

PLANT ANATOMY AND HISTOLOGY

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B.Sc. (Ed.) Biology, M.Sc. & Ph.D (Botany).

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DEDICATION

This book is dedicated to God the Almighty, for the strength and wisdom bestowed on me and to my beloved wife, Mrs. Itoro Samuel Osu and children: Enobong, Idara, Imoh and Inimfon.

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I give sincere thanks to the most High God for the wisdom bestowed upon me during the production and successful completion of this book. I am grateful to Tertiary Education Trust Fund (tetfund) for sponsoring the production of this book. I express my appreciation to Dr. Patrick J. Uko and Dr. Charles O. Effiong of the College of Education, Afaha Nsit, for granting me the opportunity to author this book. I sincerely acknowledge the contributions of Prof. G. J. Ebukanson, Prof. Bassey P. Akpan and Dr. (Mrs.) M. E. Bassey for editing the manuscripts for the first edition of this text and all who kindly provided me with original illustrations and those who gave me permissions to redraw figures from their publications.

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The completion of this book would not have been possible, without the contributions which I received from Pastor (Engr.) Udoh J. Ekaette of Mountain of Fire and Miracles Ministries, Uyo - Akwa Ibom State, and the Dean, School of Science - Elder Enobong S. Akpan. I also acknowledge with deep appreciation the suggestions of Dr. Nse S. Umoh, Mr. David Sambo, Dr. Solomon S. Monday, (Engr.) Mkpheyene A. Ayang and Mr. Mfiokma Nelson. Most importantly, I wish to specially thank my spiritual father, a seasoned man of God, a great teacher and a mentor, Rev. Emmanuel Bruno of the Assemblies of God Church, Abak- Akwa Ibom State, for his motivations, spiritual guidance and prayers during the course of writing this book.

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FOREWORD

I feel honoured to write the foreword to this book, Plant Anatomy and Histology authored by an academically active Lecturer and hard working staff in the Department of Biology, College of Education, Afaha Nsit.

This book could not have come at a better time than now considering the generally observed poor performances of students in the area of sciences, including Biology at almost all levels of education in our country, probably due to scarcity of relevant and adequate text books in these areas.

Plant Anatomy and Histology at a casual look may appear unchallenging, but as an area of study it is demanding, fairly technical and abstractive, and therefore require painstaking, detailed and down-to-earth exposition of the concepts and sub concepts there in, and the author has done justice to these.

The text has been written in quite simplified language laced with clear illustrations making it easily readable and understandable. It is indeed a significant attempt to increase the body of knowledge in the discipline of Plant Anatomy and Histology. The book will surely serve as a good resource material for students of Polytechnics, Colleges of Education and other Tertiary Institutions undertaking courses in Cell Biology, Plant Physiology, Plant Anatomy and Plant Histology. I therefore recommend this text to all students, Lecturers/Teachers of Biology.

Rev. Albert U. Archibong (Ph.D, FCAI)

Former Dean, School of Science,
College of Education, Afaha Nsit,
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PREFACE

The purpose of writing this book titled Plant Anatomy and Histology is to introduce beginners in the area of Cell Biology, Plant Physiology, Plant Anatomy, and Plant Histology in Polytechnics, Colleges of Education and Universities and all interested readers to the basic concepts and understanding in the field of Plant Anatomy and Histology.

I have taught this course at both HND and NCE levels for several years. This is where I got the motivation to put my lecture notes together which finally resulted in the present text. It is sequentially and clearly written in simple and straight forward English. This book is an attempt to satisfy the desire of students of Plant Anatomy and Histology at higher levels of education in Nigeria.

This text will go a long way in assisting Lecturers teaching Plant Anatomy and Histology at B.Sc., HND and NCE levels in schools in Nigeria, as it covers basic course requirements of the National University Commission (NUC), National Board for Technical Education (NBTE) and National Commission for Colleges of Education (NCCE) in Nigeria. More so, the availability of this text would bring relief to my students and others, since foreign texts are very costly and are not readily available.

Among other main attractions of this book is the inclusion of the standard ways of performing practicals and reporting of experimental results. Diagrams are carefully and correctly drawn and labelled. The meaning of terms used in this book is explained in the glossary. To aid effective revision, chapter summary and study questions as well as tutorials are provided at the end of each chapter.

The author shall be satisfied if students gain knowledge from this book in order to further expand their understanding of the fundamental concept of the topics included in this book.



Dr. Samuel Robert Osu

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CHAPTER ONE

1.0 PLANT ANATOMY AND HISTOLOGY IN HIGHER PLANTS

CHAPTER OBJECTIVES

By the end of this chapter, students should be able to:

- (i) explain the meaning of plant anatomy;
- (ii) identify the important of studying plant anatomy;
- (iii) define the terms: tissue, cytology and histology;
- (iv) state the relevance of plant histology in higher plants;
- (v) explain how cells are organised in seed bearing plants;
- (vi) highlight the relationship of cells in higher plants;
- (vii) state the importance of plants to man.

1.1 Plant Anatomy

Plant anatomy is the study of the structure of living plants, especially of their internal parts by means of dissection and microscopical examination. Anatomy is the study of the gross internal structures of a plant organ. Plant anatomy deals with the structure and development of tissues and cells, and their contents. It is of primary importance to all branches of research in plant science.

Plant anatomy is a foundational topic to students of Botany. Without a thorough knowledge of this field the physiological processes carried out within the plant and the phylogenetic relationships between the various plant groups cannot be fully understood. A detailed study of the elements and tissues of which the plant is constructed enhances a better understanding of adaptation to special functions as well as the adaptation of entire plants to different environmental conditions.

1.2 Plant Anatomy, Cytology and Histology

Plant anatomy is a science in its own merit. Anatomy, which draws attention to the form, variability and structure of the tissues comprising the plant body, can be said to develop an aesthetic sense in the learner. In addition to this, the awareness of the regularity and repetition at different levels of the structural patterns as well as the amazing correlation of structure and function, serves to make anatomy an important field of study.

Cytology is the study of the cell and its contents. A specialised branch of histology is known as cytology. The cell is the basic unit from which the tissue of the higher plants is built. All cells are formed from existing cells and are discrete units found within their cell wall. Cells are building blocks with which the bodies of plants are composed. Cytology deals with the study of the structure and function of cells. The development of the light and electron microscopes has enabled the detail structure of the nucleus (including the chromosomes) and other organelles to be elucidated. Microscopic examination of cells, either life or as stained sections on a slide, is also used in the detection and diagnosis of various plant diseases.

All cells are self-contained and more or less self-sufficient units. They are surrounded by a cell membrane and have a nucleus, or a nuclear area, at some stages of their existence. They show remarkable diversity, both in structure and function. They are basically spherical in shape, although they show some variation where they are modified to suit their function. In size, they normally range from 10-30 μ m. (1 micrometer = 1.0×10^{-6} m). Plant cells have all the components of animal cells but have in addition other features such as chloroplasts, a central vacuole, and a cell wall. Chloroplasts convert light energy - typically from the sun into sugar (a form of chemical energy) in a process called photosynthesis. Chloroplasts, like mitochondria, possess a circular chromosome and ribosomes, which manufacture the proteins that the chloroplasts typically need.

The central vacuole of a mature plant cell typically takes up most of the room in the cell. The vacuole, a membranous bag, crowds the cytoplasm and organelles to the edges of the cell. The central vacuole stores water, sugars, salts, proteins and other nutrients. In addition, it stores the red, purple and blue pigments that gives certain flowers their colours. The central vacuole also contains plant waste that tastes bitter to certain insects, thereby discouraging the insects from feeding on the plant.

In plant cells, a cell wall surrounds and protects the plasma membrane. Its

pores enable materials to pass freely into and out of the cell. The strength of the wall also enables a cell to absorb water into the central vacuole and swell without bursting. The resulting pressure in the cells provides plants with rigidity and support for stem, leaves and flowers. Without sufficient water and with osmotic pressure, the cells may collapse and the plant dies.

The study of plant tissues and the cells which are composed of them is termed plant histology. All multicellular plants possess groups of cells of similar structure and function assembled together to form tissues. A tissue is a group of physically linked cells and associated intercellular substances that is specialised for a particular function or functions. The cells of a tissue generally share similar origin in the embryo. Tissues improve the efficiency with which the plant body functions by allowing division of labour, that is the sharing of tasks, with each tissue being specialised for a particular job.

1.3 Organisation of Cells in Seed Bearing Plants

The cells of seed bearing plants are organised into different tissues and organs. Three of the principal organs of seed bearing plants are leaves, stems and roots. These organs are linked together by cells, tissues and organs which form systems that run the length of the plant, performing functions such as transport, protection and coordinating the plant activities.

Seed plants show a wide variety of cell types. All cells are not identical, they vary in shape, size, ecological requirements and function but in most cases the structural features of cells are related to the functions of such cells. The fascinating array of the diversity of cells in the plant body presents an interesting case study.

In the plant body, a great diversity exists in size among the cells found in them. Also, there are differences in size, shape and internal contents between parenchyma, collenchyma and sclerenchyma cells even when all of them are found in the same plants. Moreover, the palisade cells of the leaf differ from the spongy cells even though both of them constitute the mesophyll layer. The guard cells, root hair cells and other epidermal cells differ from one another in several features. Structures like chromosomes, mitochondria, endoplasmic reticulum and ribosomes are common to virtually all cells, but the shape, form and contents of individual cells show much variation. The structural characteristics of a particular cell are closely correlated with its functions. The diversity is seen between different species, and within a single species.

In plants, photosynthetic cells of various shapes and forms, packed with chloroplasts, perform the task of building up complex molecules. Parenchyma

cells, packed tightly together, fill up spaces between tissues. Epidermal cells, whose outer walls possess a waxy cuticle, protect the plant from excessive water-loss. Guard cells control the opening and closing of air pores (stomata). Root hairs absorb water and mineral salts from the soil. Collenchyma cells and sieve tubes are both elongated cells, the former is concerned with strengthening the plant, particularly the young stem, while the latter conduct soluble food materials from one part of the plant to another. One of the most striking specialisations is seen in lignified vessels, tracheids and fibre. These play an important part in strengthening the stems of higher plants and, in the case of vessels and tracheids, conducting water and mineral salts from the roots to the leaves. These cells are enormously elongated, their cellulose walls being impregnated with the complex polysaccharide lignin. The result is a non-living tube through which water can be conducted. In this case, specialisation involves the total loss of protoplasm from the cell. Therefore, the study of plant anatomy leads to a better understanding of developmental processes and the relation between structure and function.

1.4 Relevance of Plant Histology in Higher Plants

The microscopic study of the tissues of living plant is known as Histology. However, one important point which must be made clear is that the study of plant histology is more concerned with the study of tissues including its structures and functions. Consequently, many types of cells which form tissues are really dead structures, containing no protoplasm, although they still serve important functions. For this reason the amount of material which is actually living and growing in a higher plant is a varying and uncertain quantity, depending on the proportion of living to non-living cells. This proportion is greatest in early life and it diminishes progressively with age. In the embryotic stage all the body cells are living and actively growing, but in the course of development, the growth activity becomes very soon localised, particularly at the tips of shoots and roots, where the tissues attain the embryotic character throughout the whole life of the individual plant. However, reference can be made to animals, in which growth is generally in all organs until a specifically limited size is attained, after which it ceases. In higher plants, on the contrary, growth is localised from an early stage, but is maintained at these points more or less continuously. The growth size reached by a higher plant in this situation can simply be as a factor of age.

1.5 Cells and its Relationship in Higher Plants

Cells are the building blocks with which the bodies of higher plants are composed. Cells of higher plants are usually bounded by a membrane or cell wall and within each such boundary, constant biochemical activities occur. For higher plants to function properly organisation and division of labour must take place among the cells. As a result, cells are modified so that they can fulfil specific functions within the plants more easily. This modification process takes place, during growth after cell division and is termed differentiation.

After differentiation, cells of a similar type are usually found together forming a tissue. In young growing plants, tissues are essentially meristematic (actively dividing). Cells of these plants are usually differentiated to meet their structural and functional requirements in order to be successful in their terrestrial environment. Based on these structural and functional requirements of plants, cells can be differentiated into several tissues as in the stems of herbaceous plants.

Higher plants are multicellular eukaryotes; that is, their cells contain membrane bound structures called organelles. Plants differ from other eukaryotes because their cells are enclosed by more or less rigid cell walls composed primarily of cellulose. The cell may be defined as the basic or fundamental or most elementary unit of structure and function in all living organisms. It is the most rudimentary unit of life though very complex in activity.

Higher plants are by far the most important group of plants in the world, comprising the overwhelming majority of plant species. They are the basis for nearly all our food. Plants play a vital role in the existence and survival of most of the organisms in nature. They fulfil our requirements of food, fiber and shelter, beside supplying oxygen for breathing and absorbing CO₂ from the atmosphere. It is difficult to imagine the existence of human beings without the existence of plants.

1.6 Summary

Plant anatomy is the study of the physical structure of living plants especially their internal parts by means of dissection and microscopical examination. It also deals with the structure and development of tissues, cells and their contents. Knowledge of plant anatomy is essential in that it gives an insight to the adaptation abilities of plants to different environmental conditions. Living plants are made up of cells which are self contained and more or less self-sufficient unit. The study of the structure of these building blocks (cells) and their way of operations is known as cytology. Cells are spherical in shape and may range in size from 10-30µm. Physical linked cells is called a tissue and tissues coming together to perform specialised functions is called organ. The use of

microscope to study tissues and organs of plants like leaves, stems and roots which are linked together by systems and sub-systems to perform functions such as transport, protection etc. is known as Histology. There are different types of cells in plants, varying in shape, size, functions and ecological requirements but their structural features are related to the functions of such cells. The ability to photosynthesise is the most important characteristics of plants. During photosynthesis, plants make their own food by converting light energy into chemical energy. Higher plants are the most important groups of plants on earth. They provide food, fibre, shelter and supply oxygen for man and animals. Without plants, life on earth would have been impossible.

1.7 Evaluation

Having read this chapter, answer the following questions:

1. Explain the term plant anatomy.
2. State the importance of studying plant anatomy and histology.
3. Give brief explanation of the following terms: tissue, cytology and histology.
4. State the relevance of plant histology in higher plants.
5. Explain how cells are organised in seed bearing plants.
6. State the importance of plants to man.

1.8

TUTORIAL QUESTIONS

Fill in the gap in the sentences provided below:

1. _____ is the study of the gross internal structure of a plant organ.
2. The microscopic study of the tissue of living plant is known as _____.
3. The cells of a tissue generally share a _____ origin in the embryo.
4. The _____ of seed bearing plants are organised into different tissue and organs.
5. Parenchyma cells packed tightly together, fill up spaces between _____.
6. Epidermal cells whose outer walls possess a _____ protect the plant from excessive water loss.
7. _____ controls the opening and closing of air pores.
8. _____ absorbs water and mineral salts from the soil.
9. The most important characteristics of plants is their ability to _____
10. During photosynthesis, plants make their own food by converting light energy into _____ energy.
11. Higher plants are by far the most _____ group of plants in the world.
12. Plants play a vital role in the existence and survival of most of the _____ in nature.
13. The science which deals with the knowledge about plants is called _____.

14. As the cell matures, the vacuoles enlarge and condense into a single _____ vacuoles.
15. The cell sap is composed of a very _____ solution of many water soluble substances.
16. Large molecules such as nucleic acid can pass through membrane whereas some very small _____ cannot.
17. The _____ endoplasmic reticulum has ribosomes on its outer surface, the smooth endoplasmic reticulum does not .
18. The inner membrane of the mitochondria is extensively folded providing a large area at which _____ takes place.
19. Vacuoles are part of the protoplast but are non _____.
20. The study of plant tissues and cells which are composed of them is term _____.
21. In the embryotic stage all the body cells are living and actively _____
22. Cells are the _____ blocks with which the bodies of higher plants are composed.
23. Based on functional requirements of plants, cell can be _____ into several tissues as in the stems of herbaceous plants.



CHAPTER TWO

2.0 DIVERSITY OF CELLS: STRUCTURE AND SPECIALIZATION

CHAPTER OBJECTIVES

By the end of this chapter, students should be able to:

- (i) list the various types of cells;
- (ii) sketch the organisation of a generalised plant cell;
- (iii) explain the importance of mitochondrion in plant cells;
- (iv) draw and label a generalised plant cell as seen under electron microscope;
- (v) explain the functions of each part of a plant cell;
- (vi) describe the three types of plastid found in plants;
- (vii) recognise plant cell walls as shown with electron microscope;
- (viii) distinguish between simple pit and bordered pit.

2.1 General Information

One of the most important concepts in this chapter is that the basic unit of structure and function in living organisms is the cell. Cells were first seen in 1665 when the British scientist, Robert Hooke examines thin slices of cork under improved compound microscope. His discovery is one example of the way in which an advance in technology, in this case led to more scientific discoveries. Modern microscopes reveal the structure of cells in great detail. Cells are the smallest units that still retain the characteristics of life, including complex organisation, metabolic activity and reproductive behaviour.

Cells differ from each other in size, shape and organisation depending on

their environments and functions. Cells may be spherical, oval, polygonal, rectangular or considerably elongated. When young, they are often spherical or of like nature usually invisible to the naked eyes, but during differentiation, they develop in different ways to perform different tasks. This process is called cell specialisation. For example guard cells control the opening and closing of stomata on the undersides of leaves while epidermal cells at the same location protect the leaves externally.

All cells have a plasma membrane, and it surrounds an inner region of cytoplasm. The plasma membrane keeps events within the cell separate from the surrounding environment, so that the event proceeds in organised or controlled ways. Cells from the body of plants have a nucleus and other organelles (membrane-bound compartments) within the cytoplasm. Organelles are persistent structures of various shapes and sizes with specialised functions in the cell; most, but not all, are bounded by membranes. The membranes of these organelles separate different chemical reactions in the space of the cytoplasm and so allow the reactions to proceed in orderly fashion. The organelles are the sites of many different activities that take place within the cell, with the most conspicuous organelle, the nucleus, controlling those activities.

2.2 Diversity and Shapes of specialised cells

All cells are not identical; cells vary in shape, size, ecological requirements and function but in most cases the structural features of cells are related to the functions of such cells. The fascinating array of the diversity of cells in the plant kingdom presents an interesting case study. Most of these cells play specialised roles in plants. Other specialised cells mentioned here still show differences in shapes and forms. All these cells are fundamentally similar in possessing nucleus and cytoplasm together with many of the organelles present in plant cells. These cells are:

- (i) sclerenchyma cell;
- (ii) nectar secreting cell;
- (iii) a pair of guard cells forming a stoma;
- (iv) spongy parenchyma cell of the mesophyll;

- (v) pollen grain cell;
- (vi) root hair cell;
- (vii) epidermal cell;
- (viii) palisade parenchyma cell of the mesophyl;
- (ix) vessel element cell of xylem;
- (x) phleom cell;
- (xi) leaf hair cell;
- (xii) stone cell (covering the seed in stone fruit).

The cell types mentioned above are representatives of plant organ system. Each has structural or physiological features that set it apart from the other types of cells. This differentiation into different cell types indicate that they fulfill specific roles in the plant to ensure its survival and reproduction.

2.3 Organisation of a Generalised Plant Cell

The plant cell is a box like structure with one compartment that is filled (in case of the young cell) or lined (in older tissue) with living material. In some specialized or older cells this living material is absent. The nucleus stains densely and is easily visible with a light microscope. It is surrounded by the cytoplasm, which, in turn, is contained in the cell wall. In addition to the nucleus, the cytoplasm contains organelles (plastids, mitochondria, and vacuoles), together with starch grains, oil droplets and crystalline substances. This organisation is shown in Figure 2.1.

The term “protoplast” is used to describe everything inside the cell (i.e. the protoplasm and all its inclusions). The protoplasm is the living substance of the cell and is divided into nucleus and the cytoplasm. The cytoplasm is 85 to 90% water. The remaining substances are either in solution or in a colloidal state.

A protoplast is contained in a membrane (the plasma membrane or plasmalemma) which lies against the cell wall. Within the cytoplasm the organelles are also bounded by membranes, but the organic and inorganic inclusions are non-membrane bounded structures. The membranes are very important structures that have received much attention from researchers. They consist of lipid layers which sometime include proteins or other organic substances. The electron microscope can be use to reveal the membrane structure.

The membranes in the cell are important for three reasons. Firstly, they represent an interface. The reactions that take place there are determined to a substantial extent by the nature of the two membrane surfaces (the “outer” and “inner” sides of the plasma membrane). Secondly, and more important, membranes are not only semi-permeable but are differentially permeable. For example, substances that pass freely into a cell may not be able to pass out again. Thirdly, the extent to which a membrane is permeable is neither the same for all membranes, nor is it the same for a single type of membrane under all conditions.

The membranes also show enzymatic activity. Many important reactions that take place in the cell are also controlled in the membrane. There is much membrane activity that has not been fully explained. For example, large molecules such as nucleic acids can pass through membrane, some very small ions cannot. This suggests to some researchers that the large molecules passed through the membrane by a “carrier” system that expends energy. Other workers believe that there is an electrical potential across the membrane which accounts for the movement of ions.

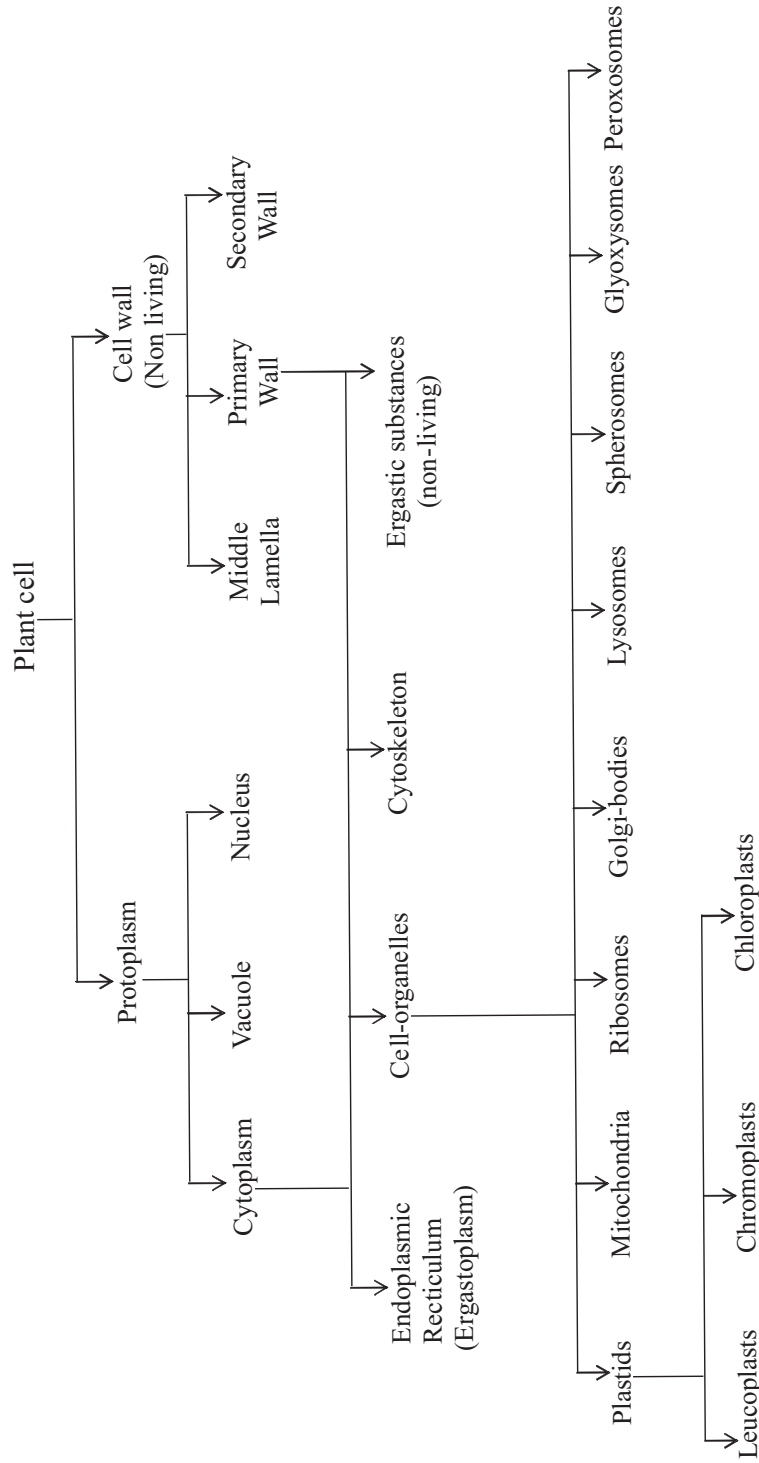


Figure 2.1: Organisation of a generalised plant cell.

Source: (Jain, 2007).

2.4 Description of the Cell Organelles

The organelles (a word meaning “small organs”) are membrane-bound structures in the cytoplasm. The plant cell as observed by the light and electron microscope is shown in Figure 2.2(a) and (b).

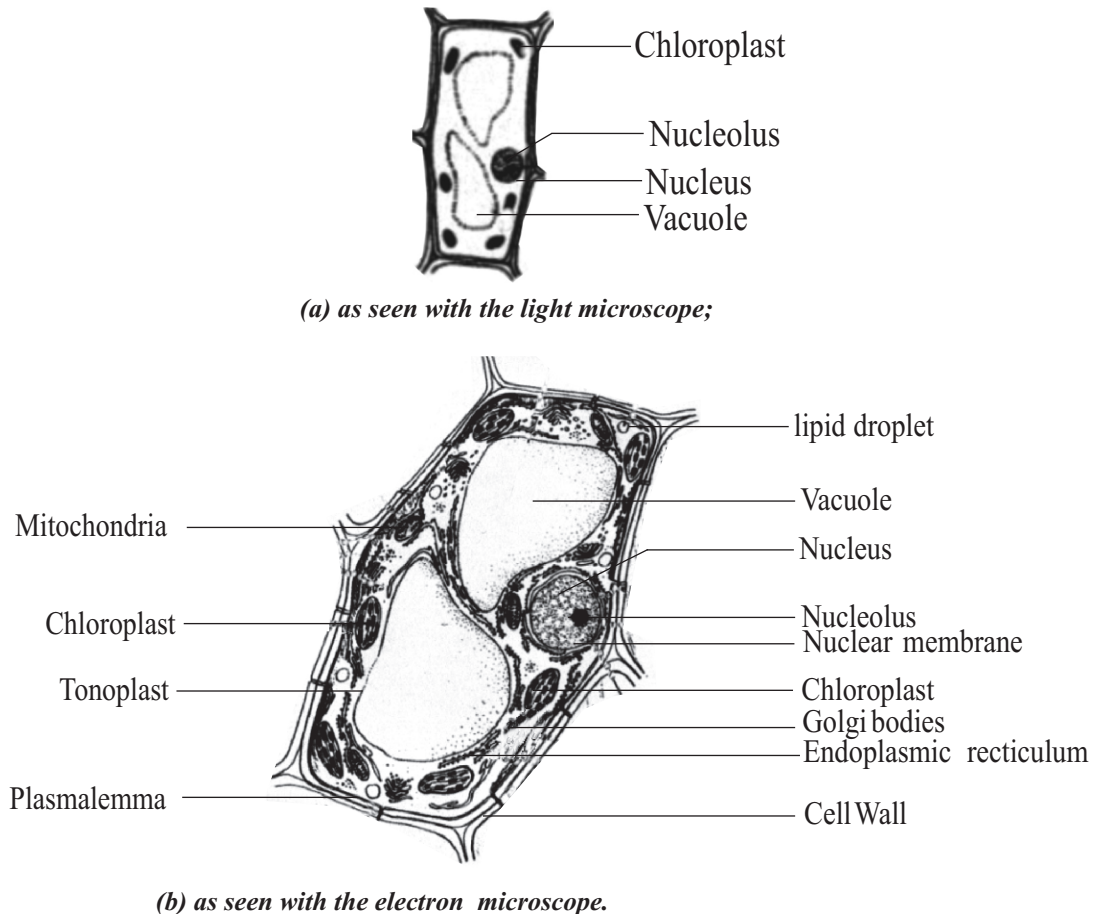


Figure 2.2: *Plant cell as seen with light and electron microscopes.*

Source: (Walter, 1988).

2.4.1 Endoplasmic Reticulum

The endoplasmic reticulum (ER) is an extensive closed system consisting of two adjacent and parallel membranes which form flattened and elongated structures that may exist extensively in the cytoplasm. It is the endoplasmic reticulum which forms the cytoplasmic connections (called the plasmodesmata)

that facilitate communication between cells. The endoplasmic reticulum is believed to be an organ for transporting the fluids found in the inner space between its two membranes from one part of the cytoplasm to another. It is also concerned with the synthesis or condensation of various substances. For example, proteins appear to be synthesized by the ribosomes that line the surface of the endoplasmic reticulum. When ribosomes are found on the surface of the ER it is called rough ER. Whereas smooth ER has no ribosomes on the surface. The whole endoplasmic reticulum can develop to an extent with increasing physiological activity and vanish again as the plant becomes less active.

2.4.2 Plastids

The plastids are disk-shaped organelles from 2 to 25 μm in diameter which have double membranes as shown in Figure 2.3. They are of three types - viz.,

- (i) chloroplasts: contain mainly chlorophyll (green) pigments and some carotenoid pigments and are concerned with photosynthesis;
- (ii) chromoplasts: contain predominantly carotenoid pigments (brown, red, or yellow) with little or no chlorophyll;
- (iii) leucoplasts: contain no pigments. The leucoplasts are associated with storage and are named according to the substances they contain (i.e. the amyloplasts store starch and elioplasts store oil).

The three groups of plastids have essentially the same organelle and may convert from one type to another and then reverse to the original type. The plastids are self-duplicating and arise only from pre-existing plastid types. The chloroplasts are the most important because these are the sites at which photosynthesis takes place. Chlorophyll is contained in grana, which are “coinlike” structures that the electron microscope shows to be stacked on top of each other in the chloroplasts.

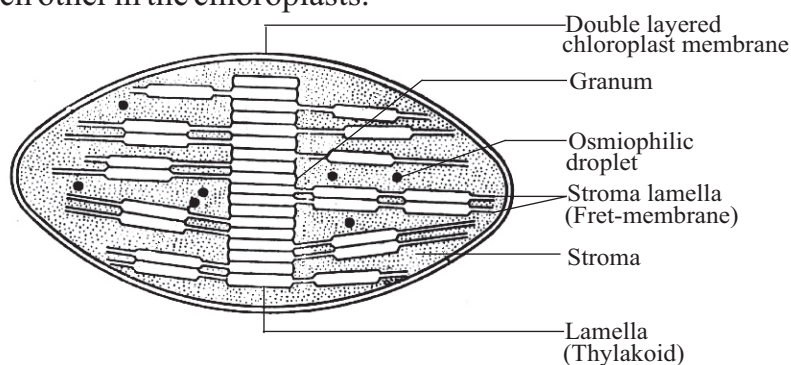


Figure 2.3: Structure of a chloroplast.

Source: (Jain, 2007).

2.4.3 Mitochondria

The mitochondrion (Figure 2.4) is a very complex organelle which provide energy for cell functions. It controls the respiration and the production of energy in the form of adenosine triphosphate (ATP). The mitochondrion is a small rod 0.5 to 2 μm in diameter and 2 to 10 μm long, which have two membranes and contains the major cations K^+ and Mg^{2+} and the anions ATP^+ , ADP^- , and P_i^{2-} .

The inner membrane of the mitochondrion is extensively in folded form, providing a large surface area at which chemical reactions take place. The inner and outer membranes have different chemical structures. The inner membrane is usually much less permeable than the outer membrane, and they always differ physically, chemically and enzymatically. In some species, the outer membrane has 55% protein and 45% lipids, while the inner membrane has 75% protein and 25% lipids.

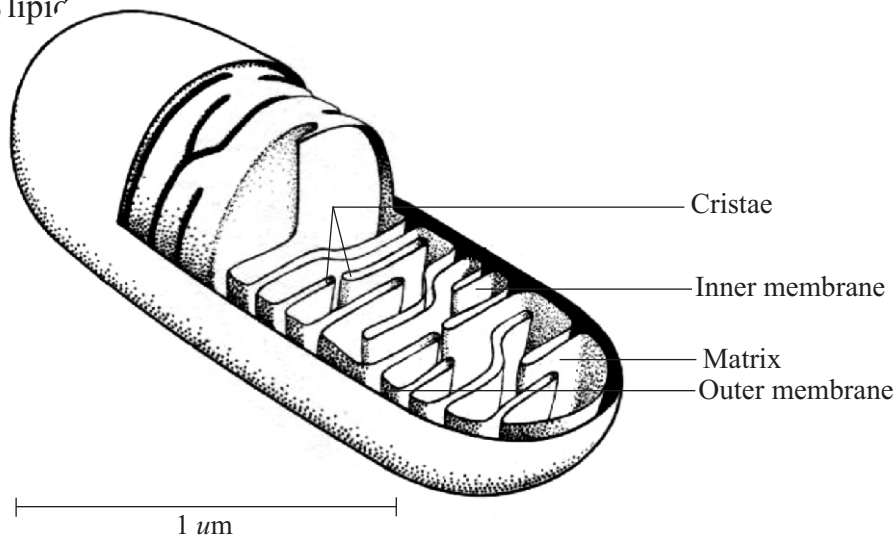


Figure 2.4: *Structure of a Mitochondrion.*
Source: (Ewer and Hall, 1972).

2.4.4 Vacuoles

Vacuoles are within the protoplasm but are non-protoplasmic (Figure 2.5). They are isolated in the cytoplasm by a single membrane (the tonoplast) and contain an aqueous substance called cell sap. The tonoplast is differentially permeable. The small anions and cations may move through this membrane quite passively, but for large molecules, movement from the cytoplasm into vacuoles is at the expense of cellular energy. In young cells the vacuoles are many and small.

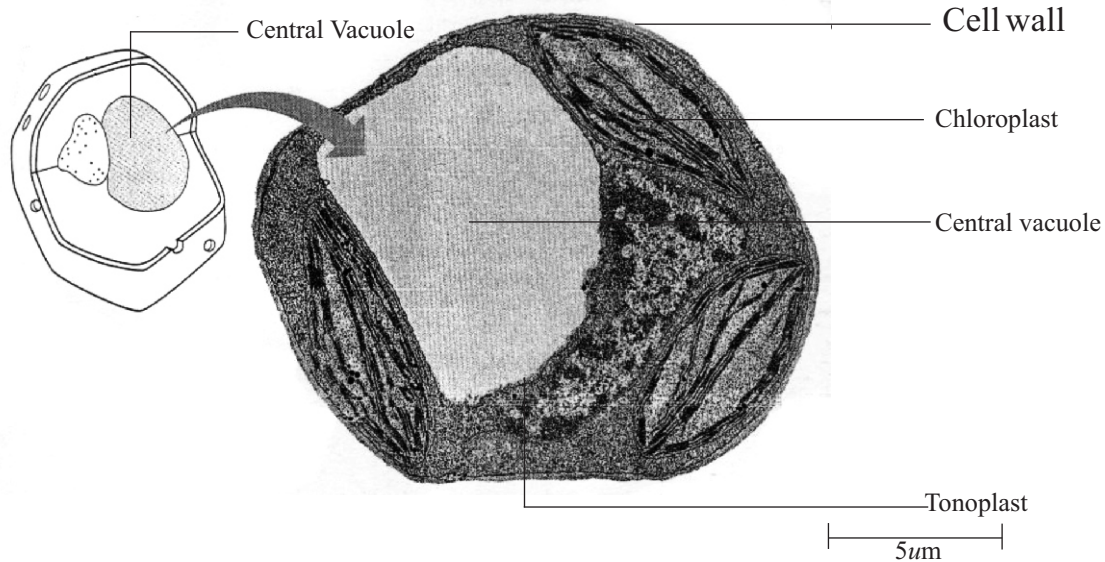


Figure 2.5: Plant cell showing a vacuole.
Source: (Campbell, 1993).

Note:

The central vacuole is usually the largest compartment in a plant cell, comprising 80% or more of a mature cell. The cytoplasm is generally confined to a narrow zone between the vacuole and the plasma membrane. The membrane bounding the vacuole, the tonoplast, separates the cytosol from the solution inside the vacuole, which is called cell sap. Like all cellular membranes, the tonoplast is selective in transporting solutes; therefore, cell sap differs in composition from the cytosol. The vacuole functions in storage, waste disposal, hydrolysis, protection, and growth.

2.4.5 Cell Sap

The cell sap is a very dilute solution of many water soluble substances, which include inorganic salts, sugars, organic acid, proteins alkaloids, and pigments. Not all the substances in the vacuoles are water soluble; calcium oxalate, for example, is present in a crystalline form. These crystals are sometimes, but not always, needlelike.

The flavonoids are water-soluble pigments which are also found in the cell sap. They are responsible for the colouring of many flowers, as are the anthocyanins. It is the pH of the cell sap that influences anthocyanin colour. Tissues that contain anthocyanin will be red when the cell sap is acidic, blue when it is alkaline, and purple at pH of 7.0.

2.4.6 Ribosomes

The ribosomes are $20\mu\text{m}$ long and carry many electrons. As in the case of endoplasmic reticulum, the ribosomes are associated with some parts of that structure. The *rough* endoplasmic reticulum (RER) has ribosomes on its outer surface; the *smooth* endoplasmic reticulum (SER) does not. The ribosomes occur in many other parts of the cell (i.e., the cytoplasm, the plastids, and the mitochondria). They are sometimes found in clusters called polyribosomes or simply polysomes. These structures synthesize proteins, sequencing amino acids and forming peptide linkage to produce polypeptide chains.

Microtubules and microfilaments also have no membranes. They are 24 to $28\mu\text{m}$ in diameter and have a variety of functions. Microtubules control spindle position and orientation and form the spindle fibres at cell division. They may also control cell shape and the orientation of the cellulose when the cell walls are laid down. Microfilaments are responsible for cytoplasmic movements and nuclear migration. They are very small (5 to $8\mu\text{m}$ in diameter). Both structures have distinctive proteins: tubulin for microtubules and actin for the microfilaments.

2.4.7 The Nucleus

The nucleus may be 5 to $30\mu\text{m}$ in diameter and is spherical or lens-shaped. The nucleus has a double membrane and there appears to be a connection between this membrane and the endoplasmic reticulum. Chemically, the two membranes are distinct. Within the nucleus lies a network of randomly coiled threads, the *chromatin*. These structures, which stain easily, may be the form the chromosomes takes during cell divisions. The nucleus also contains one or more nucleoli, which have a high RNA content. The remainder of the *nuclear envelop* is filled with a fluid like structure called the *karyolymph*. The most important and spectacular function of the nucleus is at the time of cell division.

2.4.8 The Cell Wall

The cell wall is made up of two distinct layers; the primary and secondary walls. The primary wall which is the first layer to be laid down during cell wall synthesis consists of a frame-work of microfibrils made up of the polysaccharide cellulose embedded in a matrix of several other polysaccharides and glycoproteins.

Between two adjacent primary walls is the middle lamella which consists mainly of another polysaccharide pectin, and which act as an intercellular cement binding cells together. The primary wall is elastic and capable of great extension.

This allows for enlargement of the cell although some thickening of wall can occur during elongation. In general, this happens after the cell has reached its maximum size. After this time a second layer which is the secondary wall may be laid down between the primary wall and the plasma membrane as illustrated in Figure 2.6.

The secondary wall may be thick or thin and of varying degrees of hardness or colour. The secondary wall is the part of the cell that gives various woods and plant fibres (e.g. cotton, flax, hemp) their particular characters. Cellulose used in the manufacture of rayon, nitrocellulose, cellophane and certain plastics is also derived from it.

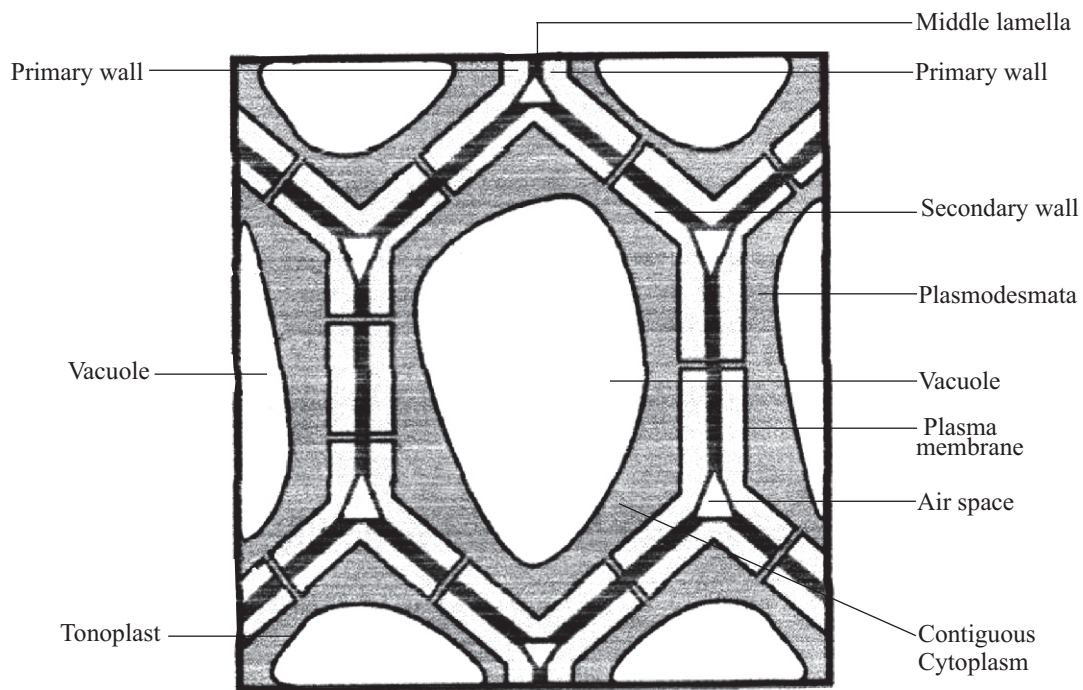


Figure 2.6: *Cell walls as shown with electron microscope.*

Source: (Uduebo, 1984)

Note: The secondary wall may be several layers thick and the layers may differ markedly in composition.

The diagram in Figure 2.6 illustrates the structure of a typical plant cell wall, it consists of a number of layers which are different in origin, structure and chemical composition.

(i) Middle Lamella

The layer which forms the first partition between two cells as they are formed during cell division is called the middle lamella or intercellular substance. It is shared by two adjacent cells and acts as an intercellular cement binding adjacent cells together. The main chemical constituent of the middle lamella is pectin.

(ii) Primary wall

The next layer is the primary wall. It lies between the middle lamella and the plasma membrane (see Figure 2.6). While the cell is still growing and enlarging the primary wall is thin and elastic but when the cell stops growing the primary wall may thicken. Chemically, this wall is primarily made up of cellulose, various kinds of sugars and proteins. Cellulose is a complex polysaccharide which is formed by a condensation of many glucose molecules.

(iii) Secondary Wall

The next layer of the cell wall is the secondary wall which forms between the primary wall and the plasma membrane. The secondary wall may be thin but it is usually thickened to varying degrees. When thickened it may consist only of cellulose but usually other chemicals may become deposited on the cellulose layer. Some of these other chemicals are lignin and suberin. When any such chemicals is present, the wall is said to be lignified or suberized. These chemical are impervious to water and air. The cells in which they occur are therefore usually non-living. The thickening material is usually not uniformly laid down but takes a number of different patterns. It may be arranged in rings, spiral bands or patches of thick and thin areas. Some of these are illustrated in Figure 2.7. These arrangements allow for flexibility.

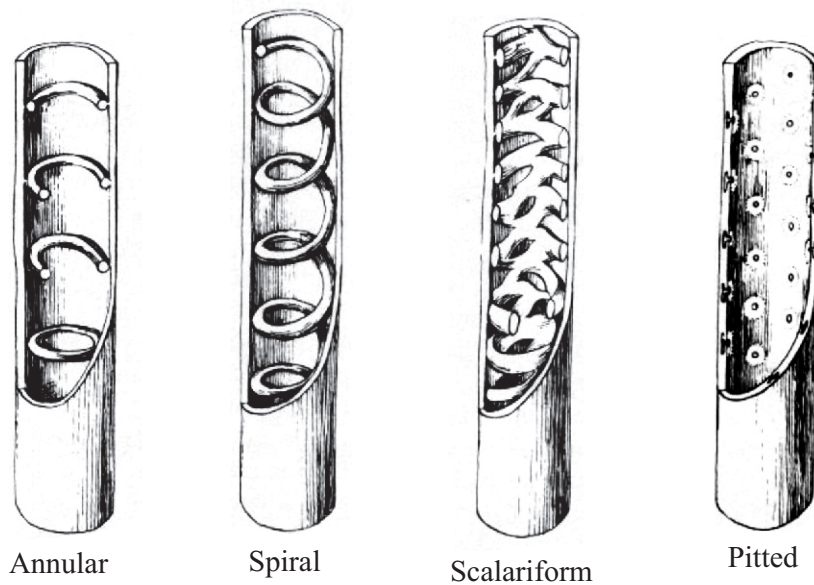


Figure 2.7: Patterns of cell wall thickening.

Source: (Walter,1988).

(iv) Pits

The secondary wall is not usually laid over the entire primary wall. It is absent altogether in some places, which remain thin. Such areas that remain thin in the walls of plants (while the rest of the wall is thickened) are called pits. When pits of two adjacent cells coincide a pit pair is formed. This is illustrated in Figure. 2.8.

The structure of a pit may be simple when its side walls are plain and parallel or more complex when various modifications are present. An extreme situation is seen in bordered pits in which the pit cavity is over-arched by an extension of portion of the cell wall.

The cytoplasm of the adjoining cells are continuous in the form of slender strands, called plasmodesma (pl: plasmodesmata), across pits. This ensures continuity of cytoplasm in organisms and facilitates the movement of molecules between adjacent cells.

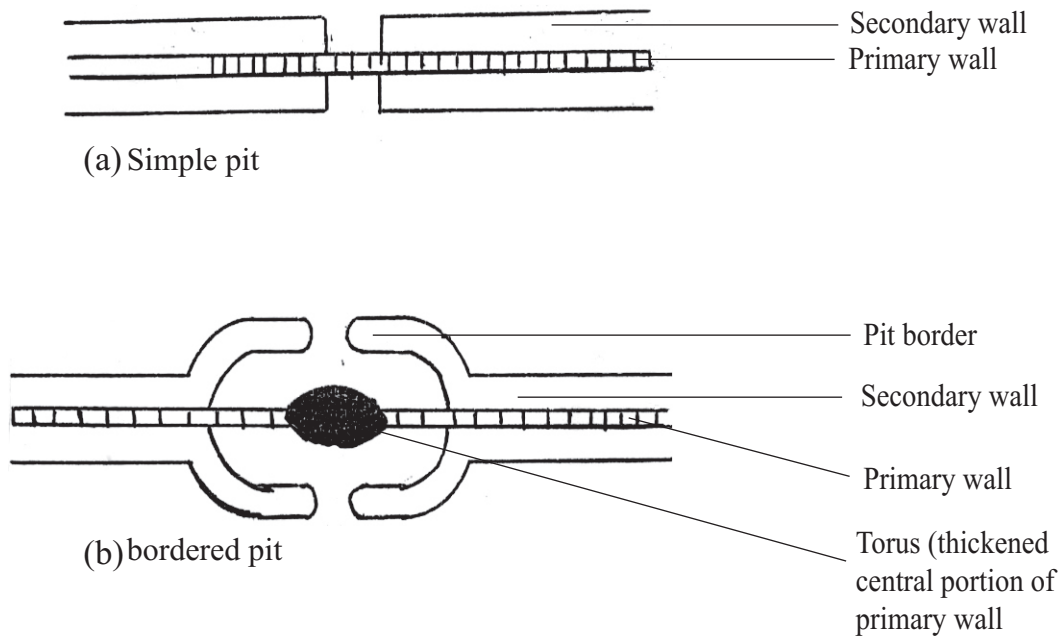


Figure 2.8: Structure of pits (a) simple pit (b) bordered pit.
Source: (Uduebo, 1984)

2.5 Summary

Cell was discovered in 1665 by Robert Hooke. Cells are microscopic and develop in different ways to perform different functions. This process in which cell performs specialised duty is referred to as cell specialisation. Specialised cells in plants include sclerenchyma, nectar secreting cell, guard cells, parenchyma, pollen grain cell, root hair cell, epidermal cells, phloem cell, leaf hair cell, stone cell and vessel elements cells of xylem. They represent plant organ systems. The plant cell is a box-like structure consisting of the nucleus and cytoplasm which contains organelles, starch grains, oil droplets, and crystalline substances. The cell membrane is important in three ways: as an interface; is semi-permeable and differentially permeable; the permeability differs from membrane to membrane and also at different conditions. In addition, the cell membranes show enzymatic activity. The endoplasmic reticulum is an extensively closed system which forms the cytoplasmic connections that facilitates communication between cells. Aside from enhancing communication, endoplasmic reticulum transports fluids found in the inner space of the membranes to different parts of the cytoplasm and also aid the synthesis or condensation of various substances. Plastids are disk-shape organelles from 2 to 25 μ m in diameter and are of three types: chloroplasts; chromoplast; and leucoplasts which differs from each other interms of whether or not, it contains pigment as well as the colour of the pigment. Mitochondria are very complex organelles which provide energy for cell functions and controls respiration and the production of energy. Chemical reactions take place in the folded inner membrane of mitochondrion. Vacuoles, though parts of the

protoplast, are isolated in the cytoplasm by the tonoplast and contains cell sap. Storage, waste disposal, hydrolysis, protection, and growth are the major duties of vacuoles. Cell sap is made up of a very dilute solution of many water soluble substances which include inorganic salts, sugars, etc. Ribosomes, 20 μ m long electrons carriers are vested with responsibilities of synthesising proteins, sequencing amino acids, and formation of peptide. The nucleus may be 5-30 μ m in diameter and is spherical or lens shaped. Within the nucleus lies the chromatin which is made up of DNA, RNA and nuclear proteins that play significant roles in cell division. The plant cell wall is made up of primary and secondary walls. The middle lamella of the plant cell wall is the first partition between two cells. It is shared by two adjacent cells and acts as an intercellular cement binding the cell together. The primary cell wall lies between the middle lamella and the plasma membrane while the secondary cell wall is formed between the primary wall and the plasma membrane. Pits are areas that remain thin in the cell walls of plants while the rest of the wall is thickened. The structure of the pit may be simple when its side walls are plain and parallel or more complex when various modifications are present. Various patterns of cell wall thickening include: annular; spiral; scalariform; and pitted.

2.6 Evaluation

Having read this chapter, answer the following questions:

1. Mention ten types of specialised cells you have studied.
2. Draw and label a plant cell as seen under the electron microscope.
3. List three types of plastids and state their features.
4. Write short notes on (a) mitochondria (b) vacuoles (c) ribosomes (d) the nucleus (e) cell sap.
5. Make an outline drawing of a plant cell wall to show its essential features.
6. State the functions of each part of a plant cell wall.
7. Distinguish between simple pit and bordered pit within the cell wall.

2.7

TUTORIAL QUESTIONS

Fill in the gap in the sentences provided below:

1. The protoplasm is the living substance of the cell and is divided into nucleus and the _____.
2. Membranes consist of lipid layers which sometimes include _____ or other organic substance.
3. Membranes are not only semi-permeable but are _____ permeable.
4. Proteins appears to be synthesized by the _____ that line the surface parts of the endoplasmic reticulum.
5. The plastids are _____ organelles from 2 to 25 μ m in diameter which have double membranes.
6. The _____ are associated with storage and are named according to the substances they contain.
7. The chloroplast are the most important because these are the sites at which _____ takes place.
8. The mitochondria are very complex organelles which provide _____ for cell functions.
9. Mitochondria control respiration and the production of energy in the form of _____.
10. The layer which forms the first partition between two cells as they are formed during cell division is called _____.
11. The main chemical constituent of the middle lamella is _____.
12. The cytoplasm of the adjoining cells are continuous in the form of slender strands called _____.

13. The primary cell wall lies between the _____ and the plasma membrane.
14. Cellulose is a complex _____ which is formed by a condensation of many glucose molecules.
15. The ribosomes which are bounded by a membrane are $20\mu\text{m}$ long and carry many _____.
16. The inner membrane of the mitochondria is extensively folded, providing a large area at which _____ takes place.
17. The secondary wall is not usually laid over the entire _____.
18. The _____ are water soluble pigments which are also found in the cell sap.
19. The ribosomes are sometimes found in _____ called polyribosomes.
20. The secondary wall is the part of the cell that gives various _____ and plant fibres.



CHAPTER THREE

3.0 ORGANISATION OF VASCULAR AND NON VASCULAR PLANTS

CHAPTER OBJECTIVES

By the end of this chapter, students should be able to:

- (i) list the major plant groups;
- (ii) distinguish between vascular and non vascular seedless plants;
- (iii) identify the three types of gymnosperm;
- (iv) mention the main features of bryophytes and pteridophytes;
- (v) state the relationship between gymnosperm and angiosperm;
- (vi) account for the organisation of vascular plant body;
- (vii) classify angiosperm into monocotyledon and dicotyledon;
- (viii) list the functions of roots, stems and leaves of a plant;
- (ix) explain briefly the morphology of a flowering plant.

3.1 General Information

The plant kingdom, comprising about 260, 000 known species of mosses, liverworts, ferns, herbaceous and woody plants, shrubs, vines, trees, and various other forms that cover the earth and are also found in the waters. Plants range in size and complexity from small, non vascular mosses, which depends on direct contact with surface water, to giant sequoia trees, which can draw water and minerals through their vascular systems to elevations of more than 100m (330 ft).

Only a tiny percentage of plant species are directly used by humans for food, shelter, fibre and drugs. Such plant include: rice, wheat, corn, legumes, cotton, conifers, and tobacco, on which whole economies and nations depend. Of even greater importance to humans are the indirect benefits reaped from the entire plant kingdom and it's more than one billion years of carrying out photosynthesis. Plants have laid down the fossil fuels that provide power for industrial societies

today. The world's biomass is composed overwhelmingly of plants, which not only underpin almost all food webs, but also modify climates and create and hold down soil, making what would otherwise be stony, sandy mass suitable for life.

The most important characteristic of plants is their ability to photosynthesize. During photosynthesis, plants make their own food by converting light energy into chemical energy, a process carried out in the green cellular organelles called chloroplasts. A few plants have lost their chlorophyll and have become saprophytes or parasites; that is, they absorb their food from dead organic matter or living organic matter, respectively. Nevertheless, details of their structure show that they possess various plant features.

3.2 Plant Groups

Plants help sustain life on earth by changing solar energy into chemical energy. They are producers of vast quantities of food and oxygen. Plants also provide shelter for countless species of organisms and man. Most plants live on land, but many live in or on fresh water. Very few plants tolerate sea water. Major plant groups that are relevant to this discussion includes: Bryophytes (Mosses and Liverworts), Pteridophytes (Ferns and Clubmosses), Gymnosperm (Pine and Cycas) and Angiosperm (Flowering Plants).

3.2.1 Bryophytes: Non vascular Plants

Bryophytes are a group of non-vascular plants that include mosses and liverworts, such as those shown in Figure 3.1a and b. The phylum contains two main classes, the Hepaticae, or liverworts, and the Musci, or mosses. Neither group is particularly well adapted for life on land nor they are mainly confined to damp, shady places.

Members of the bryophyte group are small green plants that live in moist, shady places. Of the 25,000 species of bryophytes, mosses and liverworts are the most common. Bryophytes are not completely adapted to land as they have no transport system inside their bodies to carry materials. This is one of the reasons these plants usually remain small, so that no cell is very far from water. The liverwort in nature always grows flat against the ground. Even the “giant” amongst the bryophyte group of plants rarely grow taller than 15 centimetres. Bryophytes need moisture to reproduce as their sperm must swim in water to reach their eggs. But some of these plants can survive periods of dryness by becoming dormant or inactive.

Bryophytes are small simple plants, with strengthening and conducting tissues absent or poorly developed. There is no true vascular tissue (xylem or phloem). They lack true roots, being anchored by thin filaments called rhizoids which grow from the stem. Water and mineral salts can be absorbed by the whole

Organisation of Vascular and non Vascular Plants

surface of the plant, including the rhizoids, so that the latter are mainly for anchorage, unlike true roots. (True roots also possess vascular tissue, as do true stems and leaves). The plant surface lacks a cuticle, or has only a delicate one, and so there is no barrier against loss (or entry) of water. Nevertheless, most bryophytes have adapted to survive periods of dryness using mechanisms that are not fully understood. For example, it has been shown that the well-known xerophytic moss *Grimmia pulvinata* can survive total dryness for longer than a year at 20°C. Recovery is rapid as soon as water becomes available.

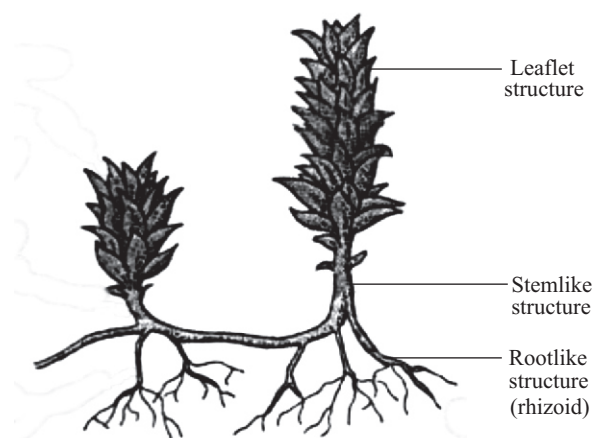


Figure 3.1 (a): *Moss: a representative bryophyte.*
Source: (Scott,1985).

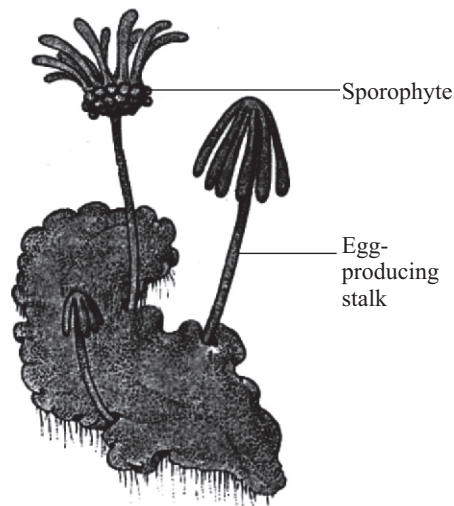


Figure 3.1 (b): *Liverwort: a representative bryophyte.*
Source: (Scott,1985).

Bryophytes are important as producers of food and oxygen used by other organisms. They also help make land suitable for other plants by breaking down rocks to make soil. The remains of mosses enrich the soil. Also, bryophytes help prevent erosion and flooding because they can absorb large amounts of water.

3.2.2 Pteridophytes

Pteridophytes are better adapted to land than bryophytes. Ferns and club mosses are common members of pteridophytes (vascular plants). Most of the 12,000 species of pteridophytes are found in the tropics. Most members need water to carry out their reproductive process. Thus, ferns must have at least seasonal periods of high moisture. Ferns and clubmosses are perennial plants bearing large conspicuous leaves usually arising from either a rhizome or a short erect stem. They have a transport system to carry materials through their roots, stems, and leaves. This system enables them to grow well above the surface of the ground. They are usually restricted to damp shady habitats.

- **Club Mosses: Vascular Plants**

Club mosses differ from true ferns in that their leaves are usually small, simple, scale-like structures superficially resembling those of mosses; hence the name. The common name of these plants probably developed because they look like mosses and grow close to the ground as mosses do. Also, notice the club-shaped, spore-producing structures of the club mosses e.g. as in *Lycopodium cernuum* in Figure 3.2. These structures can easily be mistaken for the sporophyte stalks of mosses. The leaves of club mosses tend to be small and scalelike, but each leaf has a small unbranched vein of vascular tissue. About 1,000 species of club mosses exist. Club mosses were more successful in the past when they flourished in swamplands and grew as large as trees. Representatives of two living genera are *Lycopodium* and *Selaginella*.

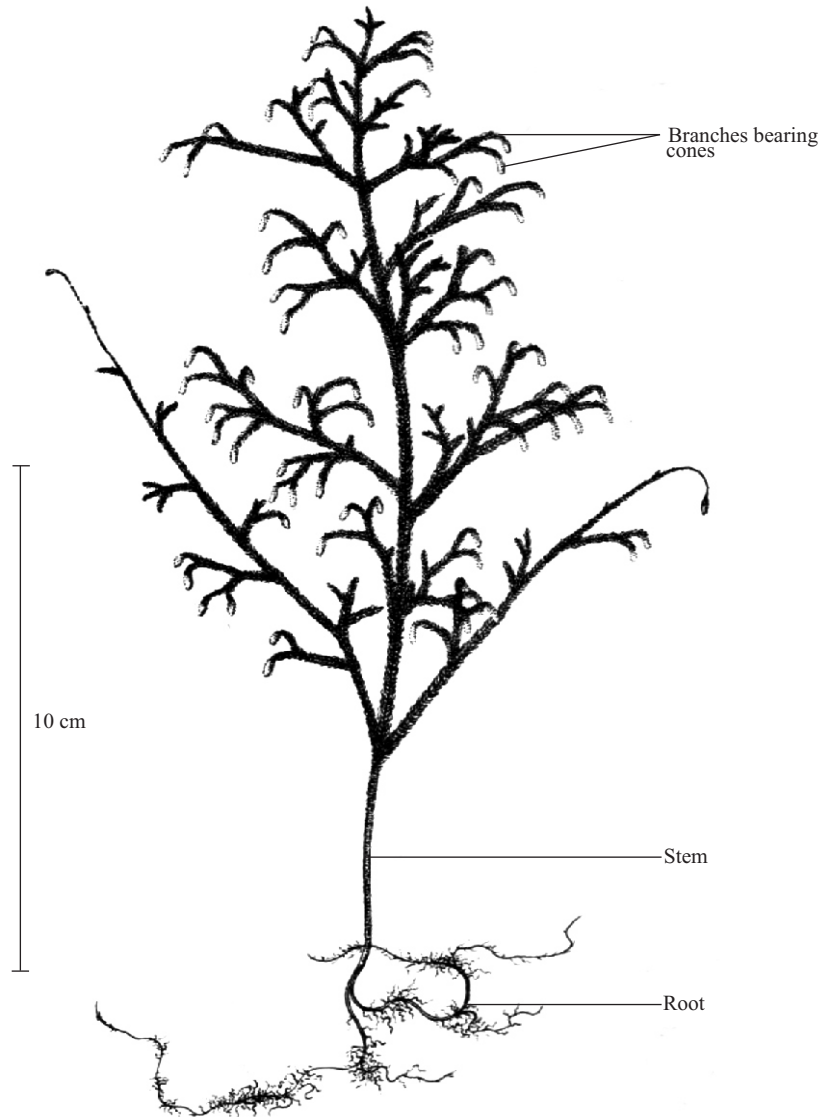


Figure 3.2: *Lycopodium cernuum*: whole plant, showing position of cones.

Source: (Ewer and Hall,1972).

- **Ferns: Vascular Plants**

Ferns are the best-known group of vascular plants. Most of the 12,000 species of ferns live in tropical areas, with the remaining species living in temperate and arid regions. In ferns the sporophyte is dominant. A fern sporophyte has an underground stem or rhizome. Rhizomes can branch and grow rapidly, allowing ferns to compete with grasses and other plants for space. Roots grow

downward from the rhizome, and large leaves or fronds grow upward, as shown in Figure 3.3 a and b. Coiled leaf buds, called *fiddleheads* unroll as they develop into fronds. The large, feathery fronds distinguish ferns from most other plants. These wide-spreading leaves can collect a large amount of light for photosynthesis. There is a characteristic uncurling of the young leaves as they expand into the adult form. Reproduction is by means of spores borne on the underside of specialised leaves.

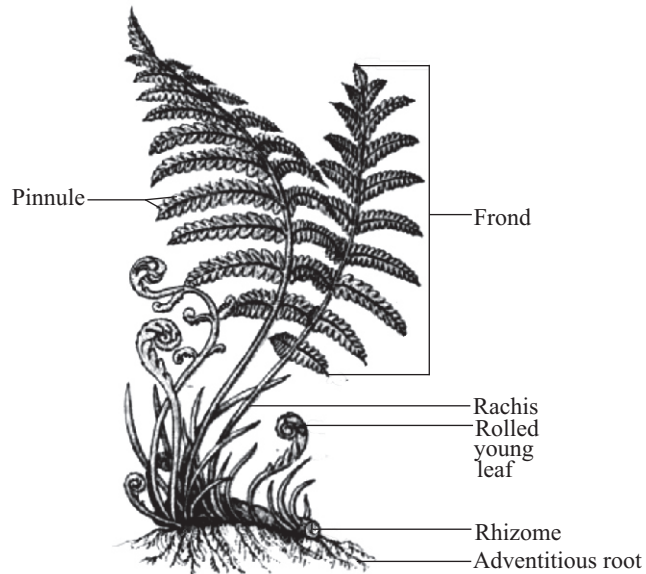


Figure 3.3 (a): *Fern sporophyte.*
Source: (Scott,1985).

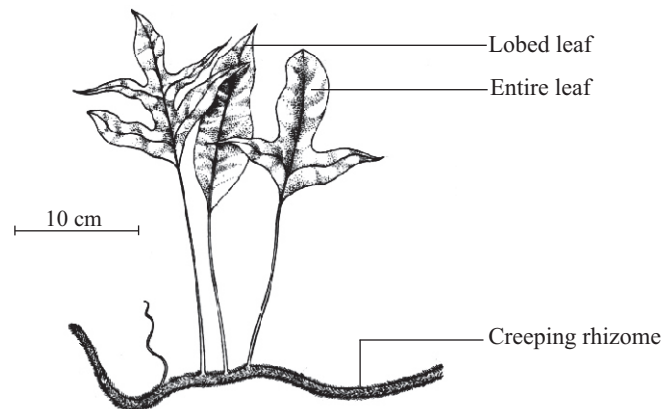


Figure 3.3 (b): *Phymatodes; an epiphytic fern with creeping rhizome and simple leaves*
Source: (Ewer and Hall,1972).

3.2.3 Gymnosperms

Seed-bearing vascular plants make up the most abundant and widespread group in the plant kingdom. The two main kinds of seed bearing plants are gymnosperms and angiosperms. In this section you will learn about gymnosperms plants whose seeds are not enclosed in fruits. The next section will present angiosperms or flowering plants which are plants with fruit enclosed seeds.

Three types of Gymnosperm

Gymnosperm means “naked seeds.” A gymnosperm seed is “naked” because it lacks a protective fruit covering, such as the pulpy fruit tissue around apple seeds. Gymnosperms include cycads, ginkgoes, and conifers.

- **Cycads** include only a few surviving species that live in tropical or warm temperate zones. Numerous species of cycads flourished during earlier eras when dinosaurs dominated the earth. A cycad looks like a small palm tree. But unlike palm trees which produce fruit-covered seeds, cycads produce large, seed-bearing, conelike structures. These conelike structures and the large leaves of many cycads have sharp, protective spines.
- **Ginkgoes** are represented by a sole surviving species. Though their ancestors are well represented in the fossil record, ginkgoes may no longer exist in the wild. The only known living ginkgo trees are cultivated in gardens and parks in temperate regions. Ginkgoes are tall trees with unusual fan-shaped leaves. Unlike most gymnosperms, ginkgoes are deciduous, which means that the leaves are shed each year. Because the ginkgo tree is so similar to its extinct ancestors, it is sometimes called a “living fossil.”
- **Conifers** get their name from the fact that they bear their seeds in cones. They are by far the most varied and widely distributed gymnosperms. Conifers are trees or shrubs that have needlelike or scalelike leaves. Conifers are well adapted to these cold climates, where ground water might be frozen much of the year. Since little water is available, plants living in these regions are at disadvantage if they lose water through their leaves. Conifers have small, compact leaves with a thick covering that prevents water loss. Also the roots of conifers can tolerate the acidic conditions produced by slow decomposition in cold soils. In addition, most conifers are not deciduous. Rather, they shed their leaves a few at a time throughout the year. As a result, conifers can photosynthesise all year long, even when water, light and heat are at low levels.

3.2.4 Angiosperm (Flowering Plants)

Angiosperms comprise about 250,000 species more species than all other kinds of plants put together. The angiosperms are the dominant plant forms of the present day. They show the most advanced structural organisation in the plant kingdom, enabling them to inhabit a very diverse range of habitat. We probably depend more on the flowering plants than any other group in the plant kingdoms. Their seeds, fruits, roots, stems, and leaves nourish our bodies.

Flowering plants occur in almost every environment and include such diverse species as oak trees, wheat plants, apple trees, and bean plants. The fruits and vegetables that people eat, such as oranges, strawberries, celery and potatoes, are all part of angiosperms. In addition to food, angiosperms produce such useful materials as wood, fibers for clothing, and chemicals for medicines. The flower is the organ that helps ensure the successful reproduction of these plants. Seeds of flowering plants are surrounded by fruit.

- **Classification of Angiosperms**

Angiosperms are classified into two main groups: the monocotyledons and the dicotyledons. A cotyledon is a leaf like structure of the embryo of a plant. Cotyledons often store food that the new plant uses during germination. A monocotyledon, or monocot, has one cotyledon in each seed. A dicotyledon, or dicot, has two cotyledons in each seed. There are two classes within this group: the monocotyledons and the dicotyledons. They are differentiated based on the following characteristics.

Table 3.1: Differences between Monocotyledons and Dicotyledons

Monocotyledons	Dicotyledons
1. Produce one cotyledon.	These produce two cotyledons
2. Produce flower parts in threes or multiples of three.	Produce flower parts in fours and fives or their multiples.
3. Their leaves possess parallel venation.	Their leaves possess net or reticulate venation.
4. Their stems usually have scattered vascular bundles.	Here the vascular bundles occur in a cylindrical pattern.

3.3 Characteristics of Vascular Plant

A plant can be described as a multicellular, photosynthetic organism that is adapted to live on land and aquatic habitats. Some exceptions, such as aquatic plants, are descended from land plants. They have become adapted again to a water environment. Plants also share other characteristics. For instance, the bodies of plants have the same basic plan. As it is shown in Figure 3.4, a plant is

made up of both an above ground (photosynthesizing part) and an under ground, (absorbing part). Plants cannot move from place to place, although some parts can move.

On a smaller scale, the cells of plants also show several similarities. Plant cells are eukaryotic, and a cell wall surrounds the cell membrane. The cell walls stiffen the cells and provide support for the plant. Plant cells also contain small membrane-enclosed organelles called plastids. One type of plastid is a chloroplast, in which photosynthesis occurs. Also, the reproductive cells of plants have a characteristic structure. In all plants, the female gamete or egg is large and stationary, and the male gamete or sperm is small. The large size of the egg is mostly due to storage of nutrients. The fertilised egg develops into an embryo which is protected by the parent plant.

One of the ways scientists classify plants is by considering the presence or absence of an internal “pumping” network, called a vascular system. This system consists of a network of tubes within the plant. Water, minerals, and nutrients are transported through these tubes to all parts of the plant. These tubes also provide support for the plant. The plants that lack vascular tissue, the non vascular plants, include mosses and liverworts. Vascular plants include ferns, conifers and flowering plants, as well as a variety of primitive plants. Plants can also be grouped by whether they produce seeds. Conifers and flowering plants are among the seed-bearing plants. Mosses and ferns do not produce seeds.

3.4 Organization of a Vascular Plant

The cells of a living plant are organized into different tissues and organs, as shown in Figure 3.4. Three of the principal organs of a living plant are roots, stems and leaves. These organs are linked together by systems and sub - systems that run the length of the plant, performing functions such as transport, protection and coordinating plant activities.

3.4.1 Leaves

Leaves are the plant's main photosynthetic systems. The broad, flat surface of many leaves help increase the amount of sunlight plants absorb. Leaves also expose a great deal of tissue to the dryness of the air and, therefore, must contain subsystems to protect against water loss. Adjustable pores in leaves help conserve water letting oxygen and carbon dioxide enter and exit the leaf.

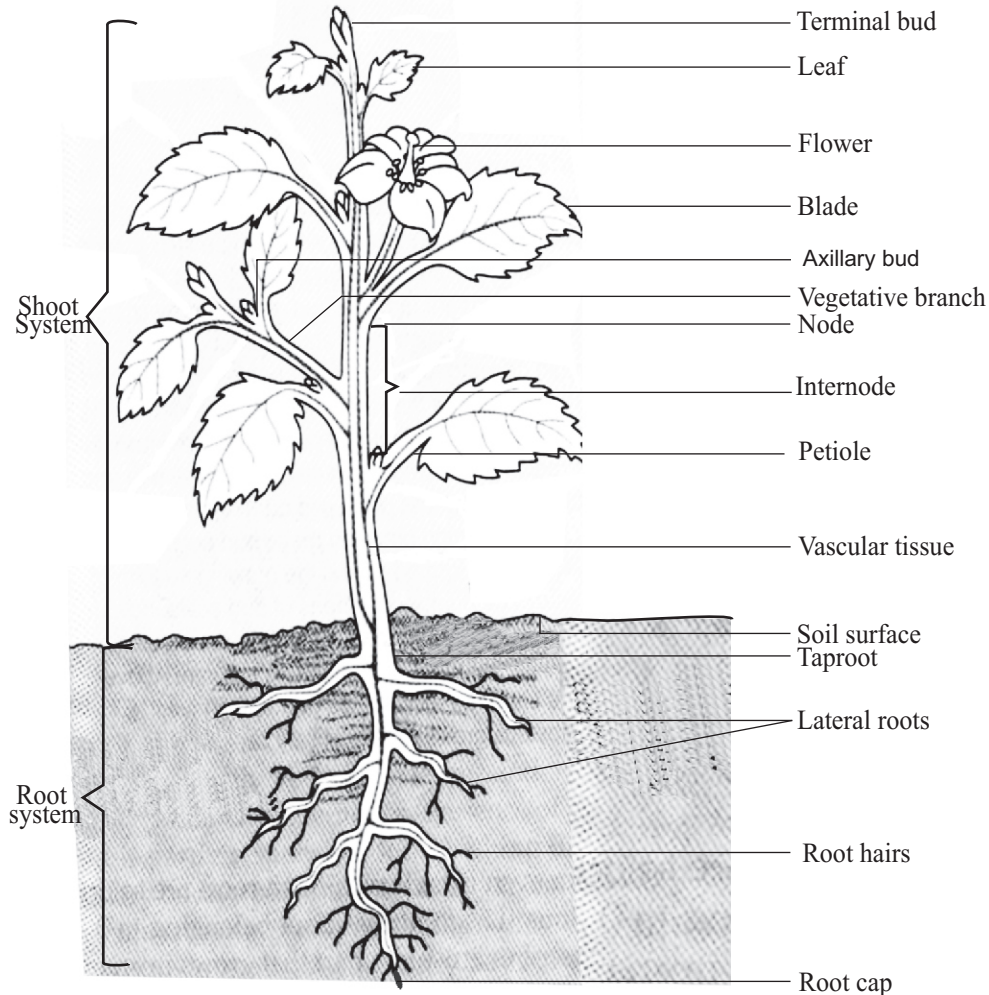


Figure 3.4: Organisation of vascular plant body

Source: (Campbell, 1993).

Note: Organisation of a Flowering Plant Body

The plant body is divided into a root system and a shoot system, connected by vascular tissue that is continuous throughout the plant. The root system of this dicot consists of a taproot and several lateral roots. Shoots system consists of stems, leaves and flowers. The blade, the expanded portion of a leaf, is attached to a stem by a petiole. Nodes, the regions of a stem where leaves are attached are separated by internodes. At a shoot's tip is the terminal bud, the main growing point of the shoot. Axillary buds are located in the upper angles of leaves. Most of these axillary buds are dormant, but they have the potential to develop into vegetative (leaf-bearing) branches or flowers.

3.4.2 Stems

A stem has a support system for the plant body, a transport system that carries nutrients, and a defense system that protects the plant against predators and disease. Stems can be as short as a few millimeters or as tall as 100 meters. Whatever its size, the support system of a stem must be strong enough to hold up its leaves and branches. Similarly, the stem's transport system must contain subsystems that can lift water from roots up to the leaves and carry the products of photosynthesis from the leaves back down to the roots.

3.4.3 Roots

The root system of a living plant absorbs water and dissolved nutrients from the soil. Roots anchor plants in the ground, holding soil in place and preventing erosion. The root system also protects the plant from harmful soil bacteria and fungi, transports water and nutrients to the rest of the plant, and holds plants upright against climatic forces such as wind and rain.

3.5 Summary

The plant kingdom comprises of over 260,000 known species of a wide variety of plants, viz, mosses, liverwort, ferns, herbaceous and woody plants, bushes, vines, and trees. Plants are found on land, seas, rivers, lakes, deserts and in polar regions of the world. Their size ranges from non-vascular mosses to giant sequoia trees. Humans use only a small percentage of plant species for food; shelter, fiber and drugs. Plants provide fossil fuel thereby supporting industrial societies. The plant kingdom is divided into bryophytes, pteridophytes, gymnosperm and angiosperm. Bryophytes are non-vascular seedless plants of which mosses and liverworts are the common examples. Lack of transport system in bryophytes gives rise to partial land life adaptation and this is evidenced in the stunted growth of bryophytes on land. Bryophytes can survive long periods of dryness. They produced food and gas to other organisms, enrich the soil, and also prevent erosion and flooding. The other phyla are collectively termed tracheophytes or vascular plants. Because of the presence of vascular tissue, xylem and phloem in tracheophytes and their ability of being asexual or spore producing, these phyla became much larger and complex and were free from direct dependence on surface water. Hence, they were able to dominate all terrestrial habitats of the earth. Three types of gymnosperm which is the most advanced tracheophyte is classified into the monocotyledons and dicotyledons. The monocot has one cotyledon while dicot has two cotyledon respectively. Characteristics of vascular plants (tracheophytes) include being multicellular, photosynthetic, and adapted to live on land. Others are adapted to live in water and are called aquatic plants. Their bodies are generally designed to grow in one spot. Plant cells are organised into tissues and organs. The principal organs are the leaves in which photosynthesis takes place, the stem which supports the plant body and acts as a transport system for nutrients and water; and the roots which absorb water and dissolved nutrients from the soil. The roots also anchor the plant to the soil.

3.6 Evaluation

Having read this chapter, answer the following questions:

1. In what ways does gymnosperm differ from angiosperm?
2. State the main features between bryophytes and pteridophytes.
3. Distinguish between vascular and non vascular seedless plants.
4. Make a large labelled drawing to show the basic morphology of flowering plants.
5. Give a brief account of the organisation of a vascular plant body.
6. State three functions each of (a) roots (b) stems and (c) leaves in plants.
7. State four ways in which monocotyledons differ from dicotyledons.

3.7

TUTORIAL QUESTIONS

Fill in the gap in the sentences provided below:

1. Plants have laid down the fossil fuels that provide _____ for industrial societies today.
2. _____ is internal conducting tissue for the movement of water, minerals and food.
3. A plant can be described as a multicellular _____ organism that is adapted to live on land and aquatic.
4. On a smaller scale, the cells of plants also show several _____.
5. The cell walls stiffen the cells and provide _____ for the plant.
6. Plant cells also contain small membrane-enclosed organelles called _____.
7. The fertilised egg develops into an _____ which is protected by the parent plant.
8. One of the ways scientist classify plants is by whether they have an internal plumbing network called a _____.
9. Vascular plants include ferns, conifers and _____ plants as well as a variety of primitive plants.
10. Conifers and flowering plants are among the _____ plants.
11. The cells of a living plant are organised into different _____ and organs.
12. Three of the principal organs of a living plants are _____, _____ and _____.
13. _____ are the plants main photosynthetic system.

14. The root system of a living plant absorbs water and dissolved _____.
15. The many species of organisms in the plant kingdom are divided into several phyla or _____.
16. Only a tiny percentage of plant species are directly used by humans for food, shelter, fibre and _____.
17. It takes _____ generations to complete the plant life cycle.
18. Roots anchor plants in the ground holding soil in place and preventing _____.
19. Adjustable pores in leaves help conserve water letting oxygen and CO₂ _____ and exit the leaf.
20. The broad, flat surface of many leaves help increase the amount of _____ plants absorb.
21. Members of the bryophyte group are _____ green plants that live in _____ shady places.
22. Bryophytes are not completely adapted to land as they have no _____ system.
23. Bryophytes need moisture to _____ as their sperm must swim in water to reach their eggs.
24. Ferns possess _____ system to carry materials through their roots, _____ and leaves.
25. The flower is an organ that helps ensure the successful _____ of the flowering plants.
26. Gymnosperm have needle-like, broad or _____ leaves.
27. Gymnosperm have cones instead of _____ where seeds are formed and do not form _____.