*CHAPTER 1*

# The Cell

## INTRODUCTION

CERTAIN objects if provided with proper environmental conditions show life properties such as sensitivity, movement, nutrition, growth, respiration, excretion, metabolism, reproduction, life cycle, life structure and death. Such objects are called living objects. Their life spans may vary from a few moments to many years.

What is life is a difficult question to answer. According to mechanistic thinkers, it is a mechanical control of some physico-chemical laws and according to vitalistic thinkers, it is a divine control of some physico-chemical laws over matter and energy. However, to some extent life can be defined as '*a dynamic equilibrium of hundreds and thousands and millions of chemical and biochemical reactions going on between non-living substances at ionic and molecular levels.*"

The study of life processes is known as physiology and the study of life processes of plants as plant physiology. Though not on an experimental or scientific basis, the study of plant physiology actually started the day man started the use of plants. Today plant physiology is a well-developed branch of study and is based on scientific facts. The more a man needs plant life for his existence, the more the science of plant physiology will have to be explored and developed in order to improve our plant wealth. The questions like how water, gases and solutes enter plants, substances pass out of plants, food and other organic substances are synthesised and utilised by plants, tissues and organs are developed in plants, vegetative and reproductive parts are produced in plants and at which stage of its development and how plant processes are influenced by environmental conditions, will have to be understood and answered in full if we have to develop our plant resources.

In recent years, the physical sciences like physics, and chemistry have become very close to the science of plant physiology. The branches like physics, chemistry, biochemistry, statistics etc. have helped us a lot in studying and understanding the life processes of plants.

The fundamental investigations of plant physiology have helped us a lot in improving the ways and methods of propagating, handling and harvesting of economically important plants, storing many plant products and controlling plant diseases.

The close relationship of plant physiology with other branches of botany such as morphology, taxonomy, ecology, plant pathology, plant genetics and plant breeding too cannot be ignored as these branches of botany help a plant physiologist in many ways while solving the mysterious problems of plants.

## Cell—The Basic Unit of Life

Cell is the most enigmatic mystery of nature about which it is believed that the day scientists will understand it fully, they would be able to unravel the secret of life and death. The word 'cell' was coined by Robert Hooke (1665) when with the help of a compound microscope, he observed the texture of a cork's thin section as composed of small spaces surrounded by a firm cell wall. The whole structure looked like honey-comb. He was thrilled to observe such figures and called them cells. Cell is a latin word derived from *cellula* which means small apartments. He published his work in *Micrographia*, London.

With the passage of time more advanced types of microscopes became available which helped Robert Brown (1831) to find a conspicuous spherical body in each cell. He called it the nucleus. By this time many scientists had started exploring the field. Mirbel (1808-09) suggested that "*plants are formed by a membranous cellular tissue.*" While Lamarck (1819) advanced this statement by saying "*nobody can have life, if its constituent parts are not cellular tissue or are not formed by cell,*" M.J. Schleiden and Theodor Schwann (1839) propounded the cell theory saying. "*The cells are organisms; and animals as well as plants are aggregates of these organisms arranged in accordance with definite laws*"–and in 1855, Virchow concluded that *Omnis cellula-e-cellula, i.e.* new living cells arise only by reproduction of pre-existing living cells. Though credit for formulating this hypothesis goes to him, it had already been postulated in prehistoric *Vedas* as follows:

'जीवो जीवस्य जीवनम्, जीवात् जीवो जायते'—अथर्ववेद
(जीव ही जीव का जीवन है, जीव से ही जीव उत्पन्न होता है।)

In 1846, Von Mohl observed a viscous, jelly-like mass surrounding each nucleus and then enunciated a concept that '*protoplasm is the physical basis of life*'. The term protoplasm was introduced by Púrkinje (1840) to refer collectively to cytoplasm and nucleus. Max Schultze (1861) established the similarity between plant and animal protoplasm. Later it was called the protoplasm theory by Hertwig (1892). The cells of all living organisms though varying to a great extent in size, mass, shape, structure and function have many things in common. A cell has been variously defined. *Cell is the structural and functional unit of plants and animals,* or *Cell is the unit of life* or *Cell is a mass of protoplasm surrounded by a thin membrane.*

However, there are many exceptions to the cell theory, *e.g.* virus. Viruses do not fit in the definition of a cell and these are therefore, often described as *living chemicals*. These are supposed to be primitive organisms as they fail to reach a cellular state. Among other examples, coenocytic forms such as *Vaucheria* (alga) and *Rhizopus* (fungus) may also be found placed outside the definition limit. Their living substances are enclosed in a wall and there is hardly any organisation like that of a cell. It is therefore difficult to accommodate these kinds of units in the context of cell theory.

The cell theory in present state may be briefly summed up as follows:

(*i*) All living things are composed of cells and their products.

(*ii*) All cells arise from pre-existing cells.

(*iii*) All cells are basically alike in chemical composition and metabolic activities.

(*iv*) The function of an organisation as a whole is the outcome of the activities and interactions of the constituent cells.

During the recent past, the cell theory has been challenged and the **organismal theory** has been proposed according to which, an organism is regarded as a protoplasmic unit when it is incompletely divided into small centres—the cells for the performance of various biological activities.

**Cell size.** The size of cells varies widely. The smallest living cells are bacteria (0.2–5.0 μm) and the largest cell is the ostrich egg which measures about six inches. The largest unicellular plant is *Acetabularia.* Table 1.1 reveals some interesting average measurements.

**Table 1.1. Average Measurements of Some Living Cells and Molecules.**

| *Name of the cell* | *Measurement* | *Name* | *Measurement* |
|---|---|---|---|
| Ostrich egg | 170 × 135 mm | Typhoid bacillus | 2.4 × 0.5 micron |
| Hen egg | 60 × 45 mm | Influenza bacillus | 0.5 × 0.2 micron |
| Humming bird egg | 13 × 8 mm | Pneumococcus bacterium | 500 × 200 μm |
| Human egg | 0.1 mm | | |
| Amoeba | 100 microns (μ) | Bacterial virus | 80 μm |
| Sea urchin egg | 70 microns (μ) | | |
| Liver cell | 20 microns (μ) | Protein molecule | 10 μm |
| Red blood cells | 7 microns (μ) | Haemoglobin | 7 μm |

**Cell shape.** The shape of cells also varies depending upon the function, needs of the organisms and environmental conditions. It can be specially observed when the various shapes of unicellular organisms such as *Amoeba, Paramoecium, Chlamydomonas,* Yeast and Bacteria are considered. Some bacteria are rods, spirals and even comma-like, while *Acetabularia* consists of a stalk and a cap, upto 10 cm in height. The shape of the cell in multicellular organisms shows some regularity where it is partly controlled by the mutual pressure of the cells. However, in these cases, some specialised cells modified for various functions show typical shapes, *e.g.* cells of glandular hairs of leaf, guard cells and root hairs.

**Cell number.** The cell number varies to a large extent. Some organisms are small and unicellular while others are giants and multicellular. Among unicellular forms *Chlamydomonas* and *Chlorella* are of common occurrence while those of multicellular forms are *Ulothrix,* mosses, ferns and phanerogams. An average man possesses about 100 trillion cells and if all of them are extended in one line, they will take 100 turns around the earth. However, some forms have a definite number of cells in their organisation such as *Gonium* (4 or 8 cells), *Pandorina* (4, 8 or 16 cells), *Eudorina* (8, 16, 32 or 64 cells) etc.

**Organisation of cells.** A cell has three distinct regions (i) cell wall, (ii) protoplasm and (iii) vacuole. Cell wall and vacuoles have been considered as non-living components. The protoplasm consists of two important components, the cytoplasm and the nucleus. It remains externally bounded by the cell membrane or plasma membrane. The cytoplasm contains several cell organelles such as plastids, mitochondria, endoplasmic reticulum, ribosomes, lysosomes, cilia, flagella etc. A plant cell is distinguished from an animal cell in presence of (i) cell wall, (ii) plastids and (iii) vacuoles. An animal cell has centrosome which is not found in plants, except in few micro-organisms.

## CELL WALL

Cell wall is the non-living component of the cell and is secreted and maintained by the living portion of the cell, called protoplasm. The synthesis of cell wall is controlled by Golgi bodies.

A typical cell wall is composed of three different regions – (i) middle lamella, (ii) primary wall (1–3 μm thick and elastic) and (iii) secon-dary wall (5–10 μm thick and rigid).

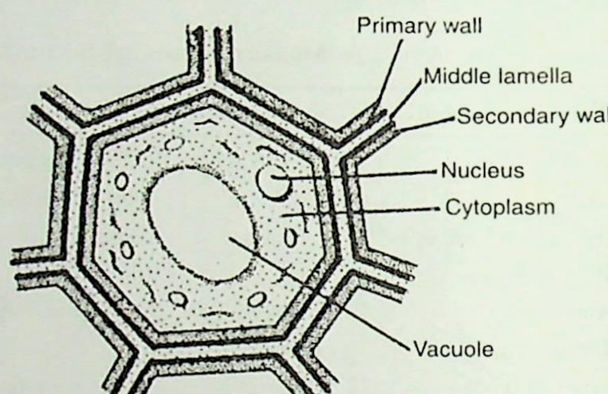


Fig. 1.1. A diagram of a typical cell showing position of cell wall and different components.

### Middle Lamella

The formation of this layer starts in the telophase stage of cell division and is formed by deposition. It works as a cementing layer between the two daughter cells and is called middle lamella. It consists of Ca and Mg pectates (composed of chains of hexuronic acids). Pectic substances are a mixture of polygalacturons (D-galacturonic acid) and polysaccharides (neutral sugars). This common layer between the two cells may be dissolved with the help of pectolytic enzymes and the two cells are separated. This is evident during the loosening of mature ripe fruits, which is the result of dissolution of middle lamella.

### Primary Wall

Bordering middle lamella, the primary wall is the first layer of individual cell, synthesised by protoplasm. In young enlarging cells, the primary wall remains thin and elastic becoming thick and rigid with the approach of cell maturity. The dry primary wall contains hemicellulose up to 50%, cellulose up to 25% and smaller amounts of pectic substances, non-cellulosic polysaccharides, fats and proteins. Hemicellulose is composed of complex polysaccharides (xylans, mannans, galactans, arabinogalactans, glucomannans) and forms the matrix of the wall in which cellulose microfibrils are embedded. The flexibility of primary cell wall during elongation is due to the presence of these pectic substances. In primary wall, the microfibrils are roughly transverse to the cell axis and do not show a longitudinal orientation at the cell corners. Primary wall layer is the principal wall layer of meristematic cells, chlorophyllous cells and true parenchyma.

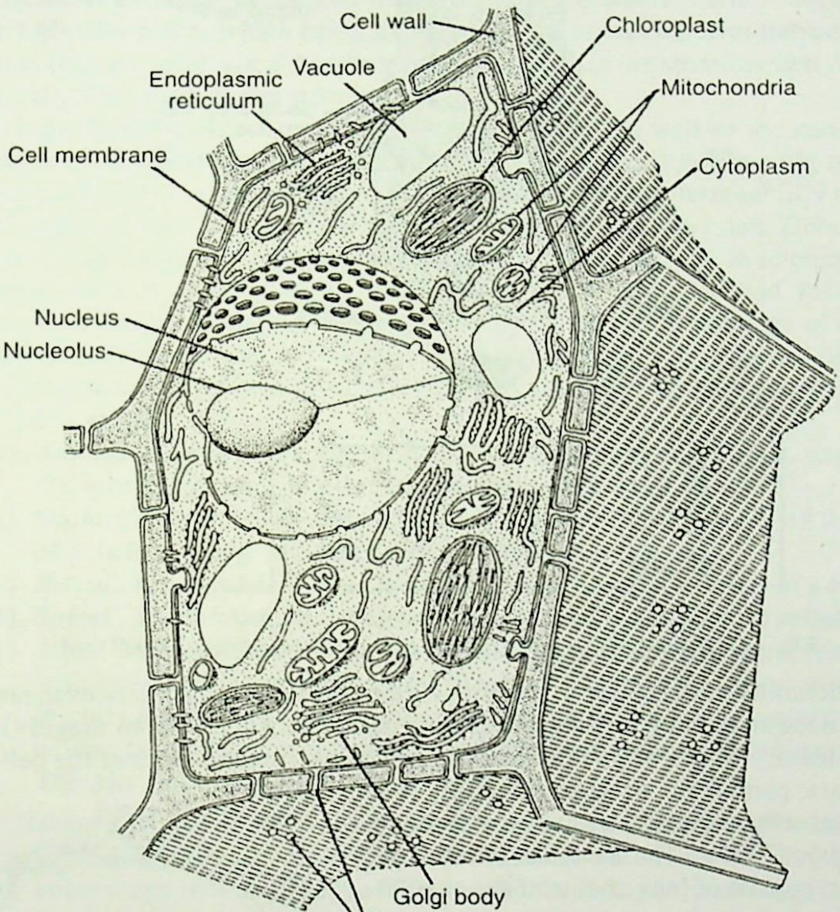


**Fig. 1.2.** A generalised diagram of a plant cell based on electron microscopic studies. The perforations on the wall indicate the sites of plasmodesmata.

### Secondary Wall

The formation of the secondary wall gives structural independence to the cell and provides rigidity to the wall. It is formed next to primary wall towards the protoplasm. The secondary wall mainly consists of a cellulosic or varying mixture of cellulose and non-cellulosic material.

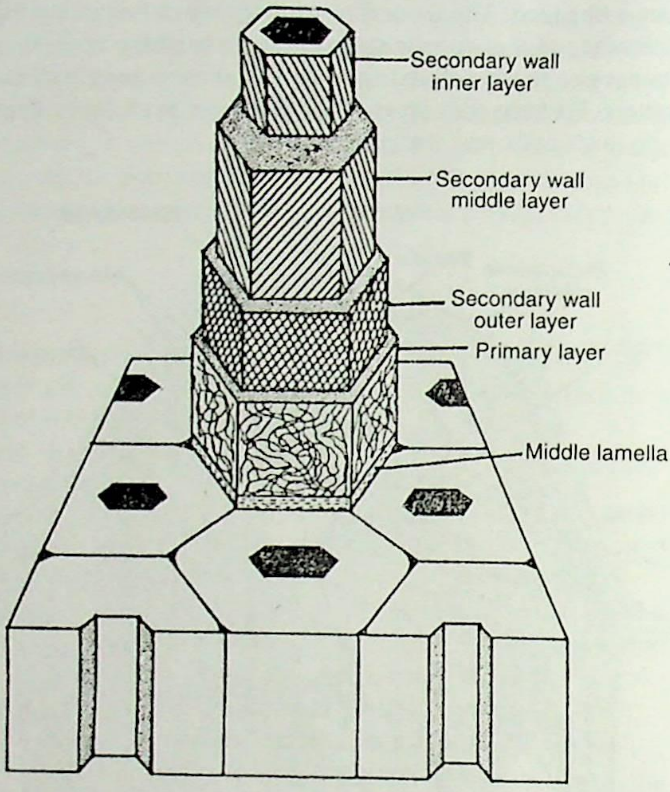


Fig. 1.3. Orientation of microfibrils in different layers of cell wall.

Structurally, the secondary wall may be thought of as a fine interwoven network of cellulose strands of varying complexity and size. According to Siegel (1962), the elementary fibrils or micelles are the smallest structural units of the cell wall. These are composed of approximately 100 individual cellulose chains with a cross-sectional area of about 3000 Å. The molecules of cellulose, however, consist of long chains of about 3000-6000 glucose units (hexose) and in the cell wall these units are associated parallel to one another to form microfibrils. Microfibrils in turn consist of smaller sub-units called micelles. About 20 micelles with a cross-sectional area of about 62,500 Å form a microfibril. Micelles and microfibrils are visible under the electron microscope. A co'ton fibre, visible to the naked eye has got as many as 1500 fibrils which contain about $7.5 \times 10^8$ individual cellulose chains. Albersheim (1965) has considered microfibril as the basic structural unit of a cell wall.

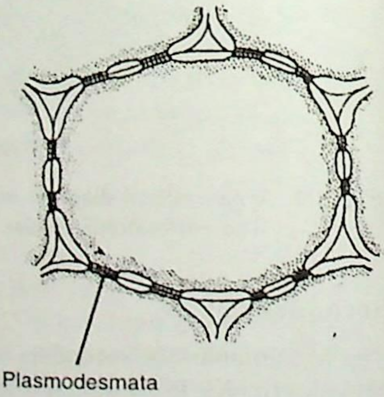


Fig. 1.4. A cell showing plasmodesmata.

In a typical secondary wall, three distinct layers are recognised with different arrangement of microfibrils. In the outer layer of the secondary wall two spirals of microfibrils may be seen forming a large angle with the cell axis. In the middle section, a steep spiral in addition to concentric rings of spirals can be observed and the inner layer is thought to have helical arrangement.

At places in the cell wall the deposition of material does not take place. These places are known as plasmodesmata through which contents of neighbouring cells remain in communication with each other.

**Chemical changes in the cell wall.** As the cell matures, various depositions on the wall take place, which bring about a change in its chemical nature. These chemical changes bring about a corresponding change in the structure and function of the cell. The various depositions are :

1. **Lignification.** The deposition of lignin on the cell wall or the conversion of cellulose into lignin is called lignification. As a result of lignification, the cells become hard, thick walled and dead. The cell wall retains its permeability to some extent but mainly serves mechanical purpose, *e.g.* tracheids and vessels. Chemically, lignin is a polyalcohol comprising coumaryl, coniferyl and sinapyl. In sclerenchyma, the lignification is uniform all around the cell, but in tracheids and vessels the thickening is localised to specific areas. Usually, after the thickenings of the cell wall, the protoplasm of the cell diminishes in size and the cell becomes dead and rigid. These secondary depositions of lignin may form various patterns on the cell wall. These are :

(*i*) ***Annular*** or ***ring-like***– Lignin is deposited in the form of rings, one above the other along the interior of the secondary wall.

(*ii*) ***Scalariform*** or ***ladder-like***–Lignin is deposited in the form of the stèps of a ladder along the inner side of the cell wall.

(*iii*) ***Reticulate*** or ***net-like***–Lignin is deposited irregularly in the form of a network.

(*iv*) ***Spiral***– The thickenings of lignin are deposited in the form of spiral bands.

(*v*) ***Pitted***–The entire inner surface of the cell wall is thickened due to depositions, with small unthickened areas here and there. These unthickened areas lying in pairs are called pits. The two pits are separated from one another by a piece of the original cell wall called closing membrane or pit membrane. The pits may be simple or bordered type.

2. **Suberization.** The cell wall of cork cells and Casparian strips of endodermis get deposited with a layer of suberin by a process known as suberization. Suberin is light, impervious to water, hence a piece of cork floats in water and does not get wet. Chemically it is a polymerised form of suberic acid (a lipid derivative).

3. **Cutinization.** In some cells, in the outer layers of the cell wall, the cellulose gets converted to cutin by the process of cutinization. This forms a definite, impermeable layer on the cell wall known as cuticle. Cutinization of cell helps in checking evaporation of water. Chemically cutin consists of fatty acids. Cutin is commonly found deposited on the outer surface of the exposed green parts of a plant, *e.g.* epidermal cells of green stem and leaves.

4. **Mucilaginous changes.** Sometimes the cellulose is changed to mucilage which has the property of absorbing and retaining water. This forms a viscous, mucilaginous coating on the cell walls and helps to tide over dry conditions. Chemically,