhi: Vikas.

## Assessment

There are two components of assessment for this course:

- Tutor-Marked Assignments (TMAs)
- the end of course examination.

## Tutor-Marked Assignment

The TMA is the continuous assessment component of your course. It accounts for 30% of the total score. You will be given four TMAs by your facilitator to answer before you can sit for the final examinations.

## Final Examination and Grading

This examination concludes the assessment for the course. The examination will account for 70% of total score. You will be informed of the time for the examination.

## Summary

This course provides you with basic knowledge of animal and plant genetics and breeding.

| | |
|---|---|
| Course Code | ANP309 |
| Course Title | Genetics and Breeding |

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National Open University of Nigeria
Headquarters
14/16 Ahmadu Bello Way
Victoria Island
Lagos

Abuja Office
5, Dar es Salaam Street
Off Aminu Kano Crescent
Wuse II, Abuja
Nigeria

e-mail: centralinfo@nou.edu.ng
URL: www.noun.edu.ng

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# MODULE 1 CELL ORGANISATION



## UNIT 1 HISTORICAL BACKGROUND AND CELL STRUCTURE

**CONTENTS**



## 1.0 INTRODUCTION

The study of living things begins with the study of cells. A proper understanding of the cell is essential for us to be able to understand the characteristics and functions of the different tissues and organs in any living organism.

## 2.0 OBJECTIVES

At the end of this unit, you should be able to:

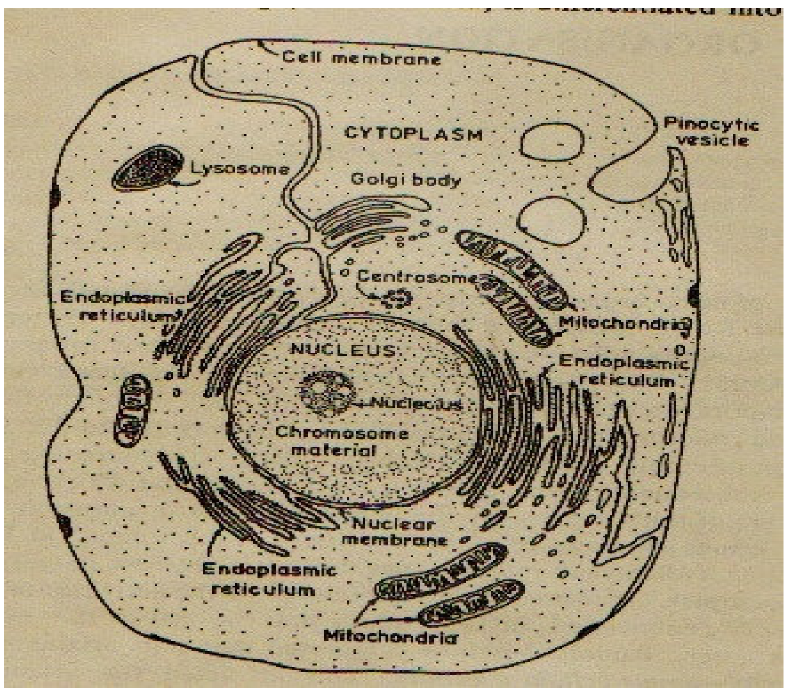
- define the term “cell”
- state the relationship between cells and tissues
- name the early proponent of cell studies
- draw and label the different parts of the cell.

## 3.0 MAIN CONTENT

### 3.1 Cells and Cell Structure

The cell is the simplest or basic functional unit of an organism. Cells were first described by Robert Hooke, a British Architect and microscopist in 1665. Robert Hooke designed one of the earliest optical microscopes with which he examined thin sections of corks. He discovered that corks were made up of numerous box-like structures which we now know to be cells. Although Hooke coined the word "cell" for these structures, he did not realise their significance. In 1675, Marcello Malpighi published an "Anatomy of Plants," the first systematic study of cell structure. In 1772, Corti observed the jelly-like material in the cell that was later called protoplasm.

In 1839, Mathias Schleiden, a German botanist and Theodor Schwann, an animal anatomist formulated the "cell theory". The theory states that "the elementary parts of all tissues are formed of cells in an analogous though very diversified manner, so that it may be asserted that there is one universal principle of development for the elementary parts of organisms, however different and that this principle is the formulation of cell." Cells are thus, the unit of life. Twenty years later, Rudolf Virchow suggested that cells originate only from pre-existed cells – *omnis cellulae* cellula. All living organisms, the diversity notwithstanding, are composed of cells which are similar in structure, function and organisation. Below is a typical diagram of a cell.



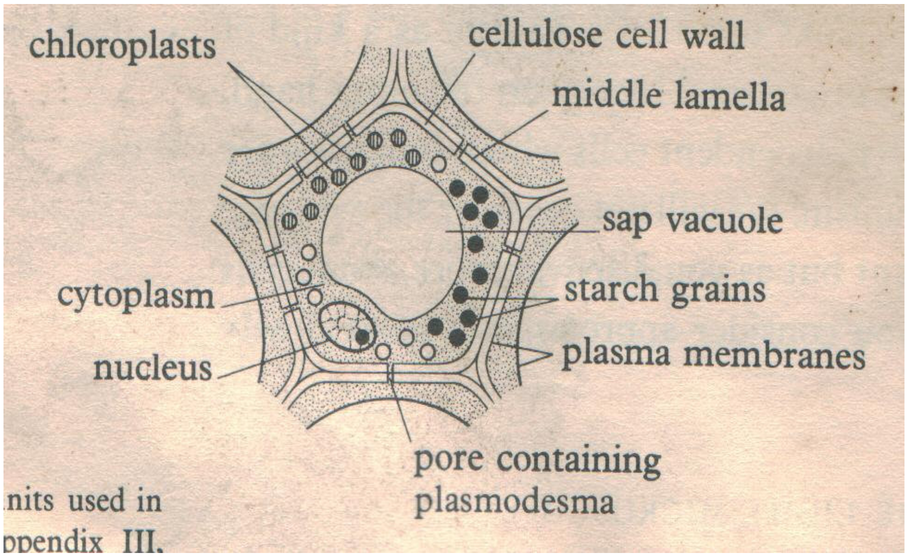



**Fig. 1 :** **A Typical Animal Cell**

**Fig. 2:** **A Typical Plant Cell** (Roberts, 1980)

Cells have many things in common but they vary to some extent in size, shape, structure and function.

## 4.0 CONCLUSION

The cell is the simplest functional unit of an organism. Robert Hooke was the first scientist to describe the cell. The first systematic study of cell structure was carried out by Marcello Schleiden, who formulated the Cell Theory. Cells are alike but vary to some extent in size, shape, structure and function.

## 5.0 SUMMARY

Cells are the basic functional unit of life. The elementary parts of all tissues are formed of cells in an analogous though very diversified manner. Cells have many things in common but they vary to some extent in size, shape, structure and function.

## 6.0 TUTOR-MARKED ASSIGNMENT

i. What is a cell?
ii. What is the relationship between cells, tissues and organs?
iii. Name four scientists that initiated the study of cells and their functions.
iv. Draw and label the different parts of the cell.

## 7.0 REFERENCES/FURTHER READING

George, A. (2007). *Principles of Plant Genetics and Breeding*. United Kingdom: Blackwell.

Roberts, M.B.V. (1980). *Biology: A Functional Approach,* 4th Edition. Hong Kong: ELBS and Nelson.

Simmonds, N. W. & Smatt, J. (1999). *Principles of Crop Improvement*, 2nd Edition. United Kingdom: Blackwell Science.

Sinha, U. & Sinha, S. (1982). *Cytogenetics, Plant Breeding and Evolution*, 2nd Edition. New Delhi: Vikas.

# UNIT 2 TYPES OF CELLS

**CONTENTS**



## 1.0 INTRODUCTION

A cell is the basic unit of living thing. It is the smallest independently functioning unit in the structure of an organism, usually consisting of one or more nuclei surrounded by cytoplasm and enclosed by a membrane. Cells also contain organelles such as mitochondria, lysosomes, and ribosomes. Multicellular organisms are made up of cells with different shapes and sizes. Animal cells are capable of changing their shape but plant cell is fixed due to the presence of cellulose. In this unit, we shall be examining the different types of cells and their characteristics.

## 2.0 OBJECTIVES

At the end of the unit, you should to be able to:

- differentiate between plant and animal cell
- list the different types of cell
- state the diameter of the different types of cells.

## 3.0 MAIN CONTENT

The diameter of most cells ranges between 0.5 and 20μ (μ or micron = 0.001 mm). Table 1 shows the range of size variation of different kinds of cells. Cells vary widely in shape and depend upon the environmental conditions, surroundings, function and need of the organism.

**Table 1: Range of Size Variation of Different Kinds of Cells**

| Cell Type | Size |
|---|---|
| Egg of ostrich | 170 x 135 mm |
| Egg of hen | 60 x 45 mm |
| Human egg | 0.1 mm= 100 μ |
| Amoeba | 100 μ |
| Sea urchin egg | 70 μ |
| Red blood corpuscle | 7 μ |
| *Typhoid bacillus* | 2.4 X0.5 μ |
| *Escherichia coli* | 1.5 x 0.7 μ |
| *Diplococcus pneumoniae* | 200 x 100 mμ |
| Influenza virus | 100 mμ |
| Tobacco mosaic virus | 300 X 15 mμ |
| $T_3$ bacteriophage | 45mμ |

Cells of multicellular organisms have different shapes. The red blood cells of human beings are biconcave, whereas muscle cells are long and with pointed ends. Animal cells are capable of changing their shape. But the shape of plant cells is fixed due to the presence of a cellulose walls. Fig. 1 shows the diversity in cell shapes.

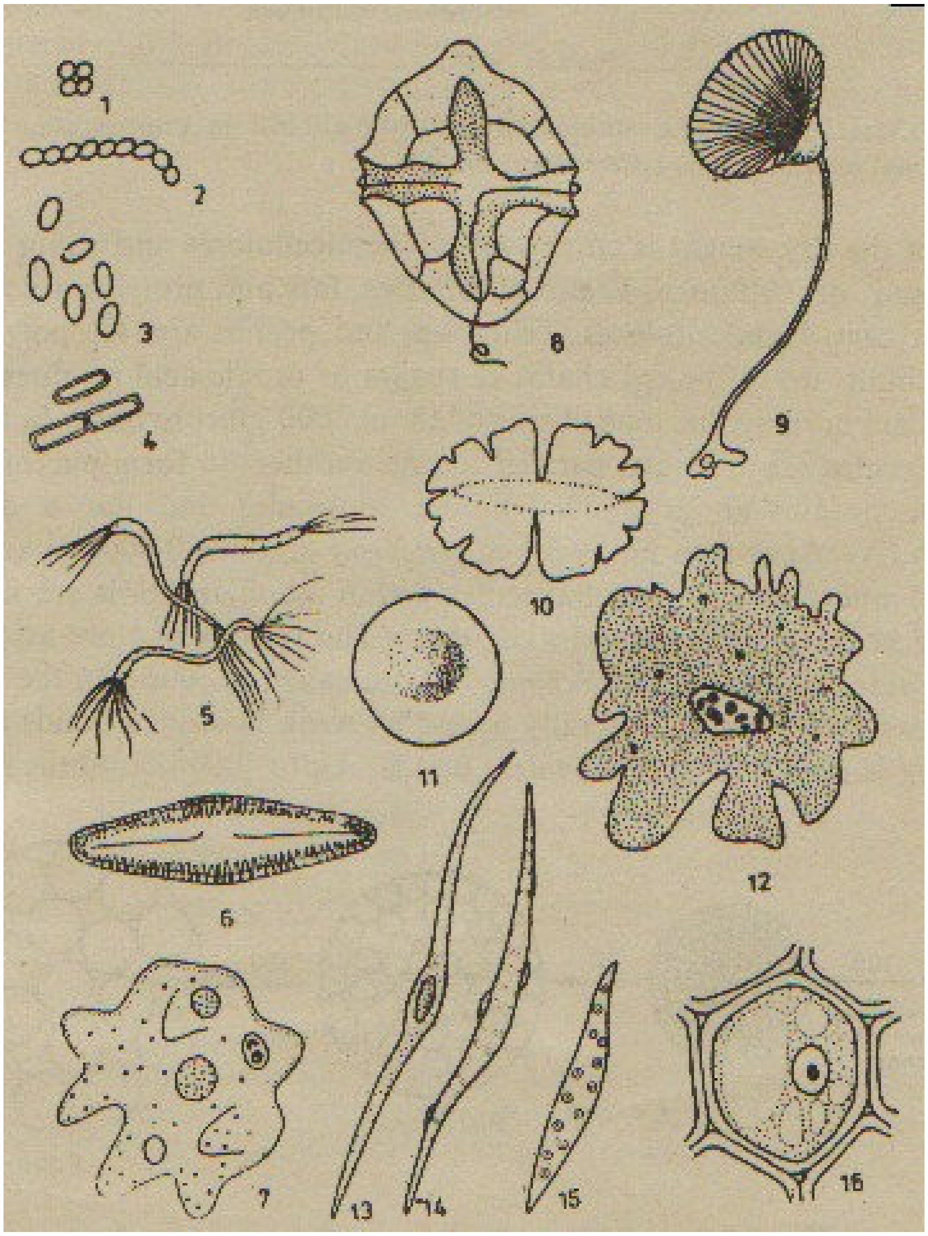


**Fig. 1 :** **Variation in Cell Shape** (Sinha and Sinha, 1982)

1. Tetracoccus
2. Streptococcus
3. Micrococcus
4. Bacillus
5. Spirillum
6. Diatom
7. Amoeba
8. Dinoflagellate
9. Acetabularia
10. Desmid
11. Human red blood cell
12. Melanocyte,

13. Smooth muscle cell
14. Striated muscle cell
15. Tracheidal cell
16. Parenchymatous cell.

## 4.0 SUMMARY

Cell is the basic unit of living thing. The cell is the smallest independently functioning unit in the structure of an organism; usually consisting of one or more nuclei surrounded by cytoplasm and enclosed by a membrane. Cells also contain organelles such as mitochondria, lysosomes, and ribosomes.

## 5.0 CONCLUSION

Cells are the smallest structures capable of basic life processes, such as taking in nutrients, expelling waste, and reproducing. All living things are composed of cells. Some microscopic organisms, such as bacteria and protozoa, are unicellular, meaning they consist of a single cell. Plants, animals, and fungi are multicellular; that is, they are composed of a great many cells working in concert. But whether it makes up an entire bacterium or is just one of trillions in a human being, the cell is a marvel of design and efficiency. Cells carry out thousands of biochemical reactions each minute and reproduce new cells that perpetuate life. Cells of multicellular organism have different shapes and sizes. Animal cells are capable of changing shape but the shape of plant cell is fixed due to the presence of cellulose wall.

## 6.0 TUTOR-MARKED ASSIGNMENT

i. What is the difference between plant and animal cell?
ii. List the different types of cells.
iii. State the diameter of the different types of cells.

## 7.0 REFERENCES/FURTHER READING

George, A. (2007). *Principles of Plant Genetics and Breeding*. United Kingdom: Blackwell.

Roberts, M.B.V. (1980). *Biology: A Functional Approach,* 4th Edition, Hong Kong: ELBS and Nelson.

Simmonds, N.W. & Smatt, J. (1999). *Principles of Crop Improvement,* 2nd Edition. United Kingdom: Blackwell Science.

Sinha, U. & Sinha, S. (1982). *Cytogenetics, Plant Breeding and Evolution*, 2nd Edition. New Delhi: Vikas.

# UNIT 3 CELL COMPONENTS AND THEIR FUNCTIONS

## CONTENTS



## 1.0 INTRODUCTION

Cells are made up of different components. In this unit, we shall examine the different components of the cell and highlight their functions.

## 2.0 OBJECTIVES

At the end of this unit, you should be able to:

- list the different components of the cell
- state the functions of the different components of the cell.

## 3.0 MAIN CONTENT

### 3.1 The Cell Wall

The cell wall is the outer boundary of the cell. It is made up of cellulose, lignin, salts and fatty substances. The cell wall of a young plant cell has a thickness of 1-3μ, which increases in both length and girth during cell growth. After a while, the primary or initial wall stops growing, and a secondary wall is laid inside it. The thickness of the secondary wall ranges from 5 to 10μ and it's rigid. It is not flexible like the primary wall. Adjacent cells are cemented together by an intercellular substance or a middle lamella in multicellular organisms. The middle lamella is composed primarily of calcum pectate. Animal cells lack a cell wall. Hemicellulose makes up 50 per cent of the dry weight of the cell wall, while cellulose makes up 25 per cent: the rest 25 per cent consist of protein, pectic substances and fats. Water makes up 90 – 95 per cent of the fresh weight of the cell wall. Hemicellulose, celluloses, and pectins are all polysaccharides and are built up of linked chains of sugars or uronic acid residues.

Cellulose is made up of about 3000 glucose units, which are arranged parallel to one another to form microfibrils. Up to 400 microfibrils are bundled together to form a macrofibril or fibril. Macrofibrils are irregularly and loosely arranged and the gaps are filled with carbohydrates, cutin, suberine, pectin, lignin, etc. The macrofibrils of secondary wall are relatively compact and the gaps are filled mainly by lignin. Cell walls give a definite shape and protection to the cell and provide mechanical support. It is permeable and hydrophilic and contains enzymes which are concerned with the synthesis, transport and degradation of cell wall macromolecules, digestion and modification of extracellular metabolites and other metabolic functions.

## 3.2 Cell Membrane

Inside the cell wall is the cell membrane, plasma membrane, plasmalemma or cytomembrane. The plasma membrane is the most important, as others are not essential for life. The plasma membrane cannot be removed or damaged without killing the cell.

The cell membrane has three properties namely:

(a) preferential permeability to lipid-soluble substances
(b) high electrical resistance
(c) low tension.

It has been proposed that a single membrane layer consist of a continuous film of lipids molecules, such as phosphatides, sterols and fats, of which the outermost two layers are so oriented that the hydrated polar groups are in the water- oil interface, with a layer of protein molecules absorbed on both of these interfaces. There is considerable freedom of movement of constituent molecules within the membrane. This is necessary if the membrane is to be a dynamic structure capable of charging its composition and function according to the exigencies of the situation. Cell organelles are also bounded by membranes.

Membranes thus, bring about compartmentalisation within the cell which is necessary for division of labour at the sub cellular level. Membranes are fluid and dynamic functional systems.

They are the sites of active transport, oxidative and photosynthetic phosphorylations, immunological response, cell-cell interaction and many other vital physiological activities.

## 3.3 Protoplasm

This is a colloidal mixture of organic and inorganic material enclosed inside the cell wall. Plasma membrane surrounds the protoplast. When cell wall is removed, the protoplast rounds off and sometimes break up into pieces.

## 3.4 Cytoplasm

Cytoplasm is that part of the cell which is enclosed by the plasma membrane and surrounds the nucleus. In many plants, the cytoplasm of adjacent cells is connected by cytoplasmic strands which pass through plasmodesmata. Sometimes, the cytoplasm can be divided into an outer ectoplasm, a middle mesoplasm and an inner endoplasm. In the cytoplasm are suspended by the various organelles such as the nucleus, endoplasmic reticulum, plastids, mitochondria, Golgi bodies, etc. Also present in the cytoplasm are many soluble and insoluble molecules which participate in various metabolic reactions of the cell.

## 3.5 Endoplasmic Reticulum

The endoplasmic reticulum is made up of a system of tubes or flattened sacs located in the cytoplasm. The endoplasmic reticulum or ergastoplasm appears to be continuous with the cell membrane on one hand and the nuclear membrane on the other. Sometimes endoplasmic reticulum is expanded to form flat and sac like cysternae which may occur singly but more often are aggregated to form parallel lamellae. Beside tubules and cysternae, there may be isolated vesicles which may be formed due to pinching off of cysternae.

The endoplasmic reticulum divides the cytoplasm into two parts: one part which is outside the tubules and vesicles and the other which is enclosed by them. In cells that can synthesise protein, part of the endoplasmic reticulum is studded with granula particles, which are known as microsomes or ribosomes. Endoplasmic reticulum covered by ribosomes is known as rough endoplasmic reticulum, while those without ribosomes are called smooth endoplasmic reticulum.

In cells where smooth endoplasmic reticulum predominates, the enzymes concerned with the synthesis of fatty substances are associated with the endoplasmic reticulum. Ribosomes are the sites of protein synthesis, and can be strung together by messenger RNA to form polysomes or polyribosomes. Endoplasmic reticulum thus, provides a suitable surface for various metabolic reactions. It also helps in the transport and storage of various metabolites and compartmentalisation of cytoplasm.

## 3.6 Golgi Body

The Golgi bodies, also known as Golgi apparatus, usually appear as a series of flattened membranous sac (2 to 20) which lie parallel to each other near the nucleus. It was named after its discoverer, Camillio Golgi (1898). The Golgi body is also known as dicytosome. Each of the sacs or cysternae is enclosed by smooth double membranes which are often dilated and fenestrated at the ends. Vesicles are constricted off the branched cysternae from time to time. The aggregation of dicytosomes along with vesicles derived from them is known as the “Golgi complex” or “Golgi apparatus”. It has been suggested that Golgi complex is concerned with the storage and transformation of lipids and lipid-like substances and participates in cell wall formation and secretion. It is also involved in inter and intra- cellular transport and formation of primary lysosomes in animal cells.

## 3.7 Lysosomes

Lysosomes are sac-like structures, which are found in animal cells. They are derived from smooth endoplasmic reticulum. Lysosomes measures 0.25 to 0.05μ in diameter and contain hydrolytic enzymes. They are composed of a homogenous matrix which is bounded by a single lipo-proteinaceous membrane. They can be separated and purified by centrifugation. They have been implicated in intra-digestion, autophagy and autolysis as they contain enzymes which control the breakdown of large molecules such as protein and fat, both of intra- and extra- cellular origin.

## 3.8 Microbodies

These are also known as cytosomes. They are sac-like organelles found in both plant and animal cells. These organelles are supposed to arise from the endoplasmic reticulum and are enclosed by a single membrane. Their matrix is fibrillar or granular.

Cytosomes were first discovered in rat liver and kidney cells where they carry out various oxidative reactions involving the formation and further degradation of hydrogen peroxide. Microbodies contain specific enzymes, depending on the type of cell and stage of differentiation. Microbodies that contain glycolytic enzymes are known as peroxisomes. They are found near the chloroplasts as they contain enzymes of the photosynthetic cycle. Microbodies containing enzymes of the glyoxylate cycle are known as glyoxysomes. Glyoxysomes are involved in the degradation of fatty acids to form carbohydrate. They are common in fatty seeds and gradually disappear after the germination of the seedling.

## 3.9 Microtubules

Microtubules are tubular structures made up of globular proteins and get aggregated to form the spindle fibres. Generally, two centrally located microtubules are surrounded by a ring of nine pairs of microtubules and the whole thing is embedded in a matrix which is enclosed by an extension of the plasma membrane.

Microtubules are present in all eucaryotic cells and are responsible for the orderly movement of chromosomes during cell division. They are also found in places where new cell wall is to be synthesised; for example, at the time of cytokinesis or at the time of cell elongation. Cilia and flagella of motile gametes or cells contain microtubules which are arranged in an orderly and definite fashion. Centrioles of animal cells possess a similar pattern of microtubules. Microfilaments are also present in cells. They are smaller than microtubules and help in photoplasmic streaming, cell mortility, changes in cell shape and muscle contraction.

## 3.10 Mitochondria

Mitochondria are bean-shaped, free floating organelles in the cytoplasm. They were discovered by Benda in 1898. Their shape, size, internal structure and number differ from cell to cell and measure 1 to 10μ long and about 0.5μ wide. The mitochondrion is bounded by a double membrane, the outer is smooth and has many round granules attached to its surface while the inner one is folded and involute inside the mitochondrial matrix to form the cristae. The mitochondrial matrix is homogenous and many granular and fibrous structures are surrounded in it. It contains ribosomes, nucleic acids and proteins. Mitochondria are capable of oxidizing various organic acids, thereby librating energy. They are the seats of respiration and contain respiratory enzymes. The reaction of the krebs cycle take place in the matrix of mitochondria.

Mitochondria are often referred to as the "power house" of the cell due to their major role in respiration and liberation of energy. It should be noted however, that mitochondria are absent in red blood corpuscles, bacteria and blue green algae. Bacteria have smaller organelles known as mesosomes and are the sites of respiratory activity.

## 3.11 Plastids

Plastids are discoid organelles found free floating in the cytoplasm of cells except in animals and a few primitive plants. They may be coloured or colourless and measure about 3-6μ in diameter and 1-3μ in thickness. Leucoplasts and chromoplasts are the major plastids found in cells. Leucoplasts are white plastids which serve the purpose of storage. Leucoplasts which store starch are termed amyloplasts. Chromoplast is the membrane-surrounded structure plastid in a plant cell that contains pigment. Red, yellow, or orange chromoplasts contain carotenoid pigments, and green chromoplasts chloroplasts contain chlorophyll. They determine the various colours of petals and other plant parts. Plastids have the potential of interconversion. For example, in the presence of light, the leucoplast of potatoes becomes green. Chloroplasts are made up of grana, which are interconnected by stroma lamella (stroma thylakoids). There may be 2 to 100 thylakoids per granum and 25-100 grana per cell. Thylakoids are the sites of light reaction of photosynthesis (photo phosphorylation). The dark reaction is completed in stroma. Stroma contains ribosomes, DNA, phospholipids, carotenoids, chlorophyll and proteins. The chemical composition of chloroplasts is as follows:

| **Component** | **Percentage Composition** |
|---|---|
| Protein | 40-50 |
| Phospholipids | 25 |
| Chlorophyll | 5-10 |
| Carotenoids | 1-2 |
| Ribose nucleic acid (RNA) | 5 |
| Deoxyribose nucleic acid (DNA) | 1 |

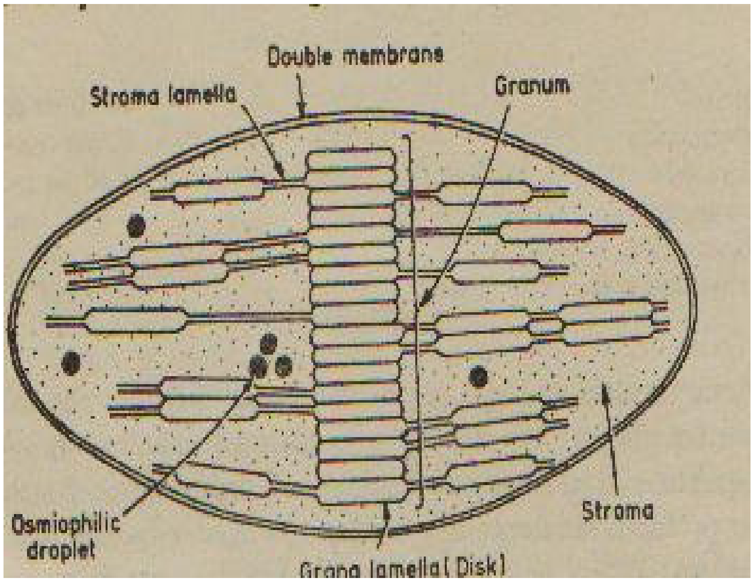



**Fig. 4: The Structure of a Chloroplast**

Photosynthetic bacteria and blue green algae have chromatophores or synthetic lamellae instead of chloroplasts. It should be noted however, that simple and undifferentiated proplastids develop into mature and differentiated chloroplasts in the presence of proper stimuli. For instance, when plastids are germinated in the dark, its cells contain small colourless double membrane structures which become green in light.

## 3.12 Vacuoles

Vacuoles are sacs of various kinds of solids and liquids found in the cytoplasm of cells. Vacuoles are surrounded by a unit membrane know as tonoplast. Vacuoles are common in old cells, as little or no vacuoles are found in young cells. They are considered as storage organs and they increase the cytoplasmic surface. They sometimes help in maintaining the turgor pressure of cells. In some plants, vacuoles serve as reservoirs of waste material and may serve as lysosomes. Vacuoles contain cell sap with atmospheric gases, sugars, mineral salts, organic acids and sometimes anthocyanin pigments. The dissolved pigments of vacuoles are responsible for different colours of petals. In lower organisms the contractile vacuoles are excretory in function.

## 3.13 Nucleus

The nucleus is a spherical body suspended in the cytoplasm. It was discovered by Brown in 1883. The nucleus is surrounded by two lipo-proteinaceous membranes. The space between the two membranes is known as the perinuclear cisterna. The nuclear membrane has many pores through which the cytoplasm communicates with the nuclear matrix (also known as nucleoplasm or nuclear sap). The nucleus also contains chromatin and nucleolus. The chromatin network is composed of DNA and histone, whereas, the nucleoplasm contains RNA and protein. Ribosomes have also been found in the nucleoplasm.

The nucleus is the most vital part of the cell and contains the information for various characters of the organism. It also controls its growth and differentiation. During cell division the nucleus divides into two identical and complete halves. When the nucleus is not dividing, metabolic activities of the cell continues and they are regulated and controlled by the nucleus. A non-dividing nucleus is often referred to as a “resting” nucleus. The nucleus contains the genetic material of the cell: chromatin in the dividing cell and chromosomes in the non-dividing cell. The nuclei of somatic cells (cells which carry out vegetative functions) contain information necessary for determining the structure of new cells and the nuclei of sex cells contain the information necessary for determining the characteristics of a new individual.

## 4.0 CONCLUSION

Cells are made up of similar components which carry out varied but specified functions. The nucleus is the most vital part of the cell and contains the information for various characters of the organism. Cells are the smallest structures capable of basic life processes, such as taking in nutrients, expelling waste, and reproducing. All living things are composed of cells.

## 5.0 SUMMARY

The cell is made up of cell wall (for plants), cell membrane, protoplasm, cytoplasm, endoplasmic reticulum, Golgi bodies, microbodies, lysosomes, microtubules, mitochondria, plastids, vacuoles and nucleus. Cells carry out thousands of biochemical reactions each minute and reproduce new cells that perpetuate life.

## 6.0 TUTOR-MARKED ASSIGNMENT

i. List the different components of the cell.
ii. State the functions of any five components of the cell.
iii. Which component of the cell is referred to as the “power house” of the cell and why?

## 7.0 REFERENCES/FURTHER READING

George, A. (2007). *Principles of Plant Genetics and Breeding*, United Kingdom: Blackwell.

Roberts, M.B.V. (1980). *Biology: A Functional Approach,* 4th Edition. Hong Kong: ELBS and Nelson.

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Sinha, U. & Sinha, S. (1982). *Cytogenetics, Plant Breeding and Evolution,* 2nd Edition. New Delhi: Vikas.

# MODULE 2 CHEMICAL COMPOSITION OF CELL, BASICS OF HEREDITY AND CELL DIVISION



## UNIT 1 CHEMICAL COMPOSITION OF CELLS

**CONTENTS**



## 1.0 INTRODUCTION

Cell is the basic unit of life. Cells are the smallest structures capable of basic life processes, such as taking in nutrients, expelling waste, and reproducing. All living things are composed of cells. Some microscopic organisms, such as bacteria and protozoa, are unicellular, meaning they consist of a single cell. Plants, animals, and fungi are multicellular; that is, they are composed of a great many cells working in concert. But whether it makes up an entire bacterium or is just one of trillions in a human being, the cell is a marvel of design and efficiency. Cells carry out thousands of biochemical reactions each minute and reproduce new cells that perpetuate life. Cells are made up of different chemical components, performing different functions within the cell.

## 2.0 OBJECTIVES

At the end of this unit, you should be able to:

- enumerate the different chemical components of the cell
- state the functions of the different chemical components of the cell
- give example of different classes of chemical constituents of the cell.

## 3.0 MAIN CONTENT

### 3.1 Chemical Composition of Cells

The major chemical constituents of the cell are water, protein, carbohydrates, lipids and inorganic salts.

**Water**

Water is the largest constituent of the cell (about 85 percent). The protoplasm is largely a colloidal solution in water. Water also acts as a solvent for inorganic substances and enters into many reactions that occur in the cell. Water occurs in the cell as free water, and is available for use in metabolism and as bound water, which is absorbed to the surface of protein and other molecules.

**Protein**

After water, protein is the next largest constituent of the protoplasm (about 10 percent). Proteins and related substances are involved in many activities of the protoplasm and the cell. The large size of many protein molecules (the molecular weight varies from $10^3$ – $10^6$) makes them an important factor in maintaining osmotic pressure in cells, so that the water level in the cell remains relatively constant.

All enzymes which catalyse chemical reactions in cells are proteins. All cell membranes
are partly protein and proteins are associated with the genes involved in the transmission of genetic information from cell to cell and generation to generation.

When proteins are digested with acids, alkalis or enzymes, they break up into small pieces and upon complete hydrolysis give rise to amino acids. Many proteins combine with other molecules to form the cellular components. Nucleoproteins, for example, are products of nuclei acid, while lipoproteins are products of lipids and protein.

**Carbohydrates**

Carbohydrates are found in the cell and may occur in soluble or insoluble form and as reserve food or as integral part of protoplasm or cell wall. Sugars, starch, resins, etc. are examples of carbohydrate. Carbohydrates can be broadly classified into sugars and polysaccharides. Polysaccharides are formed due to condensation of large number of sugar molecules. Cellulose is a regular polymer of glucose. Starch is complex polysaccharide and is mixed or irregular polymers of sugars.

Carbohydrates in the cell have a high turnover and utilization as energy. Carbohydrates are also essential components of the DNA and RNA. (DNA = deoxyribose nucleic acid and RNA = ribonucleic acid). The sugar, deoxyribose in combination with a base (purine or pyrimidine) and a phosphate, form DNA - which is the carrier of all genetic information, while ribose combines with a base and a phosphate to form RNA, which is associated with all proteins. See fig. 2 in unit 2, for the basic structures of purine and pyrimidine bases.

**Lipids**

Lipids are important in forming part of the plasma membrane and other membraneous substances. Lipids are either esters of fatty acids or hydrolytic products of such esters. Fats are the most important lipids. Fats are esters of glycerol and fatty acids. Lipids are insoluble in water but soluble in organic solvents like alcohol, ether, chloroform, etc.

Hence, they easily aggregate in the aqueous environment of the cell and thus, form a bimolecular layer which is a major component of various membranes. Lipids are also utilised in the cells for the release of energy. Lipids can also be found in combination with other substances such as phosphate (phospho-lipids) or nitrogenous base (as in lecithin).

**Inorganic Salts**

The organic components of the cell account for 99 percent of the cell weight, while the inorganic components are about 1 percent of the dry weight of the cell. The inorganic salts found in the cell include, sodium, potassium, magnesium, calcium, phosphorus, iodine, copper, zinc, cobalt, selenium, chlorine, fluorine, molybdenum, silicon, and vanadium. Inorganic salts and their ions aid in maintaining a constant pH and help to regulate osmotic pressure in the cell. Phosphorus joined with adenosine to form ADP or ATP is vital for energy release in the cells.

## 4.0 SUMMARY

The components of cells are molecules, nonliving structures formed by the union of atoms. Small molecules serve as building blocks for larger molecules. Proteins, nucleic acids, carbohydrates, and lipids, which include fats and oils, are the four major molecules that underlie cell structure and also participate in cell functions. For example, a tightly organised arrangement of lipids, proteins, and protein-sugar compounds forms the plasma membrane, or outer boundary, of certain cells. The organelles, membrane-bound compartments in cells, are built largely from proteins. Biochemical reactions in cells are guided by enzymes, specialised proteins that speed up chemical reactions. The nucleic acid deoxyribonucleic acid (DNA) contains the hereditary information for cells, and another nucleic acid, ribonucleic acid (RNA), works with DNA to build the thousands of proteins the cell needs.

## 5.0 CONCLUSION

The major chemical constituents of the cell are water, proteins, carbohydrates, lipids and inorganic salts. By itself, each cell is a model of independence and self-containment. Like some miniature, walled city in perpetual rush hour, the cell constantly bustles with traffic, shuttling essential molecules from place to place to carry out the business of living. Despite their individuality, however, cells also display a remarkable ability to join, communicate, and coordinate with other cells. The human body, for example, consists of an estimated 20 to 30 trillion cells. Dozens of different kinds of cells are organised into specialised groups called tissues. Tendons and bones, for example, are composed of connective tissue, whereas skin and mucous membranes are built from epithelial tissue. Different tissue types are assembled into organs, which are structures specialised to perform particular functions. Examples of organs include the heart, stomach, and brain. Organs, in turn, are organised into systems such as the circulatory, digestive, or nervous systems. All together, these assembled organ systems form the human body.

## 6.0 TUTOR-MARKED ASSIGNMENT

i. What are the chemical components of the cell?
ii. Briefly discuss the functions of any four chemical constituents of the cell.
iii. What are inorganic salts? Give examples of six inorganic salts found in the cell.

## 7.0 REFERENCES/FURTHER READING

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# UNIT 2 CHEMICAL BASIS OF HEREDITY

## CONTENTS



## 1.0 INTRODUCTION

Heredity is the process of transmitting biological traits from parent to offspring through genes, the basic units of heredity. Heredity also refers to the inherited characteristics of an individual, including traits such as height, eye colour, and blood type. The hereditary materials in living organisms are nucleic acids. Nucleic acids are polymers of nucleotides. They are involved in the transmission of character or trait in living organisms.

## 2.0 OBJECTIVES

At the end of the unit, you should be able to:

- name the types of nucleic acids
- describe the structure of DNA and RNA
- explain the arrangement of the four bases which are the building blocks of nucleic acid
- list the different types of RNA.

## 3.0 MAIN CONTENT

### 3.1 Chemical Basis of Heredity

Nucleic acids are not protein and are the hereditary material in living organisms. There are two types of nucleic acids involved in the transmissions of character or trait in living organisms. They are the DNA (deoxyribose nucleic acid) and RNA (ribose nucleic acid). Fig. 1 shows the structure of ribose and deoxyribose sugar. Generally, the DNA is endowed with the capacity to transmit genetic information from one generation to another. However, when DNA is not present (as in some viruses), RNA assumes this role.

Nucleic acids are polymers of nucleotides. Each nucleotide is composed of a nucleotide base, a five carbon sugar and phosphoric acid. The nucleotide of DNA is known as deoxyribonucleotides or deoxyribotides, while those of RNA are known as ribonucleotides or ribotides. The sugar of DNA is deoxyribose sugar whereas that of RNA is ribose sugar. RNA has one hydrolyl group (- OH) attached to its second carbon atom whereas DNA has only one hydrogen atom attached to its second carbon atom.

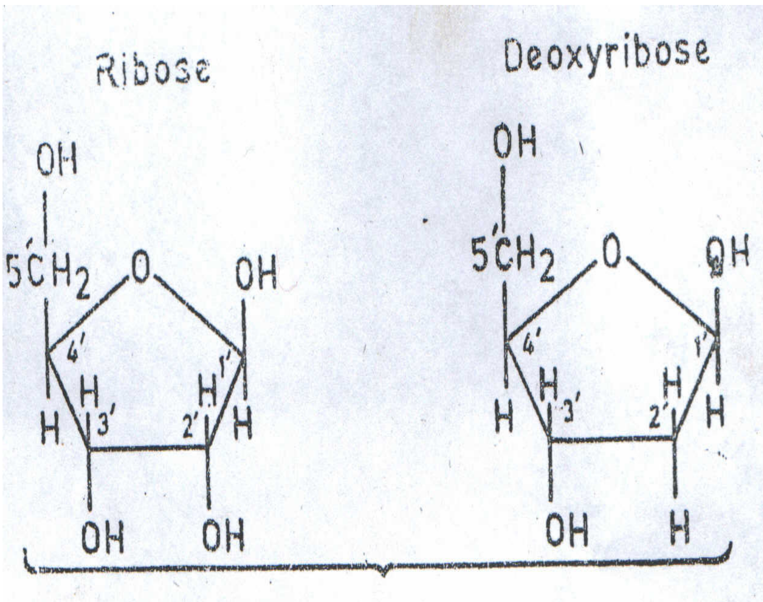


**Fig. 1 : Pentose Sugars of Nucleic Acids**

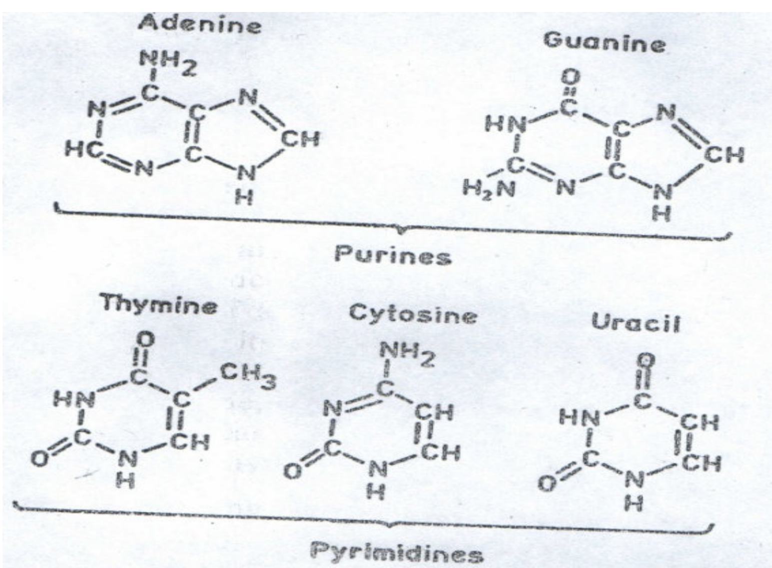


**Fig. 2 : Purine and Pyrimidine Bases of Nucleic Acids**

DNA has four bases: adenine, thymine, guanine and cytosine. Adenine and thymine are purines, whereas guanine and cytosine are pyrimidines. The structure of purine and pyrimidine bases of nucleic acid is presented in Fig. 2. RNA on the other hand, has uracil instead of thymine, while the other three bases are the same as in DNA (Figures 4, 5, 6 and 7).

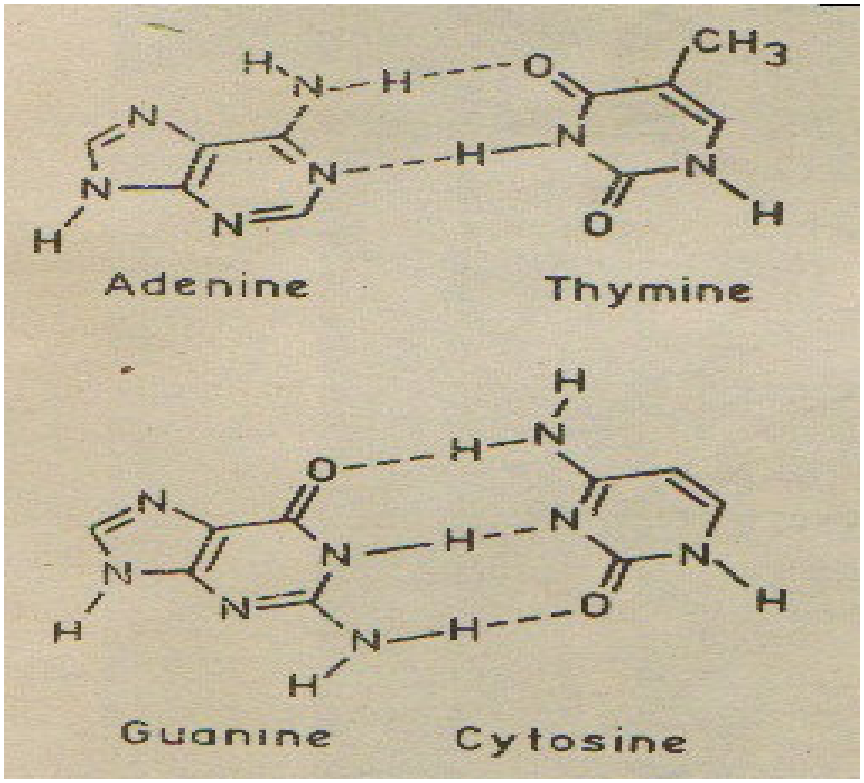


**Fig. 3 : Pairing of Bases due to Covalent Hydrogen Bonds**

## 3.2 Structure of DNA

DNA molecule according to Waston and Crick (1953) has two long anti-parallel polynucleotide chains, helically coiled around the same axis. The right handed helices are held together by their bases which are paired together by covalent hydrogen bonds. Purine polynucleotide chain pairs with pyrimidine of the other- adenine with thymine and guanine with cytosine. See fig. 3, 4 and 5. Fig. 4 shows the relative position of bases, sugars and phosphates within the double helix structure of DNA.

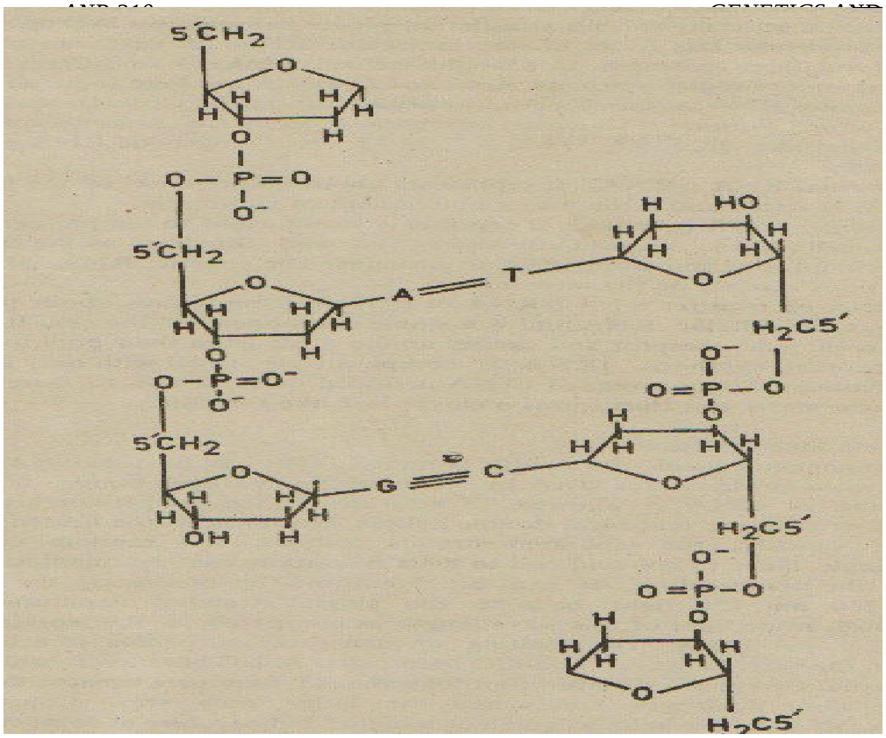

**Fig. 4 :** **A Section of the Double Helix Structure of DNA Showing Opposite Polarity of Two Strands which has Opposite Direction of Sugar-Phosphate Linkages**

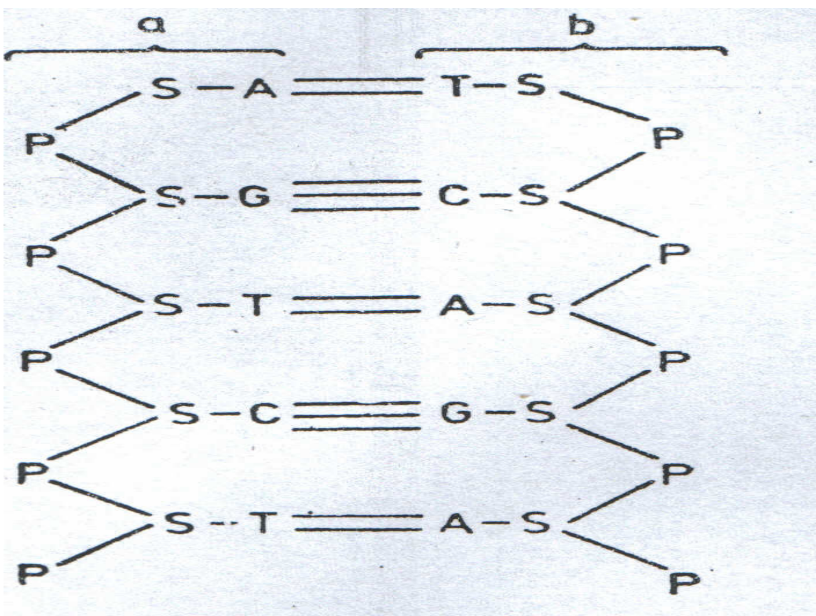


**Fig. 5:** **A Part of the Double Helix DNA Showing the Relative Positions of Bases, Sugars and Phosphates**

**(P= Phosphates, S= Sugar, T= Thiamine, A= Adenine, C= Cytosine, G= Guanine, U= Uracil).**

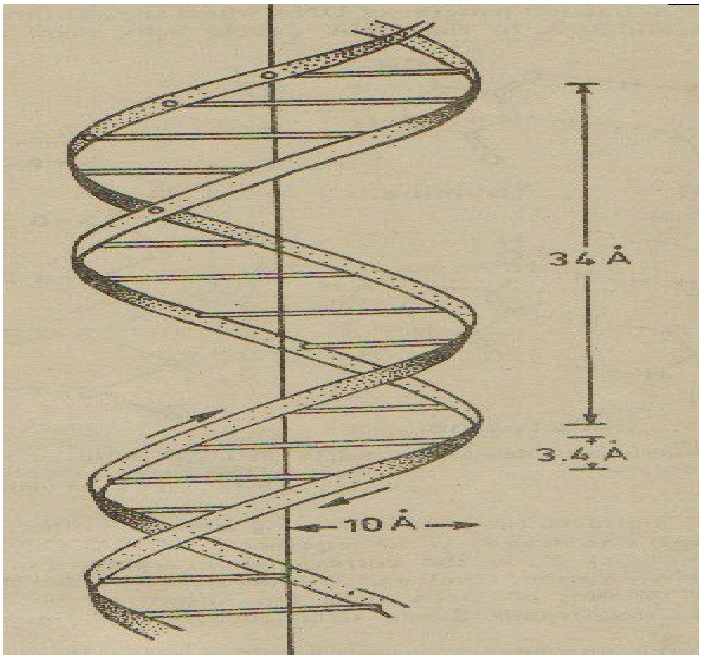


**Fig. 6: The Double Helix Model of DNA**

## 3.3 Structure of RNA

RNA is a polynucleeotide chain of ribonucleotides. The RNA counterpart of thymine is uracil. Thymine of DNA is the 5-methyl derivative of uracil of RNA. See structure below:

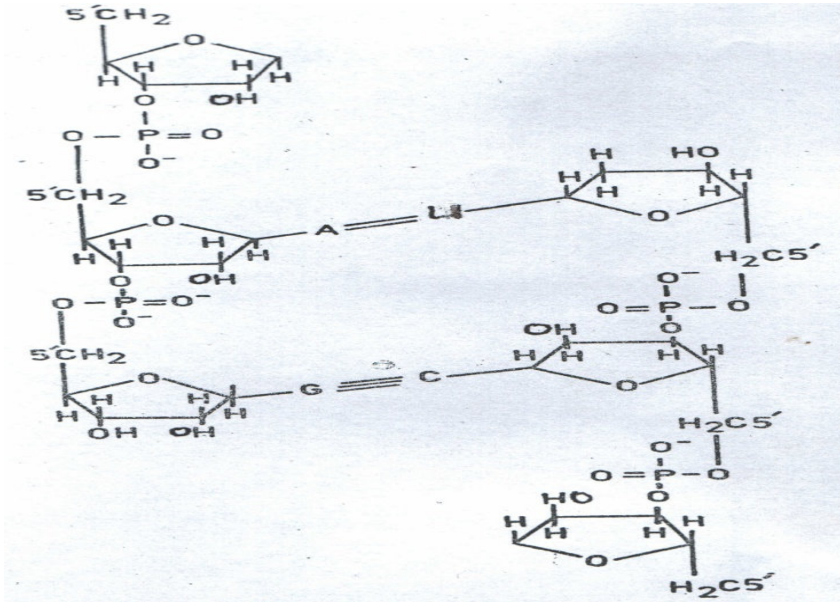

**Fig. 7: A Section of RNA Showing Opposite Polarity of Two Strands which have Opposite Directions of Sugar-Phosphate Linkages**

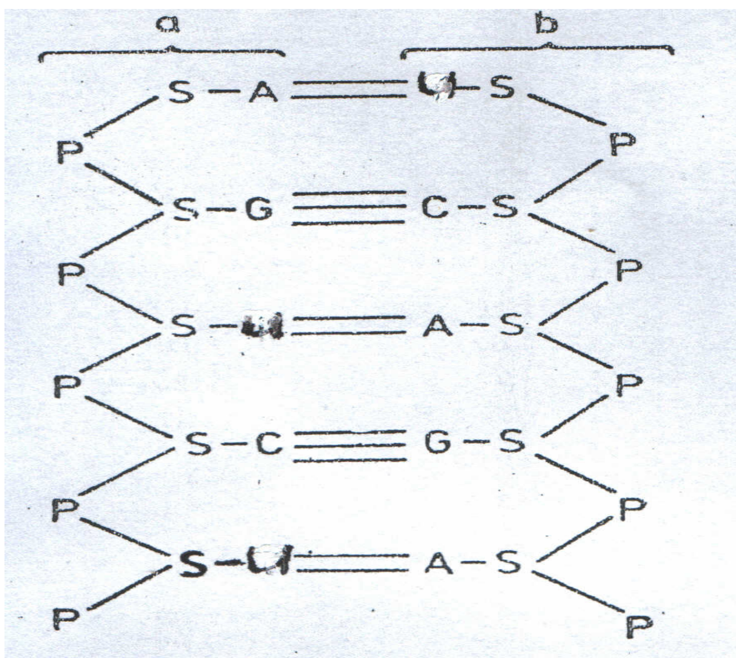


**Fig. 8: A Section of RNA Showing Opposite Polarity of Two Strands which have Opposite Directions of Sugar-Phosphate Linkages**

There are three types of RNA found in cells. These are:

(a) Ribosomal RNA (rRNA ) – It is stable and is a major component of ribosomes. It is the most abundant RNA (80 percent) in the cells.
(b) Messenger RNA (mRNA) - It is usually short lives and functions as the carrier of genetic information from DNA to proteins. It is about 10 percent of the total cell RNA.

(c) Transfer or soluble RNA (tRNA) - It is stable and acts as the amino acid receptor and carries amino acid from the pool to the site of protein synthesis. It represents about 10- 15 percent of the total cell RNA.

## 4.0 CONCLUSION

Heredity accounts for why offspring look like their parents: when two dogs mate, for example, they have puppies, not kittens. If the parents are both Chihuahuas, the puppies will also be Chihuahuas, not great Danes or Labrador retrievers. The puppies may be a little taller or shorter, a little lighter or a lot heavier than their parents are. Their faces may look a little different, or they may have different talents and temperaments. In all the important characteristics, however—the number of limbs, arrangement of organs, general size, fur type—they will share the traits of their parents. The principles of heredity hold true not only for a puppy but also for a virus, a roundworm, a pansy, or a human. Nucleic acids are the hereditary materials found in the cells of the living organism and are responsible for the transmission of characters and traits.

## 5.0 SUMMARY

DNA and RNA are the nucleic acids responsible for the transmission of genetic information from one generation to another. DNA has four bases: adenine, thymine, guanine and cytosine. In the structure of RNA, however, thymine is replaced by uracil. There are three types of RNA. These are: ribosomal RNA, messenger RNA and transfer RNA.

## 6.0 TUTOR-MARKED ASSIGNMENT

i. What are nucleic acids?
ii. Name the two major types of nucleic acid found in the cell.
iii. What is the major role of nucleic acids in the transmission of traits?
iv. Briefly describe the structure of DNA and RNA.

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George, A. (2007). *Principles of Plant Genetics and Breeding*, United Kingdom: Blackwell.

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# UNIT 3 CELL DIVISION

**CONTENTS**



## 1.0 INTRODUCTION

Living organisms grow and multiply by cell division. The process of cell division varies with organisms and even the various tissues of the same organism. The basic process is the same for all living organisms. Within all organisms, cells divide to produce new cells, each of which requires the genetic information found in DNA. Yet simply splitting the DNA of a dividing cell between two new cells would lead to disaster—the two new cells would have different instructions and each subsequent generation of cells would have less and less genetic information to work with.

## 2.0 OBJECTIVES

At the end of this unit, you should be able to:

- describe the process of cell division
- define mitosis and meiosis
- explain the various stages of cell division.

## 3.0 MAIN CONTENT

### 3.1 Cell Division

Living organisms grow and multiply by cell division. The process of cell divisions varies with organisms and even the various tissues of the same organisms. The basic process is, however, the same. The process of cell division is a complex cyclical one in which cell division of the organism is preceded by a division of the nucleus. During cell division, the nucleus and its chromosomes divide with great precision. During cell multiplication, the somatic cells divide equationally (mitosis), so that daughter cells contain the same number of chromosomes as their mother cells. But during gamete formation, the cells undergo a reduction division (meiosis), so that the gametes receive half the number of chromosomes from their mother cells. It should be noted, however, that during cell division chromosomes maintain their identity and individuality to a remarkable extent.

## 3.2 Mitosis

Mitosis is a process of cell multiplication by which a cell divides into daughter cells with each daughter cell containing the same number of chromosomes as the parent cell. It is the type of cell division that takes place during the growth of an organism.

Mitosis is a dynamic process and has four different stages which are short lived. The sub-stages are: Prophase, Metaphase, Anaphase and Telophase.

The net result of mitosis is that two identical nuclei emerge from the division of a single nucleus.

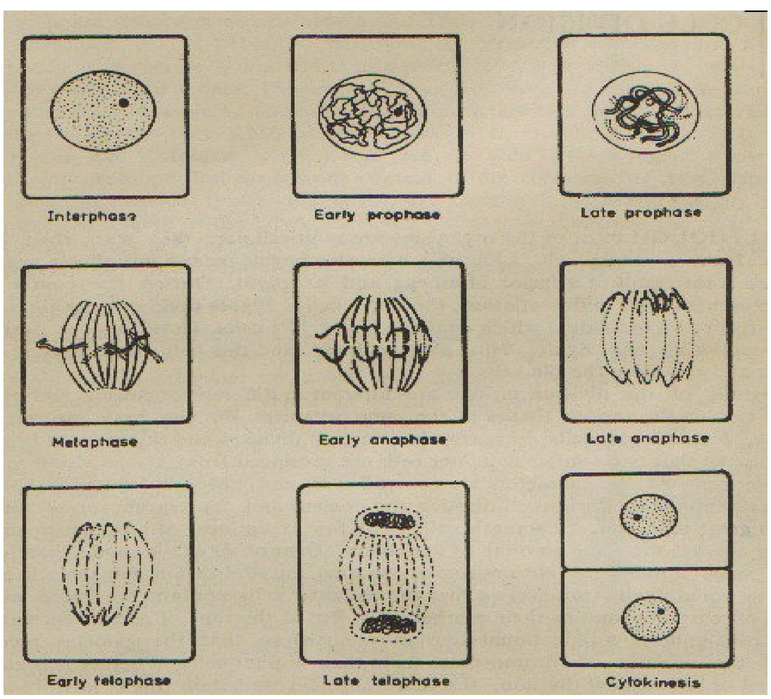


**Fig.1: Diagrammatic Representation of Different Stages of Mitosis** (Sinha and Sinha, 1982)

## 3.3 Cytokinesis

Cytokinesis is the term used to describe cytoplasmic division during cell multiplication.

Nuclear division is generally followed by cytokinesis. Cell plates sometimes start in the center of the cell soon after the anaphasic separation of daughter chromosomes. The cell plate gradually enlarges and ultimately touches the cell wall; thus, separating the two nuclei and dividing a single cell into two. Spindle fibres and cytoplasmic membranes help in the organization of the cell wall. There are however some variation in the process in different organisms. In animal cells, there is a star like body known as centrosome, which divides into two during the prophase and the daughters get situated at the two poles. They get connected by spindle fibers as soon as the nuclear membrane disappears.

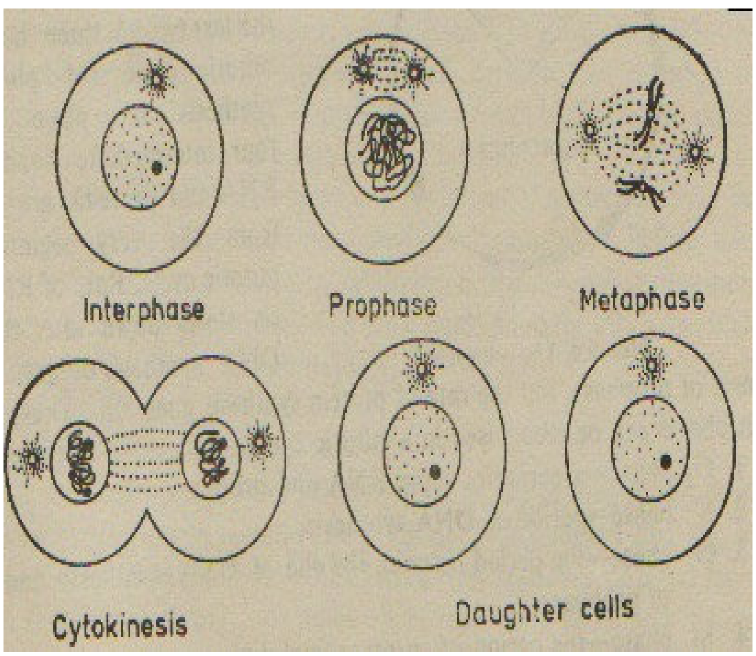


**Fig. 2: Some Stages of Cell Division in an Animal Cell Showing the Behaviour of Centrosome and Cytokinesis by Furrowing** (Sinha and Sinha, 1982)

The pattern of cytokinesis in animal cell is also different from that of plant cell. In animal cell, a furrow starts in the middle of the cell wall and gradually deepens or extends up to the middle of the cell, thereby dividing the cell into two halves. Furrows do not, however, appear in plant cell because the cell wall is rigid.

## 3.4 Significance of Mitosis in Plants and Animals

Inclusive mitotic division of a single cell gives rise to a group of cells with identical genetic make-up known as clone. Mitosis is essential to maintain a particular nucleo-cytoplasmic ratio. Proper nucleo-cytoplasmic ratio is necessary for proper functioning of the nucleus. Also if DNA synthesis continues without cell division, different cells will contain different amounts of DNA and this amount will continue to rise.

Cell division is therefore necessary to maintain the constancy of quality and quantity of the hereditary material in different cells of an organism as well as in its different generations. It also ensures the coordinated growth and function of various organs of an individual. Cell division also helps in the survival of a species, as every cell has a definite life span. Before an individual dies, it produces offspring by cell division.

## 3.5 Meiosis

Meiosis is a process of cell division by which a cell divides into daughter cells with each cell having half the total number of chromosomes present in the parent cell, as in the formation of gametes. A gamete is a cell which cannot develop further until it fuses with another gamete. The daughter cells resulting from meiosis are said to be in the haploid state. Sexually reproducing organisms produce their gametes by meiosis.

During sexual reproduction, two gametes unite to form a zygote, which divide mitotically to form an individual. It results in the blending of characters from two parents into an individual (offspring) and ensures variation, which is important for evolution. Gametes contain half the number of chromosomes as compared to somatic cells. The union of two gametes restores the somatic number of chromosomes in the zygote.

During meiosis, or the time of gamete formation, the amount of chromosomes or DNA is halved. This is achieved by two successive divisions of nuclei (meiosis I and meiosis II) and cytoplasm accompanied by only one replication of chromosomes. For example, each somatic cell of pea (*Pisum sativum*) has 14 chromosomes, but each gamete (male or female) contains only 7 chromosomes.

Meiosis in plants can be studied at the time of gamete formation which occurs in specialised organs (i.e. the embryo and the pollen sac. A single cell undergoes meiosis in the embryo while large number of spore mother cells divides meiotically to produce haploid in the pollen grains.

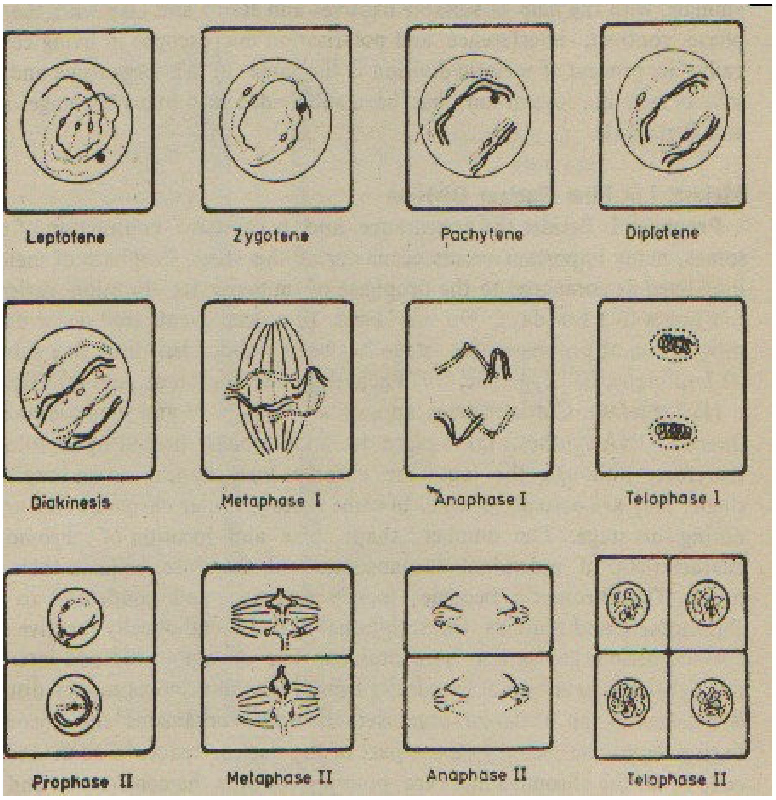


**Fig. 3: Diagrammatic Representation of Different Stages of Meiosis** (Sinha and Sinha, 1982)

In sexually reproducing organism, the gametes are haploid and two gametes fuse together to form a diploid zygote. But in order to maintain a particular diploid number through successive generations, a reduction in chromosomes number through the process of meiosis is essential at the point of gamete formation or else, the chromosomes number will continue to double after every generation. Fertilisation brings the paternal and maternal chromosomes together and the process of meiosis separates them after re-assortment. In this way, new associations of chromosomes are established.

When homologous chromosomes are in intimate contact with one another, during the prophase of the first meiotic division, the chromatids of homologous chromosomes break and rejoin at a certain point called chiasmata. Chiasmata help in exchanging parts of chromatids between homologue chromosomes, thus, ensuring new combination of characters. Meiosis therefore helps in bringing about variation in population.

## 4.0 CONCLUSION

Cell division is necessary to maintain consistency of quality and quantity of the hereditary materials in different cells of an organism as well as ensures the coordinated growth and function of various organs of an individual. Organisms use two types of cell division to ensure that DNA is passed down from cell to cell during reproduction. Simple one-celled organisms and other organisms that reproduce asexually-that is, without the joining of cells from two different organisms- reproduce by a process called mitosis. During mitosis a cell doubles its DNA before dividing into two cells and distributing the DNA evenly to each resulting cell. Organisms that reproduce sexually use a different type of cell division. These organisms produce special cells called gametes, or egg and sperm. In the cell division known as meiosis, the chromosomes in a gamete cell are reduced by half. During sexual reproduction, an egg and sperm unite to form a zygote, in which the full number of chromosomes is restored.

## 5.0 SUMMARY

Living organisms grow and multiply by cell division. During cell division, the nucleus and its chromosomes divide with great precision. The somatic cells divide equationally (Mitosis) so that daughter cells containing the same number of chromosomes as their mother cells. During gamete formation, the cells undergo reductional division (Meiosis) so that the gamete receives half the number of chromosomes from the mother cell.

## 6.0 TUTOR-MARKED ASSIGNMENT

i. Why is the study of cell division necessary?
ii. Define the terms: mitosis and meiosis.
iii. How many stages are involved in mitosis and meiosis?
iv. What is cytokinesis?
v. In which part of the plant can meiosis be studied?

## 7.0 REFERENCES/FURTHER READING

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# MODULE 3 PRINCIPLE OF INHERITANCE



## UNIT 1 LAW OF INHERITANCE

**CONTENTS**



## 1.0 INTRODUCTION

Characters are transmitted from one generation to another without much change by inheritance. In this unit, we shall examine the historic background of our understanding of the principles of inheritance and the various laws of inheritance.

## 2.0 OBJECTIVES

At the end of this unit, you should be able to:

- explain the historical background of the principle of inheritance
- state the laws of inheritance
- explain the principles governing inheritance of various traits in plants and animals.

# 3.0 MAIN CONTENT

## 3.1 Principles of Inheritance

It has been observed over time that plants and animals beget their likes. Characters are transmitted from one generation to another without much change. Although men have made this observation, they never understood the basis of inheritance until 1866. Different ideas were put forward at different times about the mode of transmission of character from one generation to another. One of such idea was that the factors responsible for character transmission were fluid in nature and during the process of reproduction, the fluid from both parents were mixed or blended to bring an offspring with intermediate character. Some other workers believed that in animals, inheritance is by the way of the blood and so offspring's are brought by a combination of the blood of both parents.

A well known philosopher, Aristotle had a different idea. He postulated that the male and female contributions are not equal, and that, while the female contributed the matter, the male contribution the emotion. Also, attempts at improving rice by ancient Chinese farmers are well documented but these ancient people were unaware of the basic principles of inheritance. They depended mainly on hybridisation and selection for their crops and animals. Hybridisation is the process of producing an individual from the union of gametes from parents that are not genetically alike, while, selection is the non-random production offspring from the parents' generations.

The reports of various studies carried out by scientists such as Knight (1799), Goss (1824) and Mendel (1866) laid the foundation for modern day understanding of the principles of inheritance.

Knight crossed a pea plant with green stem, white flowers and colourless seed-coat with another one which had purple stem, purple flowers and brown seed-coat. A cross between coloured and colourless plants yielded only coloured plants in the first filial generation ($F_{1)}$. The first filial generation is the first set of offspring resulting from intermating two inbred lines. $F_{1\ is}$ used to denote the generation after crossing. On self-fertilisation, this $F_I$ progeny segregated into pigmented and unpigmented plants (both type of seeds were found in the same pod) and concluded that there was a stronger tendency to produce pigmented than unpigmented plants. In another experiment, he pollinated a tall variety and a dwarf one and vice versa, and observed that only tall plants are produced and the two crosses are the same. He therefore discovered that reciprocal crosses give the same result.

Goss in 1824 reported that when he pollinated a green-seeded pea plant with the pollen from a yellow-seeded one, he found that the seeds of the first generation progeny ($F_I$) were yellow like those of the male parent. When the $F_I$ progeny were crossed (self fertilisation), it yielded pods, some of which had only green seeds, some had only yellow seeds and some had both yellow and green seeds. And when the second generation seeds were sown, the green seeds produced plants which bore only green seeds but the yellow seeds yielded plants with only yellow seeds as well as with mixed pods.

The works of Knight and Goss were flawed, because they did not keep proper statistical record and did not pay adequate attention to the relative frequencies of different types of plants.

The first empirical study which gave rise to our present day understating of the principles of inheritance was carried out by an Augustinian Monk by name Gregor Mendel, who in 1866 published papers that reported on data from eight years of cross-breeding experiments using common garden peas. Although the significance of most of his works was not realised until his death in 1884, he was given the credit as the father of genetics. Based on Mendel's conclusions from his studies, later workers were able to deduce three basic laws of inheritance.

These are:

1. The law of dominance
2. The law of segregation and
3. The law of independent assortment.

## 3.2 The Law of Dominance

This law states that "when a pair of contrasting characters (allelic pair) are crossed, one allele behaves as dominant while the other as recessive. This is termed complete dominance but in the case of incomplete dominance or partial dominance, both alleles interact with each other and an intermediate character is expressed.

Mendel crossed his red-flowered plants, either on self-pollination or crossed with another red-flowered plant, the progeny were all red flowered plants for many generations. He however, observed that when he crossed a tall plant with a dwarf one, all offspring or $F_I$ progeny were tall. But when the $F_I$ progeny were crossed, it yielded some tall and some dwarf plants. Indicating that some of the dwarf character was not expressed – the first generation but it remain recessive, whereas the tall character was dominant.

## 3.3 The Law of Segregation

This law states that “each character is conditioned by genes which occur in pairs and only one of the pairs can be carried in a single gamete”.

Mendel observed that when red-flowered plant was crossed with a white flowered one, all the $F_I$ plants were red-coloured, but when the $F_I$ progeny were crossed, red and white colours appeared in the $F_I$ generation in a ratio of 3:1 (red : white).

Mendel not satisfied with this result, decided to raise the third generation plants with $F_{2.}$ He found out that the 3:1 ratio was resolved into 1:2:1 ratio in which 25 percent of the first group was true-breed for the dominant character, 25 percent plants of the third group was true breed of the recessive character while the rest 50 percent were hybrid containing both character but expressed only the dominant one.

Mendel also carried out other studies using tall and dwarf varieties of peas and obtained similar results. The results of Mendel’s experiment formed the basis for the law of segregation.

## 3.4 The Law of Independent Assortment

In another study, Mendel made a cross between plants, which differed in two characters instead of one (a dihybrid cross). He crossed a round and yellow-seeded plant with a wrinkled and green-seed one. He found $F_I$ that plants bore only round and yellow seeds (Round and yellow were dominant). When $F_2$ generation was raised from these seeds, he observed that four types of plants were produced in a definite ratio of 9:3:3:1. Out of the 556 plants ($F_3$), the phenotypic expressions were: 315 round and yellow-seeded plants; 108 round and green-seeded plant, 101 wrinkled and yellow-seeded plants and 32 wrinkled and green-seeded plants. Phenotypic expression is an individual’s observable characteristics, resulting from the expression of its genotype and its surrounding environment.

The law of independent assortment was derived from the results of these studies. And it states that “each member of a pair of allele may combine randomly with either of another pair”. In other words, no matter the number of characters being considered at a time, each gene maintains its identity and may combine with or assort from others independently.

## 3.5 Application of Mendelian Genetics to Animal Improvement

The practical significance of the first two laws of Mendelian theory is of extreme importance when man is selecting for specific traits in plants and animals. We shall now examine them with reference to examples from domestic livestock.

A germ cell consists of a pair of like chromosomes, known as homologues. Each homologue contains identical genes that occur in the same order. These identical genes are known as alleles. Although the opposite genes are identical in that they affect the same phenotypic characteristic or development process of a character, they do not necessarily influence it in the same way. If both alleles have the same influence on a characteristic, the individual possessing them is said to be homozygous for that characteristic, but if they differ in that influence, the individual is said to be heterozygous for the character. If the effect of one alleles is stronger than that of the other to the extent that it masks the effect of the other, the masking alleles is said to be dominant, while the allele that has been masked is said to be recessive.

For example, in cattle the polled or absence-of-horns trait is dominant over the horned trait. Thus, when homozygous horned cattle are mated with homozygous polled cattle, the offspring possess one gene for the presence of horned and another for the absence of horns i.e. they are heterozygous for the character. Since the polled gene is dominant, all offspring are polled. If the genotype of the homozygous horned individual is designated as hh, the homozygous individuals resulting from the mating as Hh. The situation could be expressed in the following manner:

HH x hh

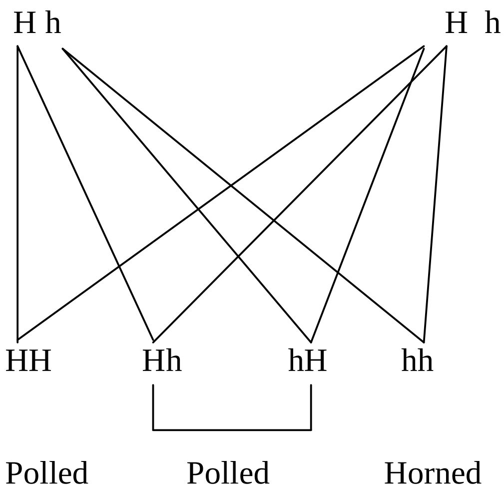
↓

Polled horned

Hh

The phenotypes of the HH and Hh individual will be the same but their genotype will be different.

If the heterozygous offspring are inter mated, then, as both parents produce equal numbers of germ cell carrying either allele, the chances of any sperm cell from the male fusing with any egg of the same type or of a different type are equal and so four combinations of the genes are possible. There combinations are HH, Hh, hH and hh.




The phenotype grouping is therefore three polled to one horned animal, but since fertilisation is at random, it must not be expected in practice that among every four progeny of such mating the result will be 3 polled and one horned animal. This will occur only when a very large number of mating are evaluated.

An example of what happens when dominance is lacking in alleles can be demonstrated by reference to the inheritance of coat colour in short horn cattle. If a red–coated short horn is represented by RR and a white–coated short horn by rr, then when red and white short horns are mated, the offspring are of a Rr type and their coat is roan rather than either red or white. This may be represented as follows:

RR x rr

Red coat white c

↓

Rr
Roan coat

If the roan offspring are intermated then segregation takes place as in the previous example. This may be represented as follows:

Rr x Rr

RR Rr rR rr
Red coat roan coat roan coat white coat

The above examples demonstrate the operation of the 1st Mendelian law on the segregation of inherited characteristics.

The second law - that of independent assortment can be demonstrated in an example where the inheritance of two pairs of genes is considered at the same time. For example, we can consider two dominant traits polledness and dwarfism in Hereford cattle. If a homozygous polled, non–dwarf individual with the genotype HHDD is mated to a homozygous horned, dwarf individual with the genotype hhdd, the F1 progeny will be phenotypically polled and non–dwarf but genotypically HhDd. If the F1 progeny are then intermated, the resulting offspring (F2) will exhibit four different phenotypes in the ratio of nine polled non–dwarf, to three polled dwarf, to 3 horned non dwarf, to 1 one horned dwarf individual (9:3:3:1). This can be represented as follows:

HHDD X hhdd

Polled : non dwarf horned : dwarf

Gametes HD hD

F1 generation HhDd

HhDd X HhDd
Polled: non dwarf polled: non dwarf

F2 gametes: HD.Hd.Hd.hd. X HD.Hd.Hd.hd.

F2 generation: (polled: non dwarf) 9:, (polled: dwarf) 3:, (horned: non dwarf) 3:, (horned: dwarf)1 the cross can be better presented with a Punnet square as follows.

| | HD | Hd | hD | Hd |
|---|---|---|---|---|
| HD | HHDD polled:non dwarf | HHDd polled: non dwarf | HhDD polled: non dwarf | Hh Dd polled: non dwarf Hhdd |
| Hd | HHDd polled: non dwarf | HHdd polled: dwarf | HhDd polled: non dwarf | Hhdd polled: dwarf |
| hD | HhDD polled: nondwarf | HhDd polled: non dwarf | HhDD horned: non dwarf | HhDd horned: non dwarf |
| Hd | HhDd polled: non dwarf | Hhdd polled: dwarf | HhDh horned: non dwarf | Hhdd horned: dwarf |

It should be noted that the number of possible combinations increase rapidly with an increase in the number of gene pairs. Thus, in domestic animals where the number of heterozygous gene pairs is very large, it is not surprising that no two individuals, with the exception of identical twins, are genotypically or phenotypically completely alike.

## 4.0 CONCLUSION

Our understanding and application of the Mendelian Laws are of extreme importance when man is selecting for specific traits in plants and animals.

## 5.0 SUMMARY

Different ideas were put forward at different times about mode of transmission of character from one generation to another. The first empirical study which gave rise to our present day understanding of the principles of inheritance was carried out by Gregor Mendel. Based on Mendel's conclusion from his studies, later workers are able to deduce three basic Laws of Inheritance. These are the Law of Dominance, Law of Segregation and Law of Independent Assortment.

## 6.0 TUTOR-MARKED ASSIGNMENT

i. Why is Gregor Mendel referred to as the father of genetics?
ii. What are the basic laws of inheritance?
iii. Briefly explain the practical significance of the laws of Mendel.

## 7.0 REFERENCES /FURTHER READING

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# UNIT 2 TYPES OF CROSSES AND GENES

## CONTENTS



## 1.0 INTRODUCTION

There are different types of crosses and terms used by breeders to achieve their objectives. The various terms are used to describe observed variations in characters as conditioned by genes. In this unit, we shall be explaining the following: Test cross, Back cross, Multiple alleles, Pleiotropism, Lethal genes, Complimentary gene, Additive gene, Epitasis and Mutation.

## 2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define the various terms stated above that was used to describe observed variations in characters as conditioned by genes
- explain the basic principles behind this observed phenomenon
- discuss the causes of mutation of genes and its significance.

## 3.0 MAIN CONTENT

### 3.1 Test Cross and Back Cross

The cross of an individual of unknown genotype to a completely recessive individual is known as a test cross. In this case, the type of progeny will depend on the types and frequencies of gametes produced by the parent of unknown genotype and can help in determining the genotype of unknown individual. Back cross involves crossing a progeny to one of the parents.

### 3.2 Multiple Alleles

This is used to describe a situation where, a single gene may have more than only two possible kinds of alleles. For example, B may give rise to $B^I$, $B^2$, $B^3$, $B^4$ …, such a group of alternatives is called a series of multiple alleles. Multiple alleles are present in eye colour of Drosophila. ABO blood group system of animals is controlled by a series of seven multiple alleles.

## 3.3 Pleiotropism

Pleiotropism is a special phenomenon and it used to describe a situation, where a gene has multiple phenotype effects. Such a gene is known as pleiotropic. Many studies have revealed that many genes are pleiotropic. For example, the seed coat colour of sweet peas control flower colour and also red spots in leaf axils.

## 3.4 Lethal Genes

Lethal genes are genes that cause the death of an organism during early stages of development. Dominant lethal genes are often lost from the population because they cause death of the organisms even in a heterozygous condition. For example, aurea is a lethal gene discovered in *Antirrhinum majus*. Aurea homozygous causes death of seedlings or sometimes before germination due to lack of ability to produce chlorophyll.

## 3.5 Complimentary Gene

Complimentary genes are dominant alleles which are located at two different locci and segregate independently of each other. Their presence or activities produces complimentary phenotypic effect. For example, flower colour in *Lathyrus adoration* is determined by two genes. Bateson and Punnett made a cross between two white flowered plants and found that the $F_I$ progeny were purple-flowered, $F_2$ progeny aggregated into 9 purple and 7 white flowered plants. On selfing the white flowered plants it yielded only white flowered plants. The purple flowered plants when selfed did not produce all purple flowered plants. (They did not breed true). It produced purple and white coloured flower plants in a ratio of 3:1. The $F_3$ progeny did not follow the normal ratio of 9:3:3:1 where the last three have the same phenotype, rather, it produced a phenotypic ratio of 9:7. The above phenomenal can be explained if we assume that the colour purple is controlled by two dominant genes C and P. If either or both of the dominant genes are absent, the flowers become white. This can be illustrated as follows:

P1 White x White
CCpp ccPP

P1 gametes Cp purple cP
F1 CcPp

F1 gametes → CP Cp Cp cp

F2

| | CP | Cp | Cp | cp |
|---|---|---|---|---|
| CP | CCPP Purple | CCPp purple | CcPP purple | CcPp purple |
| Cp | CCPp Purple | CCpp white | CcPp purple | Ccpp white |
| Cp | CcPP Purple | CcPp purple | ccPP white | ccPp white |
| Cp | CcPp Purple | Ccpp white | ccPp white | ccpp white |

**Fig. 1 : Inheritance of Flower Colour in Lathyrus Odoratus. Due to Complementary Genes the F2 Phenotypic Ratio of 9:7 is Obtained** (Sinha and Sinha, 1982)

The gene C and P are complimentary to each other and they control the synthesis of anthocyanin. White colour appears because of the absence of complementation. Aleurone colour in maize is also controlled by complementary genes.

## 3.6 Additive Genes

Additive genes are also known as polymeric genes. This is a situation where two pairs of genes determine a character. For example, in *Cucurbita pepo* plants, crossing two plants with spherical fruits yielded only discoid-fruited progeny ($F_I$). When $F_I$ are crossed, discoid, spherical and long progeny are produced. In this example, the $F_I$ progeny are not like any of the parents, and in $F_2$, a third phenotype appears. In pigs, coat colour also follows the same inheritance pattern.

## 3.7 Epistasis

This term is used to describe a modification of normal gene expression in which a particular gene at one locus masks the expression of at least one other gene at a different chromosomal location. For example, coat colour in mice follows this pattern of inheritance. Coat colour in mice is controlled by two genes: C and A. In agonti mice both genes are dominant. When only gene C is dominant, the mice are black. When only C is homozygous recessive or both C and A are homozygous recessive, albino mice are produced. The recessive gene C can thus, be said to be epistatic over gene A and does not allow its expression.

## 3.8 Mutation

Mutation can be defined as random heritable changes in DNA that introduce new alleles into the gene pool. Gene mutation occurs within a gene (as opposed to chromosomal mutations); substituting one nucleotide for another results in point mutation. The present concept of mutation includes only the hereditary changes that involve alternations in gene or Mendelian factors. The activity of genes is normally lost due to mutations. This explains why the original or wild-type genes are dominant and the mutant genes are recessive.

In a diploid organism, the chances of simultaneous mutations in both genes controlling a particular character are very remote because mutation is a random process. If mutation occurs in one of the genes, it leads to heterozygosity because the other allele remains unaffected. Recessive mutations are often not expressed immediately but may be expressed in later generations in only a few individual, which become homozygous for the mutant gene. In haploid organisms, with only one copy of the gene, each gene mutation is often expressed. Undesirable mutations are usually selected against by the environment. The chances of mutations been lost or eliminated from a population are greater with haploids than in diploids.
Mutation is however useful for evolution because the environment keeps on changing.

## 3.9 Types of Mutation

There are various types of mutation. Mutation can either by dominant or recessive, sex link or autosomal, germinal or somatic, lethal or non lethal, useful or deleterious, or neutral. Neutral mutation often goes unnoticed.

Mutations which occur in the germplasm are known as germinal mutations while those that occur in the somatic cells are called somatic mutations. Often, mutations in somatic cells fail to get transmitted to the progeny through gametes with the result that they are lost with the death of the organism. However, in vegetative or asexually- reproducing organisms, somatic mutations are transferred to the progeny and thus perpetuated. Many flowers and fruits of commercial importance today have arisen due to somatic mutations.

## 4.0 CONCLUSION

Our knowledge of test cross and back cross, as well as the various types of genes and their effect on phenotypic variations is necessary to enable the breeder select appropriate breeding techniques.

## 5.0 SUMMARY

Test cross and back cross are the major types of crosses used by breeders to unfold the genetic type of unknown individual. The terms such as multiple alleles, pleiotropism, additive genes, lethal genes, complimentary genes, epistatis and mutation and the basic principles behind these observed phenomena were properly explained in this unit.

## 6.0 TUTOR-MARKED ASSIGNMENT

i. Define the following: Test cross, Back cross, Multiple alleles, Pleiotropism, Lethal genes, Complimentary gene, Additive gene and Epitasis.
ii. What is Mutation?
iii. Name the various types of Mutation.
iv. Why is the study of Mutation necessary?

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# MODULE 4 METHODS OF CROP BREEDING



## UNIT 1 METHODS OF BREEDING SELF-POLLINATED CROPS

**CONTENTS**



## 1.0 INTRODUCTION

Pollination is the transfer of pollen grains from the open anthers to the stigma of a flower. When the pollen grains fall unto the stigma of same flower, the plant is said to be self-pollinated.

## 2.0 OBJECTIVES

At the end of the unit, you should be able to:

- list the different methods used in breeding self-pollinated plants
- explain the different methods used in breeding self- pollinating plants
- state the advantages and disadvantages of the different methods used in breeding self-pollinated crops
- give examples of self-pollinated crops.

## 3.0 MAIN CONTENT

### 3.1 Methods of Breeding Self-Pollinated Crops

Introduction, selection and hybridisation are the major methods of breeding self-pollinated plants.

### (a) Introduction

This involves growing a crop in an environment where it did not originate from. For example, tobacco, potato, maize, etc. were introduced to Asia only a few decades ago from America. Also, crops like cocoa, rubber, tomatoes, maize, rice, etc. were introduced to Nigeria from other countries. For a well-planned introduction programme, the breeder must have a good knowledge and collection of diverse genotypes of a species that can be used as a source material for desirable genes and characters. The germplasm collection should include local as well as exotic strains of the plants and its related species.

### (b) Selection

This involves sorting out from a mixed population a plant or a group of plants with desired characters. Selection can be natural or artificial and it is possible only when there are variations. Two types of selection are often practiced in breeding self-pollinated plants. Namely: mass selection and pure line selection.

### i. Mass Selection

In mass selection, plants are selected on the basis of their phenotypes and their seed are composited without progeny testing. In mass selection, a few or several hundreds of plants with similar phenotype are selected in the first year and their seeds are composited. These seeds are grown – the second year for a preliminary yield test and their performance is compared with the standard varieties. These procedures are repeated in the third, fourth, up to the seventh year. In subsequently years, the seed multiplication and distribution is then done commercially.

This method of selection has two major limitations. Because selection is done on the basis of phenotypic appearance, sometimes homozygous and heterozygous plants are composited together, and the heterozygous ones segregate during subsequent generations. Also, hereditary and environmental variations are not distinguished at the time of selection.

### ii. Pure Line Selection

A pure line is a collection of plants from a single homozygous individual, as a result of self-pollination. In pure line selection, up to a 1000 plants are selected from a genetically mixed population of a particular variety in the first year. In the second year, the progeny of each plant are grown in separate rows and seeds of superior plants within each row are composited to form experimental strains. For the next five years, different strains are grown in replicated plots, superior strains are selected and their yields are compared. In the eight-year the best strain are multiplied for commercial distribution.

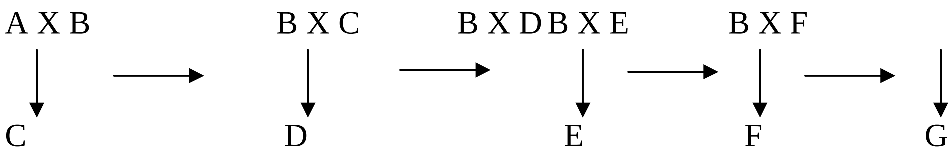
Varieties developed by pure line selection are often more homozygous genetically than varieties developed by mass selection. It should be noted, that once a pure line is established there will be no need of selection again. Results of several studies have revealed that variations observed in plants between pure lines are environmental. New genotypes are not created by this method of selection as selection is limited to the isolation of the best genotype that exists in a population.
Pure line selection thus, narrows the genetic base and may be undesirable because genetic variability is essential for adaptation in a variety of environmental conditions.

**(c) Hybridisation**

Hybridisation is a process of producing an individual from the union of gametes from parents that are not genetically alike. This involves crossing different plants. The desirable characters of two or more species, varieties or lines are combined together or transferred from one to the other. Artificial crossing is necessary for hybridising self-pollinated plants and the process involves the removal of the anther before it dehisces and collection and transfer of pollen from the male parent to the stigma of the emasculated plant.

Cross fertilisation result in heterozygous progeny but in subsequent generations, the percentage of homozygosity increases as result of self-fertilisation. To get a wider range of genetic segregation, a large number (about 10,000) of the F2 progeny (desirable progeny or genotype) are then selected using the pedigree selection or bulk population method. In pedigree selection, plants with desirable genotypes are selected from the segregants in the second and subsequent generation until genetic purity in reached. Whereas in bulk population method, selection is delayed until a later generation, (until the fifth and sixth generation) where there is plenty segregation and variation in population. Majority of this plant at this stage becomes homozygous and breed true.

When a few simply inherited characters are to be transferred from one parent to the other, repeated back-crosses are made with the parent with most of the desired characters. A scheme of such a series of crosses can be illustrated thus:




The parent A is known as the non-recurrent parent whereas B is known as the recurrent parent. The offspring contain most of the genes and character of the recurrent parent. In the recurrent back-cross method, selection is necessary after each cross and the desirable hybrids are back-crossed to the recurrent parent.

Hybridisation brings about a combination of genes from many strains and thus, generates great variations, some of which may turn out to be useful.

## 4.0 SUMMARY

Introduction, selection and hybridisation are the method of breeding self-pollinated plants. In self-pollination, pollen is transferred from the stamens to the pistil within one flower. The resulting seeds and the plants they produce inherit the genetic information of only one parent, and the new plants are genetically identical to the parent. The advantage of self-pollination is the assurance of seed production when no pollinators, such as bees or birds, are present. It also sets the stage for rapid propagation—weeds typically self-pollinate, and they can produce an entire population from a single plant. The primary disadvantage of self-pollination is that it results in genetic uniformity of the population, which makes the population vulnerable to extinction by, for example, a single devastating disease to which all the genetically identical plants are equally susceptible. Another disadvantage is that beneficial genes do not spread as rapidly as in cross-pollination, because one plant with a beneficial gene can transmit it only to its own offspring and not to other plants. Self-pollination evolved later than cross-pollination, and may have developed as a survival mechanism in harsh environments where pollinators were scarce.

## 5.0 CONCLUSION

In order for pollination to be successful, pollen must be transferred between plants of the same species—for example, a rose flower must always receive rose pollen and a pine tree must always receive pine pollen. Plants typically rely on one of two methods of pollination: cross-pollination or self-pollination, but some species are capable of both.

## 6.0 TUTOR-MARKED ASSIGNMENT

i. What are the different methods used in breeding self-pollinated plants?
ii. Give two advantages and limitations of the methods used in breeding self-pollinated plants.
iii. List four crops that are self-pollinated.

## 7.0 REFERENCES/FURTHER READING

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# UNIT 2 METHOD OF BREEDING CROSS-POLLINATED CROPS

**CONTENTS**



## 1.0 INTRODUCTION

During pollination when pollen grains of a flower are conveyed by wind, insects or some other agents to the stigma of another flower, the crop is said to be cross-pollinated.
Cross-pollinated plants exhibit great variations in floral organisation and mode of reproduction.

In this unit the different methods used in breeding cross-pollinated crops will be examined.

## 2.0 OBJECTIVES

At the end of the unit, you should be able to:

- list the different methods used in breeding cross-pollinated plants
- explain the different methods used in cross-pollinated plants
- state the advantages and limitations of the different methods
- give examples of cross-pollinated crops.

## 3.0 MAIN CONTENT

### 3.1 Methods of Breeding Cross-pollinated Crops

Cross-pollinated plants exhibit great variations in floral organisation and mode of reproduction. As a result, diverse methods are employed for their breeding. The methods popularly used are introduction, selection, development of synthetic varieties and hybridisation.

**(a)** **Introduction:** This is the same as with self pollinated plants. It involves introducing a source of desirable genes into the population. Here suitable crosses are made with the new variety.

**(b)** **Selection:** Mass selection is more commonly used in cross-pollinated plants, unlike self-pollinated plants. This is because cross- pollinated plants are highly heterozygous and individual plants are unable to maintain their purity due to segregation and cross- pollination. In mass selection, a large number of individual plants with improved phenotypic characteristics are selected and bulked together, their seeds harvested and grown the following year. However, plants such as castor, sunflower, Colton and jute give better results with progeny selection rather than mass selection because they are often harvested and evaluated as individuals.

If genes for a particular quantitative character are to be concentrated, recurrent selection is used. In the first step, plants with improved yield are selected and their progeny obtained after setting and grown in separate rows. Plants of different rows are then crossed in all possible combinations, hybrid. Seeds are composited and population is established for the first recurrent selection cycle. The entire process is repeated until improvement is shown in the chanter under investigation.

**(c) Development of Synthetic Varieties**

This entails the development of new variety of plants by compounding seeds of individual plants or strains into a synthetic variety. The success of this exercise, however, depends on the combination abilities of the component strains. New varieties of crops such as maize and sugar beets have been developed using this method. It has been observed, however, that synthetic varieties of maize are not as good as hybrids seeds but are superior to open pollinated varieties.

**(d) Hybridisation**

This involves inter varietal or interspecific crosses of crops with desirable genotype or characters. Many are normally heterozygous and this heterozygosity is maintained from one generation to the other through cross – pollination. Cross–pollination often leads to the development of hybrid vigour.

Hybrids plants with improved characteristics are selfed for a few generations to achieve homozygosity for a desirable character. Thereafter, the hybrid population is subjected to progeny selection and desirable lines are selected and multiplied. For example, in the production of hybrid maize seeds, homozygous inbred lines are first established. Then, these inbred lines are crossed in suitable combinations to give better yield. Simple cross hybrids are than crossed together to give better double – cross hybrids. It should be noted, however, that where hybrid vigor is lost, it can be restored by out–crossing.

## 4.0 SUMMARY

Diverse methods are employed for the breeding of cross-pollinated crop. The methods popularly used are introduction, selection, and hybridisation. In order for pollination to be successful, pollen must be transferred between plants of the same species—for example, a rose flower must always receive rose pollen and a pine tree must always receive pine pollen. Plants typically rely on one of two methods of pollination: cross-pollination or self-pollination, but some species are capable of both.

Most plants are designed for cross-pollination, in which pollen is transferred between different plants of the same species. Cross-pollination ensures that beneficial genes are transmitted relatively rapidly to succeeding generations. If a beneficial gene occurs in just one plant, that plant’s pollen or eggs can produce seeds that develop into numerous offspring carrying the beneficial gene. The offspring, through cross-pollination, transmit the gene to even more plants in the next generation. Cross-pollination introduces genetic diversity into the population at a rate that enables the species to cope with a changing environment. New genes ensure that at least some individuals can endure new diseases, climate changes, or new predators, enabling the species as a whole to survive and reproduce.

Plant species that use cross-pollination have special features that enhance this method. For instance, some plants have pollen grains that are lightweight and dry so that they are easily swept up by the wind and carried for long distances to other plants. Other plants have pollen and eggs that mature at different times, preventing the possibility of self-pollination.

In self-pollination, pollen is transferred from the stamens to the pistil within one flower. The resulting seeds and the plants they produce inherit the genetic information of only one parent, and the new plants are genetically identical to the parent. The advantage of self-pollination is the assurance of seed production when no pollinators, such as bees or birds, are present. It also sets the stage for rapid propagation—weeds typically self-pollinate, and they can produce an entire population from a single plant. The primary disadvantage of self-pollination is that it results in genetic uniformity of the population, which makes the population vulnerable to extinction by, for example, a single devastating disease to which all the genetically identical plants are equally susceptible. Another disadvantage is that beneficial genes do not spread as rapidly as in cross-pollination, because one plant with a beneficial gene can transmit it only to its own offspring and not to other plants. Self-pollination evolved later than cross-pollination, and may have developed as a survival mechanism in harsh environments where pollinators were scarce.

## 5.0 CONCLUSION

Most plants have specialised reproductive structures—cones or flowers—where the gametes, or sex cells, are produced. Cones are the reproductive structures of spruce, pine, fir, cycads, and certain other gymnosperms and are of two types: male and female. On conifers such as fir, spruce, and pine trees, the male cones are produced in the spring. The cones form in clusters of 10 to 50 on the tips of the lower branches. Each cone typically measures 1 to 4 cm (0.4 to 1.5 in) and consists of numerous soft, green, spirally attached scales shaped like a bud. Thousands of pollen grains are produced on the lower surface of each scale, and are released to the wind when they mature in late spring. The male cones dry out and shrivel up after their pollen is shed. The female cones typically develop on the upper branches of the same tree that produces the male cones. They form as individual cones or in groups of two or three. A female cone is two to five times longer than the male cone, and starts out with green, spirally attached scales. The scales open the first spring to take in the drifting pollen. After pollination, the scales close for one to two years to protect the developing seed. During this time the scales gradually become brown and stiff, the cones typically associated with conifers. When the seeds are mature, the scales of certain species separate and the mature seeds are dispersed by the wind. In other species, small animals such as gray jays, chipmunks, or squirrels break the scales apart before swallowing some of the enclosed seeds. They cache, or hide, other seeds in a variety of locations, which results in effective seed dispersal-and eventually germination-since the animals do not always return for the stored seeds.

Pollination occurs in cone-bearing plants when the wind blows pollen from the male to the female cone. Some pollen grains are trapped by the pollen drop, a sticky substance produced by the ovule, the egg-containing structure that becomes the seed. As the pollen drop dries, it draws a pollen grain through a tiny hole into the ovule, and the events leading to fertilization begin. The pollen grain germinates and produces a short tube, a pollen tube, which grows through the tissues of the ovule and contacts the egg. A sperm cell moves through the tube to the egg where it unites with it in fertilization. The fertilised egg develops into an embryonic plant, and at the same time, tissues in the ovule undergo complex changes. The inner tissues become food for the embryo, and the outer wall of the ovule hardens into a seedcoat. The ovule thus becomes a seed—a tough structure containing an embryonic plant and its food supply. The seed remains tucked in the closed cone scale until it matures and the cone scales open. Each scale of a cone bears two seeds on its upper surface.

## 6.0 TUTOR-MARKED ASSIGNMENT

i. What methods are used by breeders to breed cross-pollinated crops?
ii. What are the advantages and limitation of the various methods used in breeding cross-pollinated crops?
iii. Give five examples of crops that are cross-pollinated.
iv. Briefly describe the procedure for producing hybrid maize seeds.

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# UNIT 3 METHOD OF BREEDING ASEXUALLY-PROPAGATED CROPS

**CONTENTS**



## 1.0 INTRODUCTION

Asexual propagation entails the production of new individuals from the same plant. It does not involve the participation of two individuals. Asexual propagation results in the formation of clone of identical individuals.

In this unit, we shall examine the different methods of breeding asexually-propagated crops.

## 2.0 OBJECTIVES

At the end of the unit, you should be able to:

- list the different methods used in breeding asexually- propagated crops
- explain the different methods used in breeding asexually-propagated crops
- state the advantages and limitations of the different methods
- give examples of asexually-propagated crops.

## 3.0 MAIN CONTENT

### 3.1 Method of Breeding Asexually-propagated Crops

Asexual propagation results in this formation of clone of identical individuals. Plants that really produce seeds, except under special conditions are usually reproduced asexually or vegetatively. Some crops such as banana, plantain, sugar cane, potatoes and tea are examples of crops that reproduce asexually. Vegetatively propagated crops are usually highly heterozygous.

There are two methods often used in breeding asexually-propagated crops. These are clone selection and hybridisation.

**Clone Selection**

In this method, selected improved varieties of plants from a mixed population are multiplied asexually to give rise to a clone. This selection is made on the basis of phenotypic appearance.
One of the limitations of this method is that new genotypes are not created, as the genotype of a clone does not change unless mutations or chromosomal aberrations occur.

**Hybridisation**

In this method, improved clones of asexually propagation plants are selected and allowed to grow under conditions which favour flowering and seed setting. These plants are then crossed and hybrids of selected plants are multiplied by cloning. Selfing is not desirable at any stage because it leads to a reduction in hybrid vigour. However, where back-cross has to be done in order to reduce or eliminate undesirable genes, different varieties are used as the recurrent parent. Back-cross is the crossing of a progeny to one of the parents.

## 4.0 SUMMARY

Asexual reproduction is the formation of a new individual from cells of the parent, without meiosis, gamete formation, or fertilisation. There are several types of asexual reproduction. Fission is the simplest form and involves the division of a single organism into two complete organisms, each identical to the other and to the parent. Fission is common among unicellular organisms such as bacteria, many protists, some algae such as Spirogyra and Euglena, as well as a few higher organisms such as flatworms and certain species of polychaete worms. A similar form of asexual reproduction is regeneration, in which an entire organism may be generated from a part of its parent. The term regeneration normally refers to regrowth of missing or damaged body parts in higher organisms, but whole body regeneration occurs in hydroids, starfish, and many plants. Spores are another form of asexual reproduction and are common among bacteria, protists, and fungi. Spores are DNA-containing capsules capable of sprouting into new organisms; unlike most seeds, spores are produced without sexual union of gametes, that is, reproductive cells.

## 5.0 CONCLUSION

Plants that rarely produce seeds except under special conditions are usually reproduced asexually. Clone selection and hybridisation are two methods often used in breeding asexually-propagated crops.

## 6.0 TUTOR-MARKED ASSIGNMENT

i. Give five examples of asexually-propagated crops.
ii. What are clones?
iii. What is the major limitation of clone selection method?
iv. What are the major methods used by breeders for multiplying asexually-propagated crops?

## 7.0 REFERENCES/FURTHER READING

George, A. (2007). *Principles of Plant Genetics and Breeding.* United Kingdom: Blackwell.

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# MODULE 5 ANIMAL BREEDING



## UNIT 1 ANIMAL IMPROVEMENT PROGRAMMES AND SELECTION

**CONTENTS**



## 1.0 INTRODUCTION

Animal breeding is a field of the biological science which deals with the application of genetic principles in farm animal production. Essentially, it entails the incorporation of genes for desirable characteristics in animals not already possessing such characteristics, increase in gene frequency of such genes in populations in which they already exist and removal of, or decrease in, the frequency of genes responsible for undesirable characteristics in animals. In this unit, we shall study the aims of Animal Improvement Programmes and the different methods of Selection.

## 2.0 OBJECTIVES

At the end of this unit, you should be able to:

- state the aims of Animal Improvement Programmes
- define the term "Selection"
- explain the various methods of Selection.

## 3.0 MAIN CONTENT

### 3.1 Animal Improvement Programmes

Animal improvement programmes are aimed at producing improved animal with more easily transmissible or highly heritable desirable characteristics and less of undesirable characteristics. More specifically, animal improvement aims at increasing animal productivity by producing animals that yield more in terms of meat, milk, eggs, hair, etc. It also aims at decreasing the quality of some animal products e.g. percentage butterfat content of milk, carotene content of egg yolk, carcass quality, egg shell colour, egg hatch- ability, etc., and at producing animals that are resistant to diseases prevalent in the environment.

Adaptability to prevailing climatic conditions may also be an aim of an improvement programme; alternatively an improvement programme, may be concerned with the production of stronger, hardier work animals, or animals with reduced mortality during growth or animals with better reproductive ability.

Production of animals with good mothering ability is another concern of animal breeding. Animal breeders may sometimes be concerned with increased rate of gain and better efficiency of food conversion in animals. Sometimes emphasis is placed on esthetic rather than productive characteristics, e.g. a breeder may be interested in producing polled cattle, coloured milk, colour tinted eggs, or in producing good looking animals with proper physique for exhibition.

Besides trying to improve desirable characteristics in animals, a breeding programme may also aim at detection and removal of undesirable characteristics or at reduction of such characteristics in animals. Some examples of such characteristics are dwarfism in cattle, crooked legs, and buck teeth in rabbits.

Generally, improvement exercises may be carried out by introduction of animals or the semen of animals with desirable characteristics into one's stock, selection of individual within the stock that posses more of the desirable characteristics and mating of such individual to produce more of the desired animals.

### 3.2 Selection

Selection is the non–random production of offspring from the parent generations or a situation in which some individuals in a population have an advantage over other individuals in transmitting their genes to the next generation. Random production of offspring is a condition in which all the members of a generation are allowed to mate at random to produce the next generation. The gene frequencies of the two generations are equal. In non–random production of offspring or selection, however, the gene frequencies of the next generation are different from those of the first since genes determine the performance of an animal, a change in gene frequency in favour of the gene or genes that conditions desirable characteristic will improve animal performance. This, essentially, is what selection seeks to achieve. In other words, selection is done to increase the number of gene that affect the desired trait and to reduce those genes that are undesirable. The relative frequency of the gene or genes of the desirable trait in question, therefore, increases from generation to generation with selection.

Selection may be natural or artificial. Natural selection results from the action of natural forces and leads to the elimination of unfit individuals in a population in favour of the fittest individual.

Artificial selection on the other hand is a deliberate attempt by man to ensure the continued transmission of a desirable trait(s) or the removal of undesirable one by allowing only animals with the desired trait to produce offspring of the next generation.

There are various types of artificial selection:

**Individual Selection**

This involves selection of animals for breeding purposes on the basis of their individual performances. It is usually used where heritability is high i.e. when the proportion of observed variance that affects the character is predominantly due to the effect of gene. It should be noted, however, that some traits are sex limited e.g. egg production and milk yield. Generally, highly heritable traits that can be measured in both sexes are not easily improved through individual selection. Individual selection may also be employed in eliminating undesirable recessives that are highly heritable.

**Family Selection**

This is selection that is based on the performance of an entire family. In other words, a family is picked, or rejected, on the basis of what the farmers need is with respect to the desired trait. When heritability is low, the phenotypic value of an individual is a poor indication of its genetic value. The mean value of a population is, therefore, a more accurate indication of the genotype of any one member of the family.

Family selection is, therefore, used when heritability is low and environmental effect is high, and when environmental effect common to members of the same family is not high. The larger the family size the more reliable the results.

There are, however, some variations of family selection. These are:

**Sib Selection**

An individual in this case is selected on the basis of its sibs i.e. brother, sister, and half-brother and half-sister. The merits of this method will, however, depend on the number of sibs used in accessing the individual, the heritability of the trait being considered, the average genetic relationship between members of the family and the mean generation interval.

Selection for relevant sex limited trait can be done through this method, e.g. milk yield. Sib selection has been widely used in poultry because of the relatively short generation span in birds.

**Progeny Testing**

Here the progeny (offspring) of the individual are evaluated to estimate the genetic value of the individual. The average value of several samples of a gene from the same parent is believed to give a true value of the parent's genetic makeup.

It is useful where habitability of a character is low, where the character is sex limited or where the trait to be determined can only be measured after slaughter e.g. loin eye in pigs and carcass weight.

It is widely used in determining sire with desirable, but moderately, or weakly, inherited character in beef cattle.

**Within Family Selection**

This is used when heritability is low and when environmental conditions common to members of the family are high. The best member of the family is assumed to be the best genetically.

**Pedigree Selection**

In this method, individuals are selected on the basis of their ancestors. This method is useful when little, or no information, are available on the animals themselves because of their age or sex. Such record must contain sufficient and relevant information to be of any use.

## 3.3 Factors Affecting Effectiveness of Selection

**Adequacy of Selection Criteria**

The extent to which what is measured is related to what is desired affect the effectiveness of selection. For example, if back fat thickness is related to leanness in pig, it may be used as a basis for selection.

**Heritability of the Trait**

Progress is fast if the heritability of the trait under considerable is high and vice – versa.

**Intensity of Selection**

The numbers of animal one can afford to select or discard affect selection effectiveness.

**Number of Traits Selection for at a Time**

Progress is faster when one trait is considered than when two or more traits are worked on at the same time. However, in dealing with one trait, one may unavoidably deal with other traits. For example, egg size and egg weight cannot be divorced.

**Consistency of the Breeder**

The more consistent the breeding programme, the more successful it is likely to be, if the selection criteria and mating system adopted are appropriate.

## 4.0 CONCLUSION

Improvement exercises may be carried out by introduction of animals or the semen of animals with desirable characteristics into ones stock. It involves the selection of individuals within the stock that possess more of the desirable characteristics and mating of such individuals to produce more of the desired animals.

## 5.0 SUMMARY

Animal improvement programme is aimed at producing animals with more easily transmissible or highly heritable desirable characteristics and less of undesirable characteristics.

Selection and mating are the major tools used in animal improvement programmes. Selection can be natural or artificial. Artificial selection can be grouped into individual and family selection. Family selection is further subdivided into: sib selection, progeny testing, within family and pedigree selection.

## 6.0 TUTOR-MARKED ASSIGNMENT

i. What are the major aims of Animal Improvement Programmes?
ii. What is Selection?
iii. Briefly discuss the various methods of Selection.

## 7.0 REFERENCES/FURTHER READING

Banerjee, G.C. (2005). *A Textbook of Animal Husbandry*. 8th Edition. New Delhi: Oxford & Ibh.

Payne, W.J.A. & Wilson, R.T. (1999). *An Introduction to Animal Husbandry in the Tropics*. 5th Edition. Germany: Wiley-VCH.

# UNIT 2 SYSTEMS OF ANIMAL BREEDING

## CONTENTS



## 1.0 INTRODUCTION

After selection, mating or breeding follows. This unit deals with the various systems of breeding employed by animal breeders. Breeding is the selective control of mating in plants and animals to produce organisms that better serve human needs for food, work, sport, or aesthetics. Simple breeding methods have been employed throughout human history. From paintings on the walls of Egyptian tombs, archaeologists have determined that dogs were bred at least 4000 years ago, and perhaps as early as 10,000 years ago. Ancient civilizations also domesticated varieties of cattle, sheep, goats, and grains.

## 2.0 OBJECTIVES

At the end of this unit, you should be able to:

- list the various systems of breeding
- explain in detail the three breeding systems
- discuss the uses of the various breeding systems
- define artificial insemination
- explain the benefits and limitations of artificial insemination.

## 3.0 MAIN CONTENT

### 3.1 System of Breeding

After selection, mating, or breeding follows. There are three main breeding systems. These are Inbreeding, out breeding and crossbreeding.

### 3.2 Inbreeding

Inbreeding is a mating system in which the male and female mated are closely related than the average of the population from which come e.g. mating brother and sister.

Inbreeding makes more pairs of genes in the population homozygous. The more closely related the individuals, the greater the degree of inbreeding. Mating individuals with unrelated ancestry would amount to zero inbreeding.

The degree of inbreeding or the probability that genes received by an offspring are from the same ancestor when two related parents are mated is known as *inbreeding coefficient.* Thus, an inbreeding coefficient of 10% means that the probability of the gene of the resulting offspring is from the same ancestor is 10 %.

Inbreeding has also been observed to lead to the production of individuals that are less vigorous than the original parent, a phenomenon known as *inbreeding depression*. Generally, some traits, are associated with inbreeding, for example, a 10 % increase in inbreeding has been shown to depress egg production by about 6.2 %, milk production by about 3.2 %, litter size of pig about 4.6 %, litter size of mice by 8 %, while a decrease of about 0.8% was observed for body weight (a non reproductive trait) in poultry.

A third consequence of inbreeding is that it uncovers deleterious (undesirable) trait e.g. dwarfism in cattle. Deleterious traits are often recessive. It should be noted that increase in homozygosity is achieved in inbreeding with respect to dominant and recessive traits.

### 3.3 Uses of Inbreeding

- Inbreeding is usually employed in the development of pure lines where such lines are associated with dominant desirable traits.
- It can be used to uncover undesirable gene for elimination. For example, suspected carrier of undesirable trait can be crossed with known heterozygote or with their own offspring. It will bring out all the recessive genes the sire may be carrying and will

give some indications of the desirable genes as well. This will thus, help the farmer to know the actual genetic worth of his animals. Also, it helps him to identify and cull undesirable recessive genes.

- In laboratory animals, highly inbreed lines are useful in many experiments and tests.

## 3.4 Line Breeding

Line breeding is essentially inbreeding. But it involves mating individual not more closely related than half brothers and half sisters. The objective of line breeding is not to increase homozygosity but to maintain a high relationship to an outstanding ancestor. Any homozygosity taking place in such a case is only incidental.

When the herd average is high and introduction of a new sire is expected to lower the merit of the herd, line breeding is very desirable. At least two sires are necessary in the herd to practice line breeding; otherwise, inbreeding will rise to such a level that many recessive genes which are usually deleterious may surface and produce defective individuals.

## 3.5 Out breeding

Out breeding is the mating of members of the same breed that are less related than the average of the population. It has the effect of increasing heterozygosity. It is useful in maintaining certain outstanding characteristics of the breed.

## 3.6 Upgrading

This is a form of out crossing. In upgrading, the pure breed male is mated constantly to the female and the resulting female off springs of the low breed. The idea is to bring about a change of character in the low quality breed. This method is useful in developing new breed that are adapted to the environment.

## 3.7 Crossbreeding

This involves mating individuals from different breeds to obtain a hybrid since desirable gene often show dominance, the first progeny of such crosses often combine the good qualities of both breeds so that these offspring tend to be more vigorous than either of the parent breed. This phenomenon is known as *hybrid vigor* or *heterosis*.

## 3.8 Artificial Insemination

Artificial insemination (AI) is the technique in which semen with living sperms is collected from the male and introduced into the female reproductive tract at the proper time with the help of instruments.

Artificial insemination involves the following steps:- collection of semen from the male, examination of semen quality, semen dilution, insemination or deposition of semen in the respective female reproductive tract.

Some of the benefits derived from artificial insemination include:

- It allows the maximum exploitation of the best sires.
- If properly organised, it reduces breeding costs, as there is a reduction in the total number of sires that have to be maintained.
- As Artificial insemination demands that the farmer should closely monitor his female stock, it also probably improves general standard of management.
- Artificial insemination also minimises the spread of venereal and other diseases.
- Artificial insemination is very useful where it is desired to import exotic livestock for cross breeding and or upgrading purposes, and where it is doubtful whether exotic sires will thrive.

Several factors, however, militate against the use of artificial insemination technique in the tropics. Some of these are:

- In most countries the low level of farm recording has been a major handicap in the testing of artificial insemination bulls.
- Many livestock owners in the tropics rear all their animals to maturity for meat purposes, so that the use of artificial insemination does not reduce their costs of bull maintenance.
- The females of many tropical breeds, in particular, the females of Zebus or humped cattle breed, have short heat period and often difficult to identify, as it usually occurs at night. Under these circumstances, many heat periods may be missed and this seriously reduces the efficiency of the artificial insemination operation. Short and silent heats are also very frequent in the females of exotic dairy breeds managed in the tropics, and in consequence, artificial insemination in many exotic dairy herds has tended to become an uneconomic operation.

## 4.0 CONCLUSION

Modern animal-breeding practices today are still based largely on mass selection, supplemented by three other methods: pedigree selection, family selection, and progeny selection. Pedigree selection focuses on the quality of the ancestors rather than of the individual. Pedigree selection is useful in evaluating young animals whose phenotypes are not fully developed, and in selecting for traits that are known to have high heritability. However, pedigree selection is a slow process. Family selection, based on analyzing the qualities of relatives, is faster. Family selection is often used in conjunction with individual selection, and it is valuable in estimating sex-limited traits (egg-laying ability or milk production, for example) in selecting the males from which to breed. Progeny selection involves selecting individuals based on the records of their progeny. Like family selection, it is useful when selecting for such sex-limited traits as milk yields in the progeny of a bull and traits with low or uncertain heritability. However, progeny selection is a slow process because it requires waiting for one generation or more to determine the quality of a given individual's offspring. In order to achieve meaningful animal improvement, the breeder must adopt appropriate breeding systems.

## 5.0 SUMMARY

There are three main breeding systems. These are inbreeding, out breeding and cross breeding. Each of the breeding systems has its limitations. Artificial insemination is the technique in which semen with living sperms is collected from the male and introduced into the female reproductive tract at the proper time with the help of instruments. In carrying out artificial insemination, the proper procedure should be followed. Artificial insemination, however, has its limitations.

## 6.0 TUTOR-MARKED ASSIGNMENT

i. What is the difference between inbreeding and out breeding?
ii. What are the uses of inbreeding?
iii. What is heterosis?
iv. What is the major advantage of cross breeding?
v. What are the steps involved in artificial insemination?
vii. List four factors that militate against the effective use of artificial insemination in Nigeria.

## 7.0 REFERENCES/FURTHER READING

Banerjee, G.C. (2005). *A Textbook of Animal Husbandry*. 8th Edition. New Delhi: Oxford & Ibh.

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