Department of Genetics and Plant Breeding
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Plant Physiology: An Open Elective Course

(Study Material)

Cell physiology: Cell organelles and their physiological functions, structure and physiological functions of cell wall, cell inclusions, cell membrane structure and functions.
------(syllabus of Unit 1)

Suggested Readings

(i) Salisbury FB and Ross, CW (1986) Plant Physiology, CBS Publishers & Distributors, New Delhi.
(ii) Taize L and Zeiger E (2006) Plant Physiology. Sinauer Associates, Inc, Publishers, Sunderland, Massachusetts, USA.
(iii) Hopkins WG and Huner NPA (2004) Introduction to Plant Physiology. John Wiley & Sons.
(iv) Oxlade Edwin (2010) Plant Physiology: The Structure of Plants Explained. In-focus: Studymates.
(v) Lodish, H, et al. "The Dynamic Plant Cell Wall." *Molecular Cell Biology*. 4th ed., W. H. Freeman, 2000, www.ncbi.nlm.nih.gov/books/NBK21709/.
(vi) Young, Kevin D. "Bacterial Cell Wall." *Wiley Online Library*, Wiley/Blackwell (10.1111), 19 Apr. 2010, onlinelibrary.wiley.com/doi/abs/10.1002/9780470015902.a0000297.pub2.

Eukaryotic Cell Organelles

Eukaryotic cells are structurally complex, and by definition are organized, in part, by interior compartments that are themselves enclosed by lipid membranes that resemble the outermost cell membrane. The larger organelles, such as the nucleus and vacuoles, are easily visible with the light microscope. They were among the first biological discoveries made after the invention of the microscope.

Not all eukaryotic cells have each of the organelles listed below. Exceptional organisms have cells that do not include some organelles that might otherwise be considered universal to eukaryotes (such as mitochondria).[18] There are also occasional exceptions to the number of membranes surrounding organelles, listed in the tables below (e.g., some that are listed as double-membrane are sometimes found with single or triple membranes). In addition, the number of individual organelles of each type found in a given cell varies depending upon the function of that cell.

Details of major eukaryotic organelles

Organelle Name	Main Function	Structure	Occurrence in Organisms	Other Information
Cell membrane or plasma membrane	Separates the interior of all cells from the outside environment (the extracellular space) which protects the	two-dimensional liquid	all eukaryotes	

	cell from its environment.			
Cell wall (The outer covering of the cell that protects the plant cell and gives it shape is the cell wall)	Cell wall keeps the organelles inside the cell, and does not let the cell burst due to changes in osmotic pressure.	Cellulose. (The bacterial cell wall is composed of peptidoglycan)	plants, protists, rare kleptoplastic organisms	
Chloroplast (plastid)	Carry out photosynthesis, traps energy from sunlight	double-membrane compartment	plants, protists, rare kleptoplastic organisms	has own DNA; theorized to be engulfed by the ancestral eukaryotic cell (endosymbiosis)
Endoplasmic reticulum	Involved in translation and folding of new proteins (rough endoplasmic reticulum), expression of lipids (smooth endoplasmic reticulum)	single-membrane compartment	all eukaryotes	rough endoplasmic reticulum is covered with ribosomes, has folds that are flat sacs; smooth endoplasmic reticulum (without ribosomes) has folds that are tubular
Flagellum	locomotion, sensory	protein	some eukaryotes	
Golgi apparatus	Sorting, packaging, processing and modification of proteins	single-membrane compartment	all eukaryotes	cis-face (convex) nearest to rough endoplasmic reticulum; trans-face (concave) farthest from rough endoplasmic reticulum
Mitochondrion	Energy production from the oxidation of glucose substances and the release of adenosine triphosphate	double-membrane compartment	most eukaryotes	constituting element of the chondriome; has own DNA; theorized to have been engulfed by an ancestral eukaryotic cell (endosymbiosis)
Nucleus	DNA maintenance, controls all activities of the cell, RNA transcription	double-membrane bound compartment	all eukaryotes	contains bulk of genome—the hereditary/genetic material

Vacuole	storage, transportation, helps maintain homeostasis	single-membrane compartment	eukaryotes	

Minor eukaryotic organelles and cell components

Organelle/Macromolecule	Main function	Structure	Organisms
Acrosome	helps spermatozoa fuse with ovum	single-membrane compartment	most animals
Autophagosome	vesicle that sequesters cytoplasmic material and organelles for degradation	double-membrane compartment	all eukaryotes
Centriole	anchor for cytoskeleton, organizes assembly of microtubules / spindle fibres during cell division	Microtubule protein	• Animals
Cilium	movement in or of external medium; "critical developmental signaling pathway".[20]	Microtubule protein	animals, protists, few plants
Enidocyst	stinging	coiled hollow tubule	cnidarians
Eyespot apparatus	detects light, allowing phototaxis to take place		green algae and other unicellular photosynthetic organisms such as euglenids
Glycosome	carries out glycolysis	single-membrane compartment	Some protozoa, such as *Trypanosomes*.
Glyoxysome	conversion of fat into sugars	single-membrane compartment	plants
Hydrogenosome	energy & hydrogen production	double-membrane compartment	a few unicellular eukaryotes

Lysosome	breakdown of large molecules (e.g., proteins + polysaccharides)	single-membrane compartment	animals
Melanosome	pigment storage	single-membrane compartment	animals
Mitosome	probably plays a role in Iron-sulfur cluster (Fe-S) assembly	double-membrane compartment	a few unicellular eukaryotes that lack mitochondria
Myofibril	myocyte contraction	bundled filaments	animals
Nucleolus	Pre-ribosome production / synthesis	Circular structure with the nucleus, protein-DNA-RNA	most eukaryotes
Ocelloid	detects light and possibly shapes, allowing phototaxis to take place	double-membrane compartment	members of the family Warnowiaceae
parenthesome	not characterized	not characterized	fungi
peroxisome	breakdown of metabolic hydrogen peroxide	single-membrane compartment	all eukaryotes
proteasome	degradation of unneeded or damaged proteins by proteolysis	very large protein complex	all eukaryotes, all archaea, and some bacteria
Ribosome (80S)	Translation of RNA into proteins	Composed of RNA and proteins	all eukaryotes
Stress granule	mRNA storage	Membrane less (mRNP complexes)	most eukaryotes
TIGER domain	mRNA encoding proteins	membraneless	most organisms
vesicle	material transport	single-membrane compartment	all eukaryotes
Plasmodesmata	Allows molecules	These are the	Plants

	and communication signals to pass between individual plant cells	pores or channels between plant cell walls	

Cell Wall : Structure and Functions

A **cell wall** is a rigid, semi-permeable protective layer in some cell types. This outer covering is positioned next to the cell membrane (plasma membrane) in most plant cells, fungi, bacteria, algae, and some archaea. Animal cells however, do not have a cell wall. The cell wall has many important functions in a cell including protection, structure, and support.

Cell wall composition varies depending on the organism. In plants, the cell wall is composed mainly of strong fibers of the carbohydrate polymer **cellulose**. Cellulose is the major component of cotton fiber and wood, and it is used in paper production. Bacterial cell walls are composed of a sugar and amino acid polymer called **peptidoglycan**. The main components of fungal cell walls are **chitin**, glucans, and proteins.

Plant Cell Wall Structure

The plant cell wall is multi-layered and consists of up to three sections. From the outermost layer of the cell wall, these layers are identified as the middle lamella, primary cell wall, and secondary cell wall. While all plant cells have a middle lamella and primary cell wall, not all have a secondary cell wall.

- **Middle lamella:** This outer cell wall layer contains polysaccharides called pectins. Pectins aid in cell adhesion by helping the cell walls of adjacent cells to bind to one another.
- **Primary cell wall:** This layer is formed between the middle lamella and plasma membrane in growing plant cells. It is primarily composed of cellulose microfibrils contained within a gel-like matrix of hemicellulose fibers and pectin polysaccharides. The primary cell wall provides the strength and flexibility needed to allow for cell growth.
- **Secondary cell wall:** This layer is formed between the primary cell wall and plasma membrane in some plant cells. Once the primary cell wall has stopped dividing and growing, it may thicken to form a secondary cell wall. This rigid layer strengthens and supports the cell. In addition to cellulose and hemicellulose, some secondary cell walls contain lignin. Lignin strengthens the cell wall and aids in water conductivity in plant vascular tissue cell.

Characteristics of the primary cell wall:

- Found in all plants
- Elastic in nature and ranges between 1 and 3 um in thickness
- Fibrils are loosely arranged

- Elongates over time
- In the cells of dicot plants, the primary wall consists of about 30 percent pectic polysaccharides
- Consists of between 15 and 30 percent of cellulose
- Contains about 20 percent of proteins

Some of the main characteristics of the secondary cell wall include:

- Ranges between 5 and 10um in thickness
- Has a number of pores
- Is only present in some cells
- Water content ranges between 30 and 40 percent
- Microfibrils are elongated and compact

***** Secondary cell walls can be found in tracheids, sclereids and xylem fibers.

Plant Cell Wall Function

A major role of the cell wall is to form a framework for the cell to prevent over expansion. Cellulose fibers, structural proteins, and other polysaccharides help to maintain the shape and form of the cell. Additional **functions of the cell wall** include:

- **Support:** The cell wall provides mechanical strength and support. It also controls the direction of cell growth.
- **Withstand turgor pressure:** Turgor pressure is the force exerted against the cell wall as the contents of the cell push the plasma membrane against the cell wall. This pressure helps a plant to remain rigid and erect, but can also cause a cell to rupture.
- **Regulate growth:** The cell wall sends signals for the cell to enter the cell cycle in order to divide and grow.
- **Regulate diffusion:** The cell wall is porous allowing some substances, including proteins, to pass into the cell while keeping other substances out.
- **Communication:** Cells communicate with one another via plasmodesmata (pores or channels between plant cell walls that allow molecules and communication signals to pass between individual plant cells).
- **Protection:** The cell wall provides a barrier to protect against plant viruses and other pathogens. It also helps to prevent water loss.
- **Storage:** The cell wall stores carbohydrates for use in plant growth, especially in seeds.

The Cell Wall of Bacteria

Unlike in plant cells, the cell wall in prokaryotic bacteria is composed of **peptidoglycan**. This molecule is unique to bacterial cell wall composition. Peptidoglycan is a polymer composed of double-sugars and amino acids (protein subunits). This molecule gives the cell wall rigidity and helps to give bacteria shape. Peptidoglycan molecules form sheets which enclose and protect the bacterial plasma membrane.

The cell wall in **gram-positive bacteria** contains several layers of peptidoglycan. These stacked layers increase the thickness of the cell wall. In **gram-negative bacteria**, the cell wall is not as thick because it contains a much lower percentage of peptidoglycan. The gram-

negative bacterial cell wall also contains an outer layer of lipopolysaccharides (LPS). The LPS layer surrounds the peptidoglycan layer and acts as an endotoxin (poison) in pathogenic bacteria (disease causing bacteria). The LPS layer also protects gram-negative bacteria against certain antibiotics, such as penicillins.

Cell Wall Key Points

- The cell wall is an outer protective membrane in many cells including plants, fungi, algae, and bacteria. Animal cells do not have a cell wall.
- The main functions of the cell wall are to provide structure, support, and protection for the cell.
- The cell wall in plants is composed mainly of cellulose and contains three layers in many plants. The three layers are the middle lamella, primary cell wall, and secondary cell wall.
- Bacterial cell walls are composed of peptidoglycan. Gram-positive bacteria have a thick peptidoglycan layer and gram-negative bacteria have a thin peptidoglycan layer.

Cell Inclusions

Inclusions are stored nutrients, secretory products, and pigment granules in cytoplasm. They are also called as Ergastic substance or Deutoplastic substances , and are the products of cell metabolism, appearing and disappearing at various stages of cell's life-cycle. These ergastic substances may be present in the cell walls or vacuoles or in the organelles of protoplasm. They may be present in soluble or insoluble state and may be organic or inorganic in nature. **These substances belong to three categories:**

1. Reserve foods : Starch grains, glycogen granules, fat droplets (largely found in endosperm of seeds, abundantly in oilseeds), aleurone grains (insoluble storage proteins occuring inside special leucoplasts called aleuroplasts, and in the outer endosperm cells of cereals, such as wheat, rice, maize grains.)

2. Inorganic Materials (Mineral matter): The accumulation of inorganic materials within the plant and their cells mostly takes place in the form of calcium salts or anhydrous silicate salts. One very important type of deposit is that of calcium oxalate which is common in plants of many families.

3. Secretory products: Such as **(i) colouring matter:** Green colouring matter because of the presence of chlorophyll a and chlorophyll b. Orange and yellow colouring matter occur due to yellow pigments, carotene and xanthophyll. The flowers and fruits become differently coloured because of the presence of carotene and xanthophyll. Blue, purple and pink colours are due to anthocyanin pigments which are found in vacuolar sap of fruits and petals of flowers and young leaves of some plants. **(ii) enzymes:** Enzymatic proteins occur in colloidal state in the protoplasm including cell organelles. **(iii) nectars,** secreted by nectaries in plants.

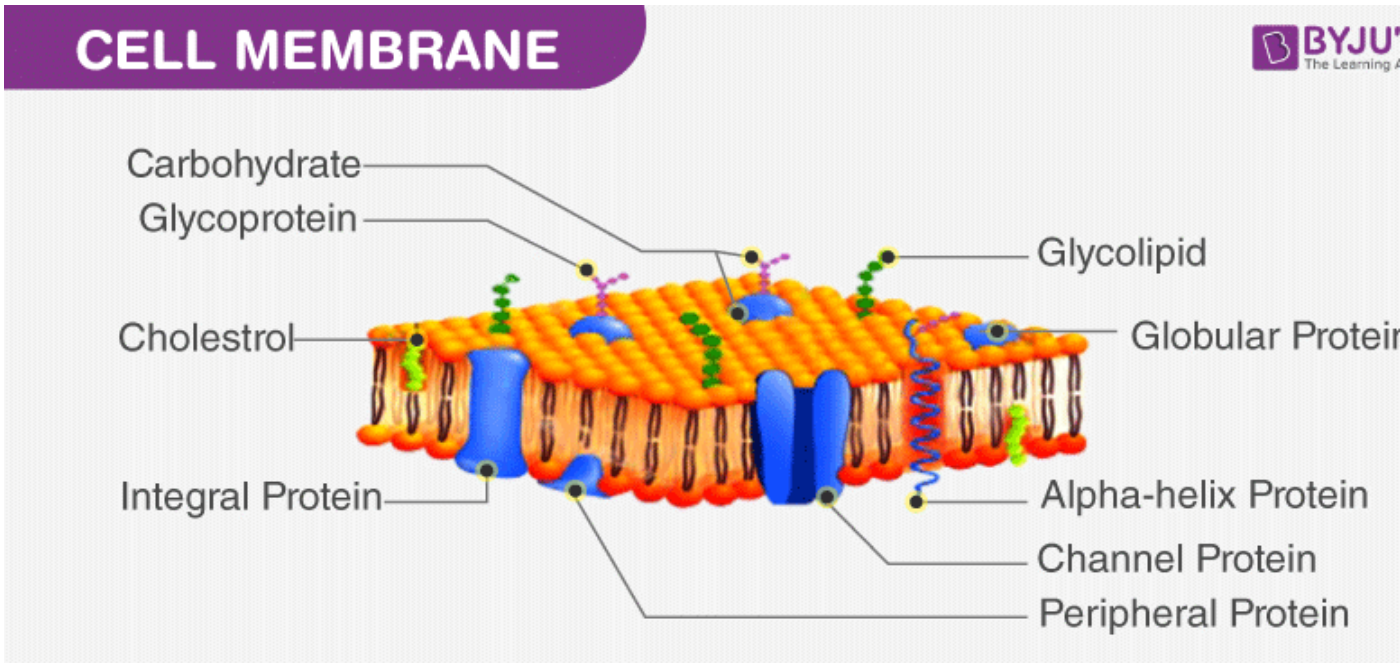
(iv) **excretory products,** such as alkaloids, glucosides, tannins, latext, essential oils, rasins, gums, organic acids, etc.

Cell membrane structure and functions

The cell membrane is **the** semi-permeable **structure** that surrounds **the cell**. Something that is semi-permeable will allow specific substances to pass through it while preventing **the** passage of other substances. **Plant cell membranes** are found between **the cell wall** and **cytoplasm**,

The cell membrane is also known as the plasma membrane. It is the outermost covering of animal cells. It is a semi-permeable membrane composed of lipids and proteins. The main functions of the cell membrane include:

1. Protecting the integrity of the interior cell.
2. Providing support and maintaining the shape of the cell.
3. Helps in regulating cell growth through the balance of endocytosis and exocytosis.
4. The cell membrane also plays an important role in cell signalling and communication.
5. It acts as a selectively permeable membrane by allowing the entry of only selected substances into the cell.



Cell Membrane is present in all organisms including plants

Difference between Cell Wall and Cell Membrane

One of the fundamental difference between the plasma membrane and the cell wall is in the type of organisms that they are found. The cell wall is present only in plants and the cell membrane is present in every living organism including plants.

CELL WALL	**CELL MEMBRANE**
Present only in plants, and in some fungi, bacteria, algae.	Present in all types of cells, in humans, animals, plants, bacteria, etc.
It is the outer non-living part of the cell but not an organelle which encloses cell membrane and provides a fixed shape.	It is an outermost, flexible, living organelle of the cell which provides shape to the cell.
It is made up of pectin, chitin, lignin, glycol proteins, glycolipids, sugar, and cellulose.	It is a lipid bi layer. And is composed of lipo-proteins and carbohydrates.
The structure of the cell wall is 20- 80nm in thickness	The structure of the cell membrane is 7.5–10 nm in thickness
It is the thick and rigid structure with a fixed shape.	It is thin and delicate structure. It is flexible to change the shape as needed.
It protects the cell from the external environment.	It protects and maintains the internal environment of the cell.
The cell wall is elastic.	The cell membrane is non-elastic.
The cell wall is metabolically inactive	The cell membrane is metabolically active.
Cell wall lack receptors.	The cell membrane has receptors to receive signals from external chemicals.
The cell wall grows in thickness over time. Further, it occupies the whole cell in the plant as the cell ages and dies.	It is of the same thickness for the whole lifetime of the organism.
The cell wall is semi-permeable. It allows passage of substances with the size of 30-60 kD.	The membrane is permeable and controls the movement of the substance into and outside the cell. That is, it can allow water and other substance to pass through selectively.
Functions include protection from the external environment.	Functions include permeability, signal reception, motility conduction, cell division, sexual reproduction etc.

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