LEC. 3 | COMPONENTS OF THE CELL (Pt.2)

The Structure and Function of the PLASMA MEMBRANE & CELL WALL

INTRODUCTION

CELLULAR ORGANIZATION

Every human cell has a plasma membrane, a nucleus, and cytoplasm. (Some exceptions to this rule exist. A mature erythrocyte, or red blood cell, eliminates its nucleus once development is complete. Thus, erythrocytes are *a nucleate*. Cells of skeletal muscle, liver, and other tissues may have up to 50 nuclei and are *multinucleate*.).

The major components of the cell are:

(1) **Cell Membrane** (**Plasma Membrane**), (2) **Cytoplasm**, (3) **Nucleus** and (4) **Organelles**.

The **Cell Membrane (Plasma Membrane)**, which surrounds the cell and keeps it intact, regulates what enters and exits a cell. The plasma membrane is a phospholipid bilayer that is said to be *semipermeable* because it allows certain molecules but not others to enter the cell. Proteins present in the plasma membrane play important roles in allowing substances to enter the cell.

The **Nucleus** is a large, centrally located structure that can often be seen with a light microscope. The nucleus contains the chromosomes and is the control center of the cell. It controls the metabolic functioning and structural characteristics of the cell.

The **Nucleolus** is a region inside the nucleus. The **Cytoplasm** is the portion of the cell between the nucleus and the plasma membrane. Cytoplasm is a gelatinous, semifluid medium that contains water and various types of molecules suspended or dissolved in the medium. The presence of proteins accounts for the semifluid nature of cytoplasm. The cytoplasm contains various **Organelles** (Table 1). Organelles are small, usually membranous structures that are best seen with an electron microscope. Each type of organelle has a specific function. For example, one type of organelle transports substances, and another type produces ATP for the cell. *Organelles* compartmentalize the cell, keeping the various cellular activities separated from one another. Just as the rooms in your house have particular pieces of furniture that serve a particular purpose, organelles have a structure that suits their function. Cells also have a **Cytoskeleton**, a network of interconnected filaments and microtubules in the cytoplasm. The name cytoskeleton is convenient in that it allows us to compare the cytoskeleton to our bones and muscles. Bones and muscles give us structure and produce movement. Similarly, the elements of the cytoskeleton maintain cell shape and allow the cell and its contents to move. Some cells move by using cilia and flagella, which are made up of microtubules.

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Table 1: Structures in Human Cells

Name of MEMBRANOUS STRUCTURES	Composition	Function
Plasma membrane	Phospholipid bilayer with embedded proteins	Cell border; selective passage of molecules into and out of cell; location of cell markers, cell receptors
Nucleus	Nuclear membrane (envelope) surrounding nucleoplasm, chromatin, and nucleolus	Storage of genetic information; control center of cell; cell replication
Nucleolus	Concentrated area of chromatin, RNA, and proteins	Ribosomal formation
Ribosome	Two subunits composed of protein and RNA	Protein synthesis
Endoplasmic reticulum	Complex system of tubules, vesicles, and sacs	synthesis and/or modification of proteins and other substances; transport by vesicle formation
Rough Endoplasmic Reticulum	Endoplasmic reticulum studded with ribosomes	Protein synthesis for export
Smooth Endoplasmic Reticulum	Endoplasmic reticulum without ribosomes	Varies: lipid and/or steroid synthesis; calcium storage
Golgi apparatus	Stacked, concentrically folded membranes	Processing, packaging, and distribution of molecules
Vacuole	Small membranous sac	Isolates substances inside cell
Vesicle	Small membranous sac	Storage and transport of substances in/out of cell
Lysosome	Vesicle containing digesting enzymes	Intracellular digestion; self-destruction of the cell
Peroxisome	Vesicle containing oxidative enzymes	Detoxifies drugs, alcohol, etc.; breaks down fatty acids
Mitochondrion	Inner membrane within outer membrane	Cellular respiration
Cytoskeleton	Microtubules, actin filaments	Shape of cell and movement of its parts
Cilia and flagella	9 - 2 pattern of microtubules	Movement by cell; movement of substances inside a tube
Centriole	9 - 0 pattern of microtubules	Formation of basal bodies for cilia and flagella; formation of spindle in cell division

THE PLASMA MEMBRANE (CELL MEMBRANE)

Each cell has a limiting boundary, the cell membrane, plasma membrane or **Plasmalemma**. It is a living membrane, outermost in animal cells but next to cell wall in plant cells. It is flexible and can fold in (as in food vacuoles of *Amoeba*) or fold out (as in the formation of pseudopodia of *Amoeba*). The plasma membrane is made of proteins and lipids and several models were proposed regarding the arrangement of proteins and lipids. The **fluid mosaic model** proposed by Singer and Nicholson (1972) is widely accepted. Our cells are surrounded by an outer plasma membrane. The plasma membrane separates the inside of the cell, termed the cytoplasm, from the outside. Plasma membrane integrity is necessary to the life of the cell. The plasma membrane is a phospholipid bilayer with attached (also called **peripheral**) or embedded (also called

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integral) proteins. The phospholipid molecule has a polar head and nonpolar tails (Fig. 3.2a). Because the polar heads are charged, they are hydrophilic (**water-loving**) and face outward, where they are likely to encounter a watery environment. The nonpolar tails are hydrophobic (**water fearing**) and face inward, where there is no water. When spherical bilayer because of the chemical properties of the heads and the tails. At body temperature, the phospholipid bilayer is a liquid; it has the consistency of olive oil, and the proteins are able to change their positions by moving laterally. The fluid-mosaic model, a working description of membrane structure, suggests that the protein molecules have a changing pattern (**form a mosaic**) within the fluid phospholipid bilayer (Fig. 1). Our plasma membranes also contain a substantial number of cholesterol molecules. These molecules stabilize the phospholipid bilayer and prevent a drastic decrease in fluidity at low temperatures. Short chains of sugars are attached to the outer surfaces of some protein and lipid molecules (called **glycoproteins** and **glycolipids**, respectively). These carbohydrate chains, specific to each cell, mark the cell as belonging to a particular individual. Such cell markers account for such characteristics as blood type or why a patient's system sometimes rejects an organ transplant. Some glycoproteins have a special configuration that allows them to act as a receptor for a chemical messenger such as a hormone. Some integral plasma membrane proteins form channels through which certain substances can enter cells, while others are carriers involved in the passage of molecules through the membrane.

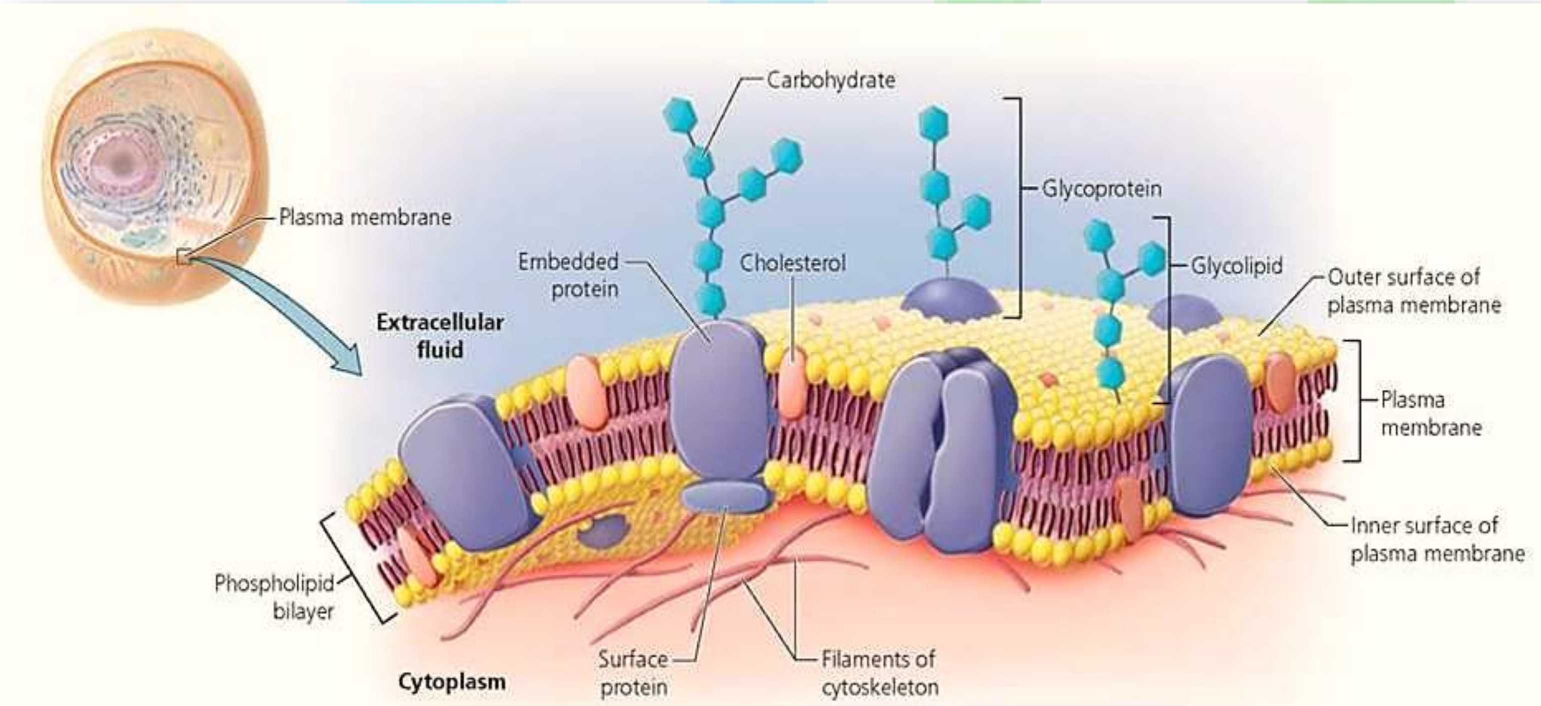

Fig. 1: Fluid-mosaic model of the plasma membrane. a. In the phospholipid bilayer, the polar (hydrophilic) heads project outward and the nonpolar (hydrophobic) tails project inward. b. Proteins are embedded in the membrane. Glycoproteins have attached carbohydrate chains, as do glycolipids.

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The outer walls of a house or car provide a strong, inflexible barrier that protects its human inhabitants from an unpredictable and harsh external world. You might expect the outer boundary of a living cell to be constructed of an equally tough and impenetrable barrier because it must also protect its delicate internal contents from a nonliving, and often inhospitable, environment. Yet cells are separated from the external world by a thin, fragile structure called the **Plasma Membrane** that is only 5 to 10 nm wide. It would require about five thousand plasma membranes stacked one on top of the other to equal the thickness of a single page of this book. Because it is so thin, no hint of the plasma membrane is detected when a section of a cell is examined under a light microscope. In fact, it wasn't until the late 1950s that techniques for preparing and staining tissue had progressed to the point where the plasma membrane could be resolved in the electron microscope. These early electron micrographs, such as those taken by J. D. Robertson of Duke University (Fig. 2), portrayed the plasma membrane as a three-layered structure, consisting of two darkly staining outer layers and a lightly staining middle layer. All membranes that were examined closely whether they were plasma, nuclear, or cytoplasmic membranes, or taken from plants, animals, or microorganisms showed this same ultrastructure. In addition to providing a visual image of this critically important cellular structure, these electron micrographs touched off a vigorous debate as to the molecular composition of the various layers of a membrane, an argument that went to the very heart of the subject of membrane structure and function.

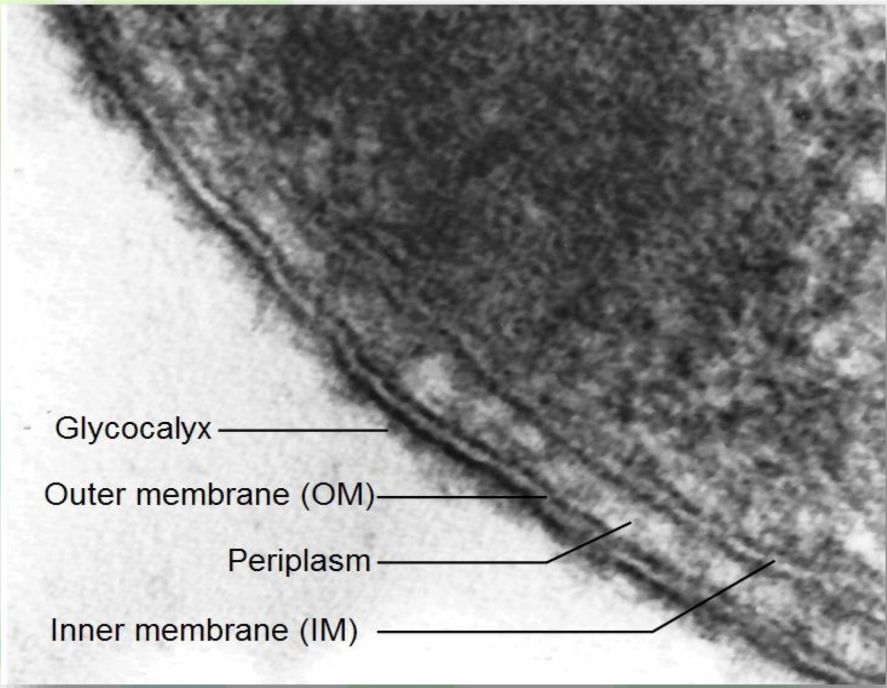

Fig. 2: The trilaminar appearance of membranes. Electron micrograph showing the three-layered (trilaminar) structure of the plasma membrane of an erythrocyte after staining the tissue with the heavy metal osmium.

AN OVERVIEW OF MEMBRANE FUNCTIONS

1. Compartmentalization.

Membranes are continuous, unbroken sheets and, as such, inevitably enclose compartments. The plasma membrane encloses the contents of the entire cell,

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whereas the nuclear and cytoplasmic membranes enclose diverse intracellular spaces. The various membrane-bound compartments of a cell possess markedly different contents. Membrane compartmentalization allows specialized activities to proceed without external interference and enables cellular activities to be regulated independently of one another.

2. Scaffold for biochemical activities.

Membranes not only enclose compartments but are also a distinct compartment themselves. As long as reactants are present in solution, their relative positions cannot be stabilized and their interactions are dependent on random collisions. Because of their construction, membranes provide the cell with an extensive framework or scaffolding within which components can be ordered for effective interaction.

3. Providing a selectively permeable barrier.

Membranes prevent the unrestricted exchange of molecules from one side to the other. At the same time, membranes provide the means of communication between the compartments hey separate. The plasma membrane, which encircles a cell, can be compared to a moat around a castle: both serve as a general barrier, yet both have gated “bridges” that promote the movement of select elements into and out of the enclosed living space.

4. Transporting solutes.

The plasma membrane contains the machinery for physically transporting substances from one side of the membrane to another, often from a region where the solute is present at low concentration into a region where that solute is present at much higher concentration. The membrane’s transport machinery allows a cell to accumulate substances, such as sugars and amino acids, which are necessary to fuel its metabolism and build its macromolecules. The plasma membrane is also able to transport specific ions, thereby establishing ionic gradients across itself. This capability is especially critical for nerve and muscle cells.

5. Responding to external signals.

The plasma membrane plays a critical role in the response of a cell to external stimuli, a process known as signal transduction. Membranes possess receptors that combine with specific molecules (or ligands) having a complementary structure. Different types of cells have membranes with different receptors and are, therefore, capable of recognizing and responding to different ligands in their environment.

The interaction of a plasma membrane receptor with an external ligand may cause the membrane to generate a signal that stimulates or inhibits internal activities. For

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example, signals generated at the plasma membrane may tell a cell to manufacture more glycogen, to prepare for cell division, to move toward a higher concentration of a particular compound, to release calcium from internal stores, or possibly to commit suicide.

6. Intercellular interaction.

Situated at the outer edge of every living cell, the plasma membrane of multicellular organisms mediates the interactions between a cell and its neighbors. The plasma membrane allows cells to recognize and signal one another, to adhere when appropriate, and to exchange materials and information.

7. Energy transduction.

Membranes are intimately involved in the processes by which one type of energy is converted to another type (energy transduction). The most fundamental energy transduction occurs during photosynthesis when energy in sunlight is absorbed by membrane-bound pigments, converted into chemical energy, and stored in carbohydrates. Membranes are also involved in the transfer of chemical energy from carbohydrates and fats to ATP. In eukaryotes, the machinery for these energy conversions is contained within membranes of chloroplasts and mitochondria.

Small molecules can be transported across the plasma membrane by any one of the following three methods:

(I) Diffusion:

Molecules of substances move from their region of higher concentration to their region of lower concentration. This does not require energy. Example: absorption of glucose in a cell.

(II) Osmosis:

Movement of water molecules from the region of their higher concentration to the region of their lower concentration through a semipermeable membrane. There is no expenditure of energy in osmosis. This kind of movement is along concentration gradient.

(III) Active Transport:

When the direction of movement of a certain molecules is opposite that of diffusion i.e. from region of their lower concentration towards the region of their higher concentration, it would require an “active effort” by the cell for which energy is needed. This energy is provided by ATP (adenosine triphosphate). The active transport may also be through a carrier molecule.

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TRANSPORT OF LARGE MOLECULES (BULK TRANSPORT)

During bulk transport the membrane changes its form and shape. It occurs in two ways:

(i) Endocytosis (taking the substance in)

(ii) Exocytosis (passing the substance out)

Endocytosis is of two types:

Endocytosis		
Phagocytosis	**Pinocytosis**	**Endocytosis**
intake of solid particles	intake of fluid droplets	intake metabolites, hormones, other proteins - and in some cases viruses
membrane folds out going round the particle, forming a cavity and thus engulfing the particle	. membrane folds in and forms a cup like structure sucks in the droplets	inward budding of plasma membrane vesicles containing proteins with **receptor** sites specific to the molecules being absorbed

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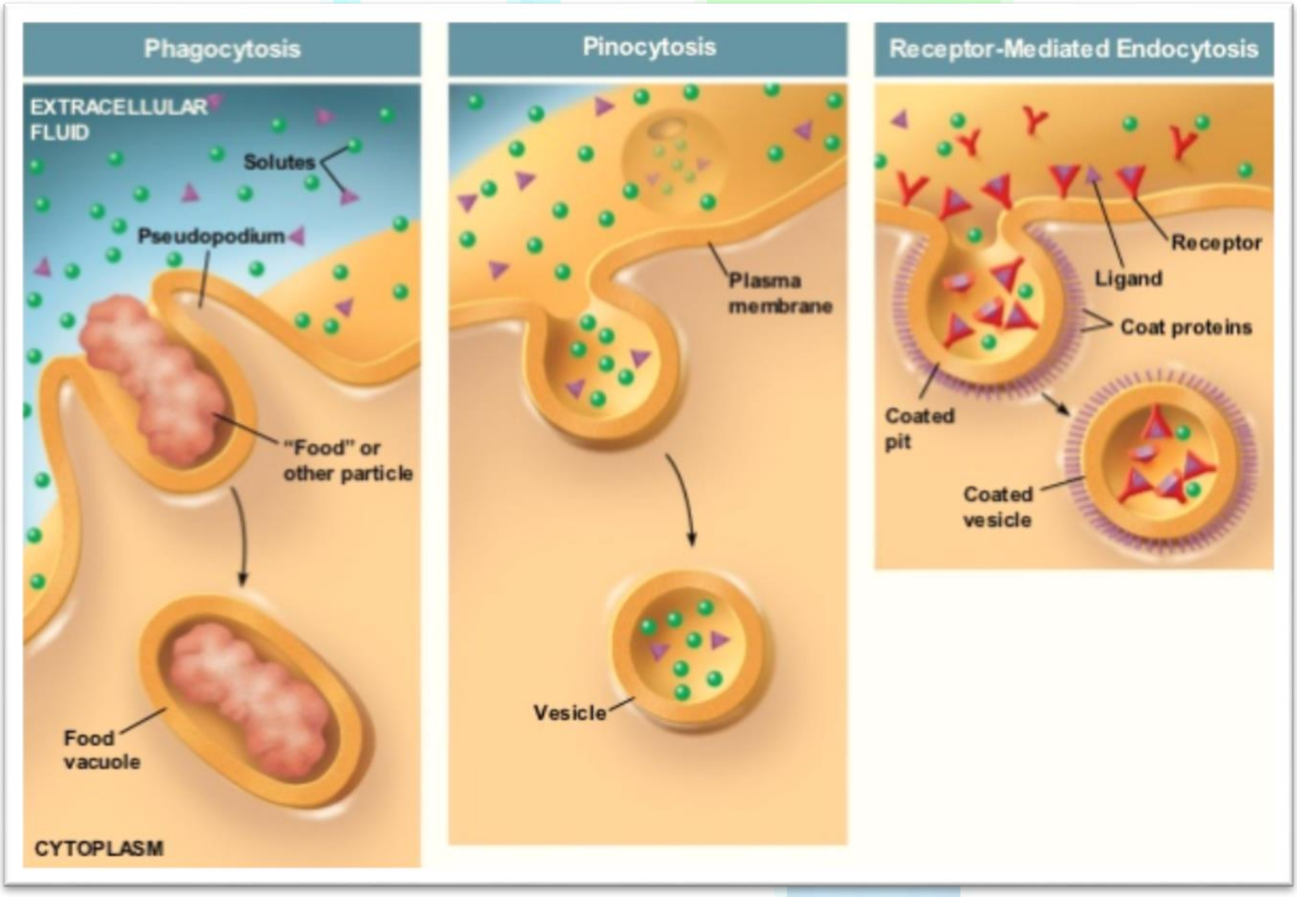
Cell membrane regulates movement of substance into and out of the cell. If the cell membrane fails to function normally the cell dies.

THE FUNCTIONS OF MEMBRANE PROTEINS

Depending on the cell type and the particular organelle within that cell, a membrane may contain hundreds of different proteins. Each membrane protein has a defined orientation relative to the cytoplasm, so that the properties of one surface of a membrane are very different from those of the other surface. This asymmetry is referred to as membrane "sidedness." In the plasma membrane, for example, those parts of membrane proteins that interact with other cells or with extracellular ligands, such as hormones or growth factors, project outward into the extracellular space, whereas those parts of membrane proteins that interact with cytoplasmic molecules,



such as G proteins or protein kinases, project into the cytosol. Membrane proteins can be grouped into three distinct classes distinguished by the intimacy of their relationship to the lipid bilayer. These are

1) Integral proteins

That penetrate the lipid bilayer. Integral proteins are **transmembrane proteins**; that is, they pass entirely through the lipid bilayer and thus have domains that protrude

from both the extracellular and cytoplasmic sides of the membrane. Some integral proteins have only one membrane-spanning segment, whereas others are multi spanning. Genome sequencing studies suggest that integral membrane proteins constitute about 30 percent of all encoded proteins.

2) Peripheral proteins

That are located entirely outside of the lipid bilayer, on the cytoplasmic or extracellular side, yet are associated with the surface of the membrane by noncovalent bonds.

3) Lipid-anchored proteins

That are located outside the lipid bilayer, on either the extracellular or cytoplasmic surface, but are covalently linked to a lipid molecule that is situated within the bilayer.

CELL WALL

INTRODUCTION

PLANT CELLS, UNLIKE ANIMAL CELLS, are surrounded by a relatively thin but mechanically strong cell wall. This wall consists of a complex mixture of polysaccharides and other polymers that are secreted by the cell and are assembled into an organized network linked together by both covalent and noncovalent bonds. Plant cell walls also contain structural proteins, enzymes, phenolic polymers, and other materials that modify the wall's physical and chemical characteristics. The cell walls of prokaryotes, fungi, algae, and plants are distinctive from each other in chemical composition and microscopic structure, yet they all serve two common primary functions: regulating cell volume and determining cell shape. As we will see, however, plant cell walls have acquired additional functions that are not apparent in the walls of other organisms. Because of these diverse functions, the structure and composition of plant cell walls are complex and variable. In addition to these biological functions, the plant cell wall is important in human economics. As a natural product, the plant cell wall is used commercially in the form of paper, textiles, fibers (cotton, flax, hemp, and others), charcoal, lumber, and other wood products. Another major use of plant cell walls is in the form of extracted polysaccharides that have been modified to make plastics, films, coatings, adhesives, gels, and thickeners in a huge variety of products.

The cell wall is the strong, outermost layer of a plant cell, located external to the plasma membrane. The cell wall often far outlives the protoplast which synthesized it. In cork, for example, the wall serves its particular biological role (physical protection of a tree trunk) for many years after the death of the protoplast. However, the walls of living cells are not inert ‘boxes’ but complex and dynamic subcellular compartments that play diverse and subtle roles in plant growth, development and defense. The walls range from ~ 0.1 to over 10 mm thick and are composed mainly of polysaccharides; they thus

differ fundamentally from cell membranes, which are 50.01 mm thick and composed of phospholipids and proteins.

THE STRUCTURE AND SYNTHESIS OF PLANT CELL WALLS

Without a cell wall, plants would be very different organisms from what we know. Indeed, the plant cell wall is essential for many processes in plant growth, Development, Maintenance, and Reproduction:

- Plant cell walls determine the **Mechanical Strength** of plant structures, allowing those structures to grow to great heights.
- Cell walls **Glue Cells Together**, preventing them from sliding past one another. This constraint on cellular movement contrasts markedly to the situation in animal cells, and it dictates the way in which plants develop.
- A tough outer coating **Enclosing the Cell**, the cell wall acts as a cellular "exoskeleton" that controls cell shape and allows high turgor pressures to develop.
- **Plant morphogenesis** depends largely on the control of cell wall properties because the expansive growth of plant cells is limited principally by the ability of the cell wall to expand.
- The cell wall is required for **Normal Water Relations** of plants because the wall determines the relationship between the cell turgor pressure and cell volume.
- The **Bulk Flow** of water in the xylem requires a mechanically tough wall that resists collapse by the negative pressure in the xylem.
- The wall acts as a **Diffusion Barrier** that limits the size of macromolecules that can reach the plasma membrane from outside, and it is a major structural barrier to pathogen invasion.

Much of the carbon that is assimilated in photosynthesis is channeled into polysaccharides in the wall. During specific phases of development, these polymers may be hydrolyzed into their constituent sugars, which may be scavenged by the cell and used to make new polymers. This phenomenon is most notable in many seeds, in which wall polysaccharides of the endosperm or cotyledons function primarily as food reserves. Furthermore, oligosaccharide components of the cell wall may act as important signaling molecules during cell differentiation and during recognition of pathogens and symbionts. The diversity of functions of the plant cell wall requires a diverse and complex plant cell wall structure. In this section we will begin with a brief description of the morphology and basic architecture of plant cell walls. Then we will discuss the organization, composition, and synthesis of primary and secondary cell walls.

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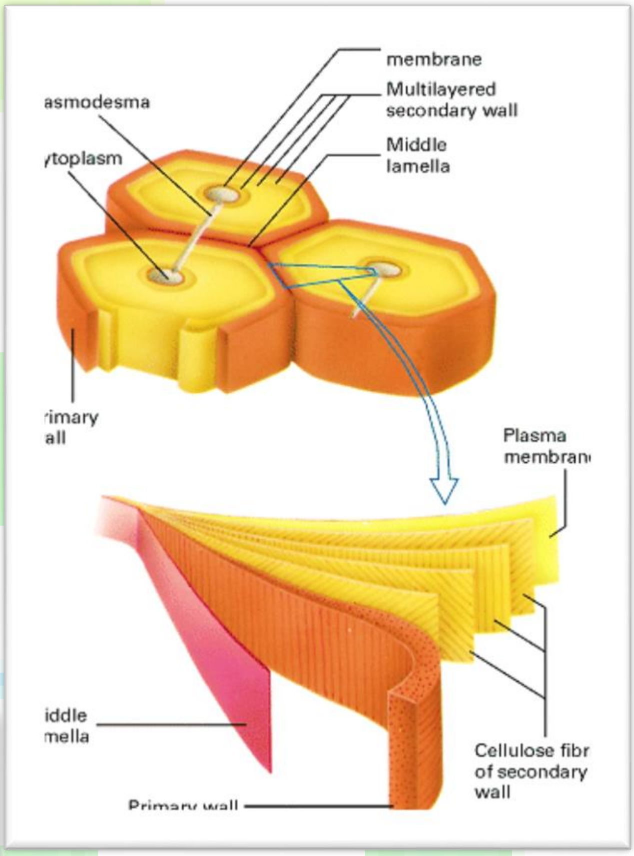
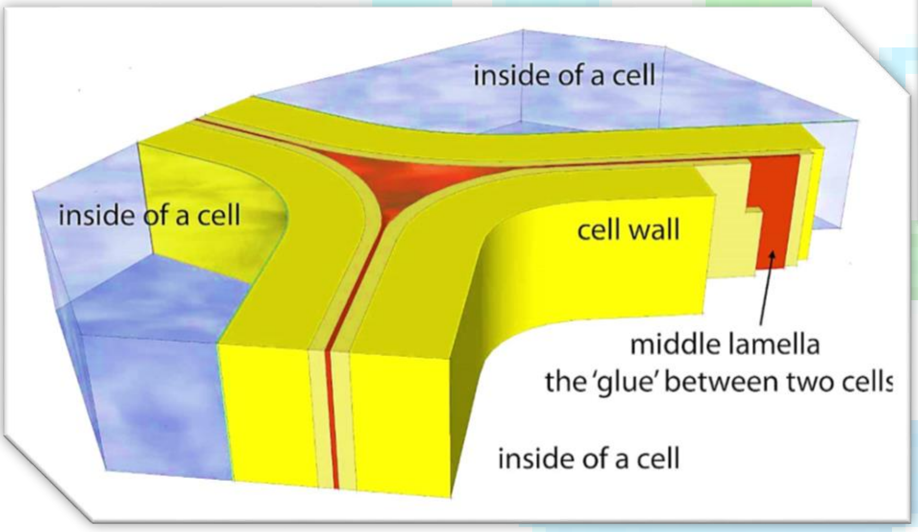
CELLULOSE CELL WALL

1. One of the most important features of **all** plants is presence of a **cellulose cell wall**.
2. Secreted by the cell itself. – In plant, made of cellulose but may also contain other chemical substance such as **pectin** and **lignin**.
3. Fungi such as Mushrooms and Yeast also have cell walls, but these are made of **chitin**.
4. The cell wall is **freely permeable** (porous), and so has no direct effect on the movement of molecules into or out of the cell.
5. The rigidity of their cell walls helps both to **support** and **protect** the plant.
6. Plant cell walls are of **two types:**





A. Primary (cellulose) cell wall - While a plant cell is being formed, a **Middle Lamella** made of Pectin, is formed and the cellulose cell wall develops between the middle lamella and the cell membrane. As the cell expands in length, more cellulose is added, enlarging the cell wall. When the cell reaches full size, a secondary cell wall **may** form.

B. Secondary (lignified) cell wall - The secondary cell wall is formed only in woody tissue (**mainly xylem**). The secondary cell wall is stronger and waterproof and once a secondary cell wall forms, a cell can grow no more.

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Functions of CELL WALL

1. The cell wall protects the delicate inner parts of the cell.
2. Being rigid, it gives shape to the cell.
3. Being rigid, it does not allow distension of the cell, thus leading to turgidity of the cell that is useful in many ways
4. It freely allows the passage of water and other chemicals into and out of the cells
5. There are breaks in the primary wall of the adjacent cells through which cytoplasm of one cell remains connected with the other. These cytoplasmic strands which connect one cell to the other one are known as plasmodesmata.
6. Walls of two adjacent cells are firmly joined by a cementing material called middle lamella made of calcium pectate.