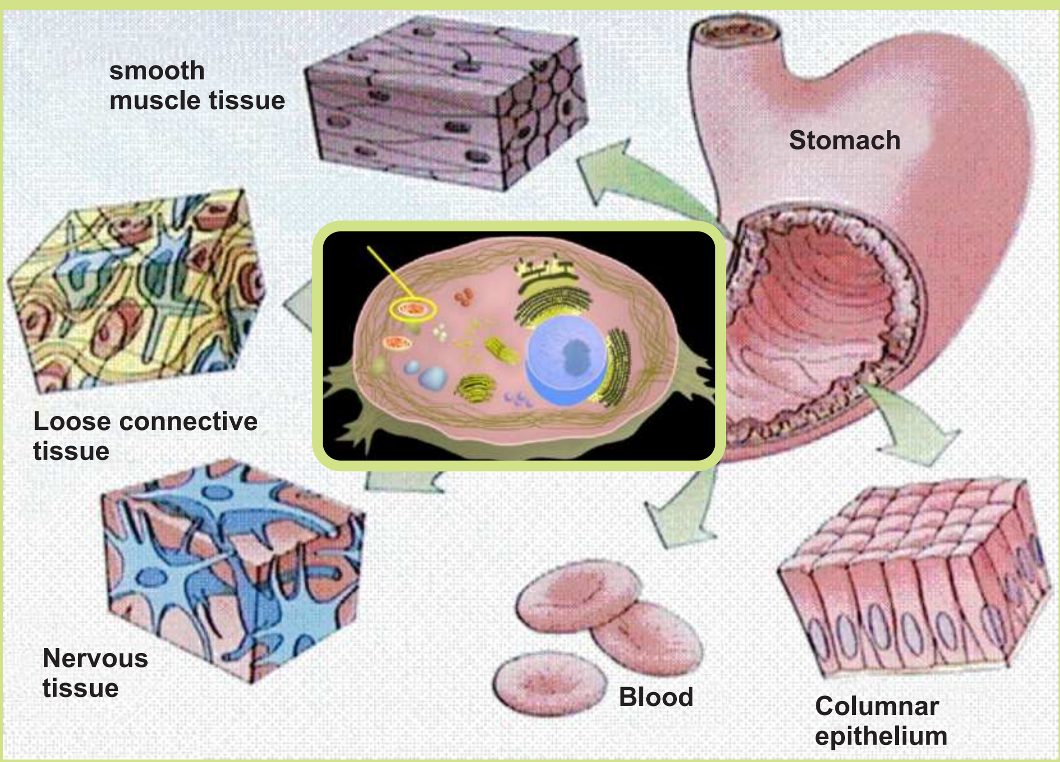
CELLS AND TISSUES

Chapter 4

Major Concept

In this Unit you will learn:

- Microscope and Emergence of Cell Theory
  - Light microscope and electron microscope
- Cellular Structures and Functions
  - Difference in prokaryotic and eukaryotic cells
  - Relationships between cells function and structure
- Cell size and shape as they relate to surface area to volume ratio
- Active and Passive Transport of Matter
  - Diffusion
  - Facilitated diffusion
  - Osmosis
  - Filtration
  - Active transport
  - Endocytosis
  - Exocytosis
- Tissues
  - Animal tissues
  - Plant tissues

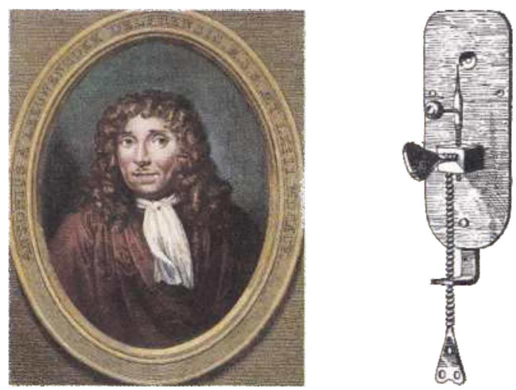


You could find cells just as intricately patterned and beautifully formed in any plant you looked at-from the rose in your backyard, to the grass growing up through the sidewalk, to the carrots you ate for a snack. Let's not limit it to plants, either: exquisite layers of cells can be found in your skin, in an insect's wing, and in just about any other living tissue you choose to look at. We, and the world around us, are made of cells. We just need some microscopy to appreciate it.

4.1 MICROSCOPE AND EMERGENCE OF CELL THEORY

Zacharias Janssen is generally believed to be the first investigator to invent the compound microscope in the 1590. It was simply a tube with lenses at each end and its magnification ranged from 3X to 9X.

Zacharias Janssen (1580-1638)



Van Leeuwenhoek's microscope

Robert Hooke had improved his version of the compound microscope to observe organisms.

Microscopes are instruments designed to produce magnified visual or photographic images of objects too small to be seen with the naked eye. There are two parameters especially important in microscopy; magnification and resolution.

Magnification: The enlargement of an image is called magnification. By combining a number of lenses in the correct manner, a microscope can be produced that will yield very high magnification values.

Resolution: The resolution of a microscope is defined as the smallest distance between two points on a specimen that can still be distinguished as two separate objects. It helps to measure clarity of object.

Both magnification and resolution are very important if you want a clear picture of something less than 0.1. For example, if a microscope has high magnification but low resolution, all you'll get is a bigger version of a blurry image.

4.1.1 Light microscope and electron microscope:

There are two microscopes are used in microscopy i.e. light microscope (LM) and electron microscope (EM).

(a) Light microscope:

In a light microscope, visible light passes through the specimen (the biological sample you are looking at). A photograph of an image taken through a microscope is called micrograph.

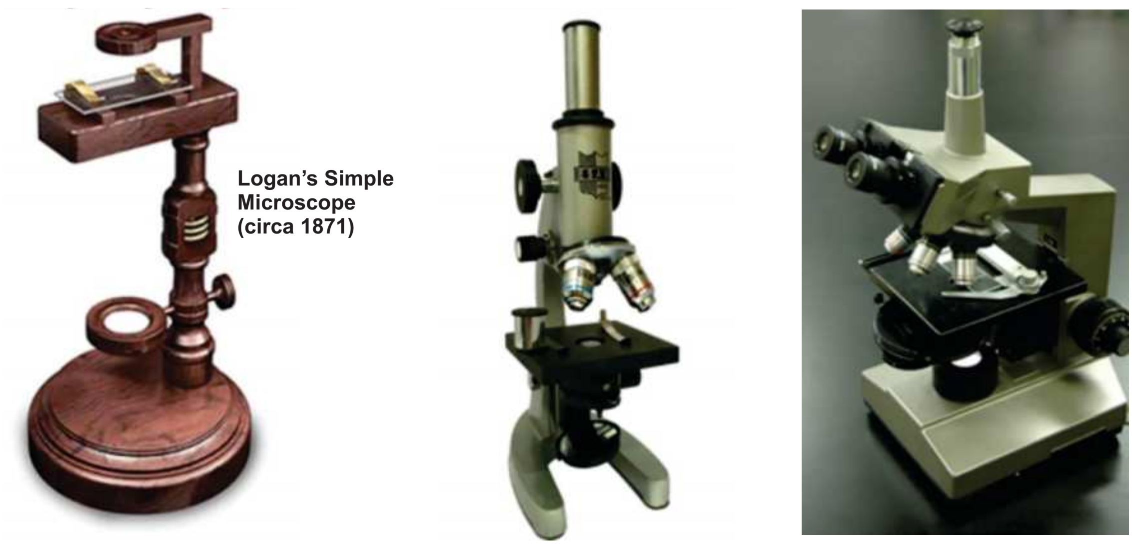


Figure 4.1 Light microscopes from simple to complex

The magnification of a light microscope is formed by using a mixture of the powers of the eye piece and the objective lens.

In order to ascertain the total magnification when viewing an image with a compound light micrscope, take the power of the objective lenses, which is at 4x, 10x, 40x and multiply it by the power of the eye piece which is typically 10x. Therefore, a 10x eyepiece used with a 10x objective lens will produce a magnification of 100x. This means that the object can be magnified, 40x, 100x or 400x.

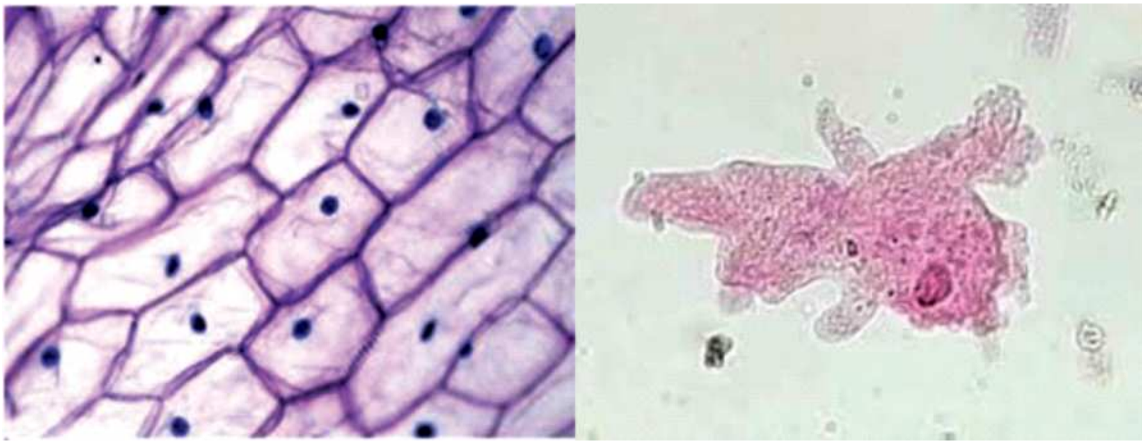


Figure 4.2 Light microscopic micrograph of onion cells and Amoebae

(b) Electron microscope:

Electron microscopes differ from light microscopes, that they produce an image of a specimen by using a beam of electrons rather than a beam of light. Electrons have a much shorter wavelength than visible light, and this allows electron microscopes to produce higher-resolution images than standard light microscopes. Electron microscopes can be used to examine not just whole cells, but also the subcellular structures and compartments within them. A live cell cannot be imaged by electron microscope.

Figure 4.3 Electronic microscope (TEM)

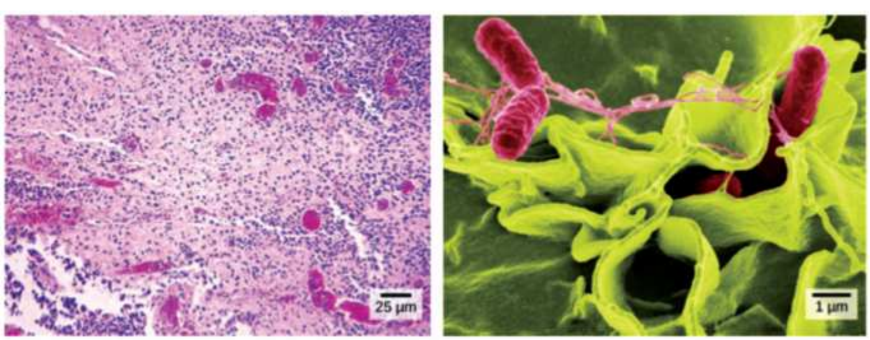


Figure 4.4 Salmonella bacteria under light micrograph (left) and through electron microscope (right).

Electron microscope has a resolution as small as 0.2 nanometer (nm) and magnification upto 250,000 times. There are two major types of electron microscopes.

1. Scanning electron microscopy (SEM)
2. Transmission electron microscopy (TEM)

In scanning electron microscopy, a beam of electrons moves back and forth across the surface of a cell or tissue, creating a detailed image of the 3D surface.

In transmission electron microscopy, in contrast, the sample is cut into extremely thin slices before imaging, and the electron beam passes through the slice rather than skimming over its surface. TEM is often used to obtain detailed images of the internal structures of cells.

Figure 4.5 SEM (left) and micrograph of Amphipod (right)

4.2 HISTORY OF THE DEVELOPMENT OF CELL THEORY

Ancient Greeks were the first to make comprehensive attempts to organize the data of the natural world. Aristotle presented an organized observation to support the idea that all animals and plants are somehow related. Later this idea gave rise to questions like 'is there a fundamental unit of structure shared by all organisms?" But before microscope was first used in 17th century, no one knew that living organisms do share a fundamental unit i.e. cell.

1665	Cell was first observed by ***Robert Hooke***, an English scientist, discovered a honeycomb-like structure in a cork slice using a primitive compound microscope. He only saw cell walls as this was dead tissue. He coined the term "cell" for these individual compartments he saw.
1670	First living cells were seen by ***Anton van Leeuwenhoek***, a Dutch biologist, from pond water with a microscope.
1683	**Miniature animals:** ***Anton van Leeuwenhoek*** made several more discoveries on a microscopic level, eventually publishing a letter to the Royal Society in which he included detailed drawings of what he saw. Among these was the first protozoa and bacteria discovered.
1833	The center of the cell was seen by ***Robert Brown***, an English botanist, discovered the nucleus in plant cells.
1839	**Cell theory:** ***Theodor Schwann***, a German botanist reached the conclusion that not only plants, but animal tissue as well is composed of cells.
1839	This ended debates that plants and animals were fundamentally different in structure. He also pulled together and organized previous statement on cells into one theory, which states: 1- Cells are organisms and all organisms consist of one or more cells. 2 - The cell is the basic structure unit for all organisms.
1840	Where does life come from ***Albrecht von Roelliker*** discovered that sperm and eggs are also cells.
1845	***Carl Heinrich Braun*** reworked the cell theory, calling cells the basic unit of life.
1855	3rd part to the cell theory added by ***Rudolf Virchow***, a German physiologist/physician/pathologist. Added that cell is not Denovo structure. This translates mean that all cells develop only from existing cells.
1862	***Louis Pasteur*** was a French biologist; microbiologist and chemist provided the experimental proof of this idea.

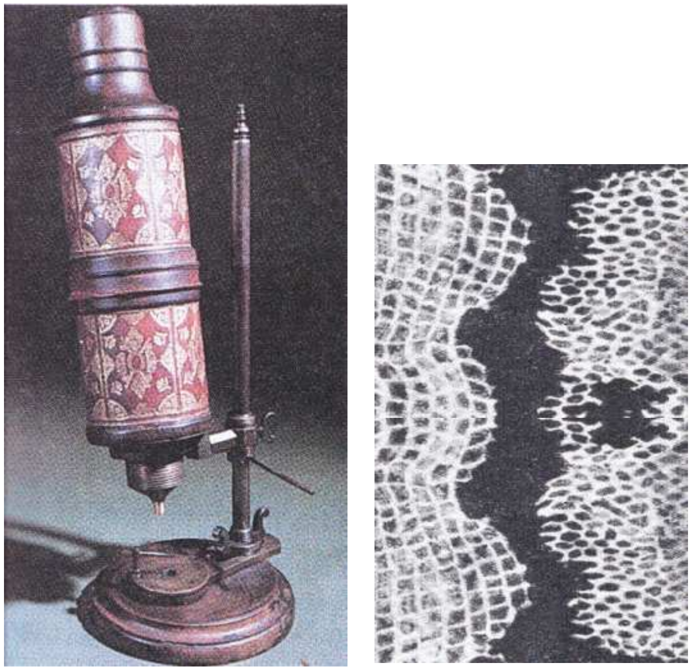


Figure 4.6 *Robert Hooke*, an English scientist, discovered a honeycomb-like structure in a cork slice using a primitive compound microscope.

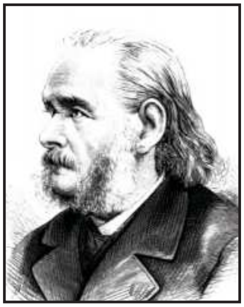
4.2.1 Cell theory:

One of the most important concepts in biology is that a cell is a basic structural and functional unit of living organism. This is known as a cell theory and was proposed jointly by two scientists in 1839. A Belgian Botanist called ***Schleiden*** and the German zoologist called ***Schwan***.

In 1855 ***Rudolf Virchow***, a German physicians proposed an important extension of cell theory-that all living cells arise from pre-existing.

The postulates of cell theory are:

1. All Living organisms are made of one or more cells.
2. The cell is the fundamental unit of structure and function in all living organisms.
3. The new cell is derived from pre-existing cells dividing into two by cell division.
4. The cell contains the hereditary material which is passed from generation to generation.



Mathias Jakob Schleiden

Theodor Schwann

Rudolf Virchow

Major contributors in the development of cell theory

Sub-cellular or Acellular Particles:

According to the first principle of the cell theory all organisms are composed of one or more cells.

Viruses, prions and viroids are not composed of cells rather they are sub-cellular or acellular particles but do not run any metabolic activity inside them. As they show some characteristics of living organisms i.e. they can increase in number and can transmit their characteristics to the next generations.

Cell:

Cells are the basic units of organisms and all tissues and organs are composed of cells. There are different types of cells. Cells can either be prokaryotic or eukaryotic. Eukaryotic cells have a proper nucleus and membrane bound organelles. Plant and animal cells are eukaryotes. Plant cells are generally a cubical shape while animal cells are usually spherical. Plant cells and animal cells have evolved different organelles to perform specific functions.

The activity of an organism depends on the total activity of independent cells. Energy flow occurs in cells through the breakdown of carbohydrates by respiration. Cells contain the information necessary for the creation of new cells. This information is known as 'hereditary information' and is contained within DNA. The contents of cells from similar species are basically the same.

DNA (the hereditary information of cells) is passed from 'parent' cells to 'daughter' cells during cell division.

Cells are the smallest form of life; the functional and structural units of all living things. Your body contains several billion cells, organized into over 200 major types, with hundreds of cell-specific functions.

Some functions performed by cells are so vital to the existence of life that all cells perform them (e.g. cellular respiration). Others are highly specialized (e.g. photosynthesis).

4.2.2 Comparison between Prokaryotes and Eukaryotes:

Organisms whose cells have a membrane bounded nucleus are called eukaryotes (from the Greek words **'Eu'** means well or truly and **'karyon'** means kernel or nucleus. Organisms whose cells do not have a membrane bounded nucleus are called prokaryotes (**'pro'** means before).

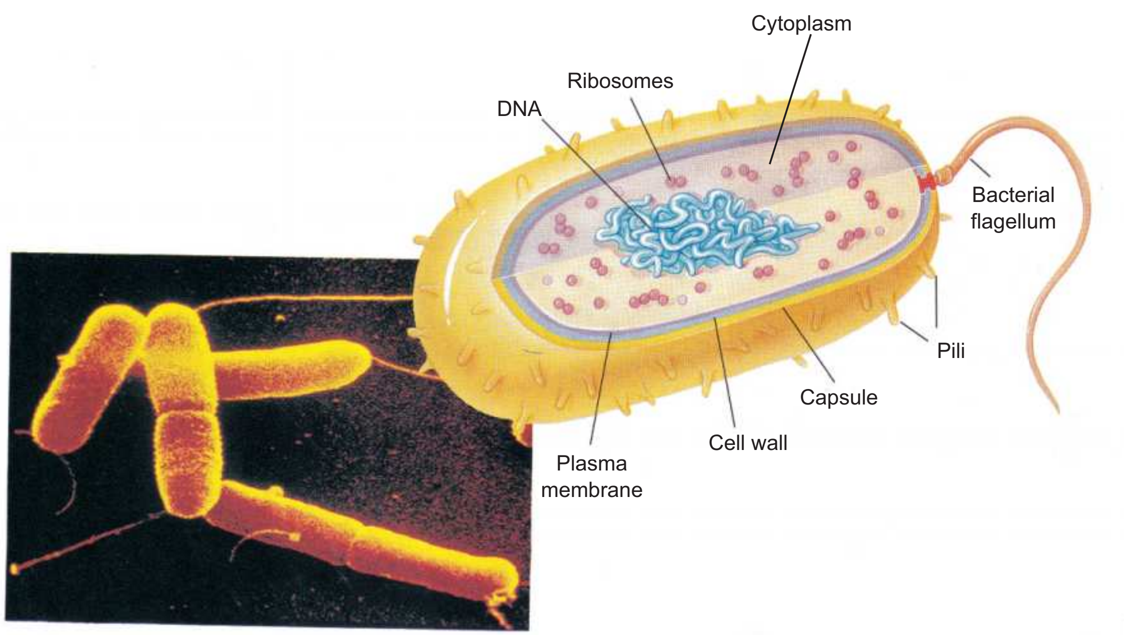


Figure 4.7 The structure of Bacterial Cell

Compare between prokaryotes and eukaryotes:

Cellular Structures	Prokaryotic cell	Eukaryotic cell
Example;	Bacteria and Cyanobacteria	Animals and plants
Nucleus	Without membrane	Membrane bounded
Number of chromosomes	One but not true chromosomes:	More than One
Number of cells	Unicellular	Unicellular and Multicellular
True membrane bound orgenelles	Absent	Present
Lysosomes and Peroxisome	Abscent	Present
Microtubules	Absent or rare	Present
Endoplasmic reticulum	Absent	Present
Mitochondria	Absent	Present
Ribosomes	Smaller 70S	Larger 80S
Vesicles	Present	Present
Golgi Apparatus	Absent	Present
Chloroplasts	Absent	Present (in plants)
Plasma membrane with steroid	Usually no	Yes
Permeability of nuclear membrane	Not present	Selective
Vacuoles	Absent	Present
Cell Size	1-10 µm	1-1000 µm
Flagella	Submicroscopic in size, composed of only one fiber	Microscopic in size; membrane bound

4.2.3 Cellular Structures and Functions:

We will now look at some of the basic cell structures and organelles in animal and plant cells. You will be noticed that there are key differences between plant and animal cells. The table below summarizes these differences.

Difference between animal and plant cell:

Animal Cells	Plants Cells
Do not contain plastids.	Almost all plants cells contain plastids such chloroplasts, chromoplasts and leucoplasts.
No cell wall.	Have a rigid cellulose cell wall in addition to the cell membrane.
Animals do not have plasmodesmata or pits.	Contain plasmodesmata and pits.
Few vacuoles (if any).	Large central vacuole filled with cell sap in mature cells.
Nucleus is generally found at the centre of the cytoplasm.	Nucleus is found near the edge or periphery of the mature cell.
Animal cells possess lysosomes which contain enzymes that digest cellular macromolecules.	Plant cells rarely contain lysosomes as the plant vacuole handles molecule degradation.
Animal cells contain these cylindrical structures that organize the assembly of microtubules during cell division.	Plant cells do not typically contain centrioles.

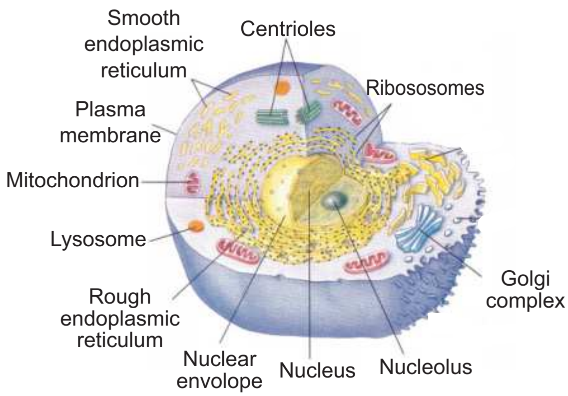


Figure 4.8 Animal cell

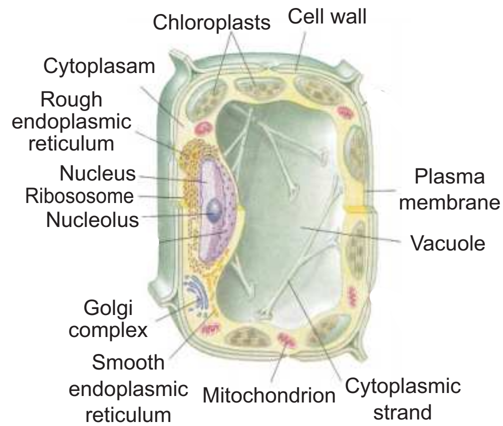


Figure 4.9 Plant cell

1. Cell wall:

A cell wall is a tough, rigid non-living and permeable protective layer in some cell types. This outer covering is positioned next to the cell membrane (plasma membrane) in plant cells, fungi, algae and bacteria. 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 cellulose. Bacterial cell walls are composed of a sugar and amino acid called peptidoglycan. The main components of fungal cell walls are chitin, glucans, and proteins.

In plants, the wall is composed of cellulose. It may consist up to three layers that help to support the plant. These layers include the middle lamella, the primary cell wall and the secondary cell wall.

Middle lamella: It separates one cell from another. It is a thin membranous layer on the outer side of the cell and is made of a sticky substance called pectin and cellulose.

Primary cell wall: It lies on the inside of the middle lamella and is mainly composed of cellulose.

Secondary cell wall: It lies along side the cell membrane. It is made up of a thick and tough material of cellulose which is held together by a hard, water proof substance called lignin. It is only found in cells which provide mechanical support in plants, i.e., Some cells of xylem like tracheid and vessels.

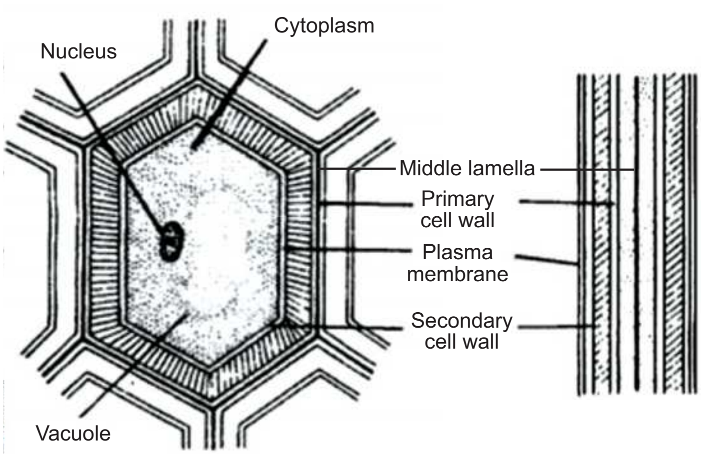


Figure 4.10 (a) Structure of cell wall

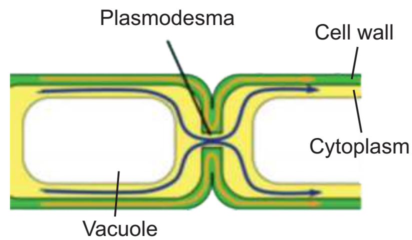


Figure 4.10 (b)
Cell wall showing plasmodesma

The openings in the cell wall are called **plasmodesmeta** which contain strands of cytoplasm that connect adjacent cells. This allows cells to interact with one another, allowing molecules to travel between plant cells.

The main function of the wall is to protect the inner parts of the plant cell, it gives plant cells a more uniform and regular shape and provides support for the plant body. The cell wall is completely permeable to water and mineral salts which allows distribution of nutrients throughout the plant.

2. Cell membrane:

The cell membrane is the outer most living boundary of all cells. The cell membrane, also called the plasma membrane, physically separates the intracellular space (inside the cell) from the extracellular environment (outside the cell). The cell membrane surrounds and protects the cytoplasm.

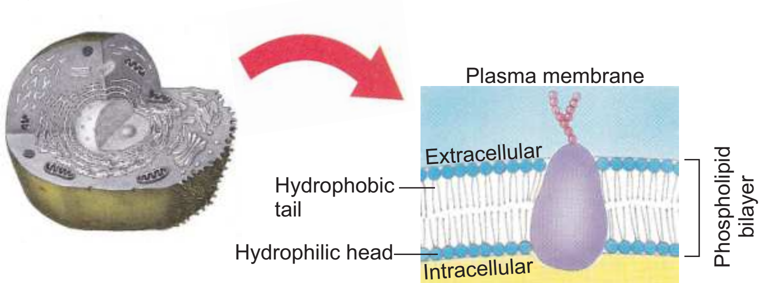


Figure 4.11 Cell membrane showing arrangment of phospholipid molecules in bilayers

The cell membrane is composed of a double layer (bilayer) of special lipids called phospholipids.

4.2.4 Structure of the cell membrane – the fluid mosaic model:

S.J. Singer and ***G.L. Nicolson*** proposed the Fluid Mosaic Model of the cell membrane in 1972. This model describes that phospholipid acting like matrix and conjugated glycoproteins (glucose and protein together) may float freely in this matrix.

This model describes the structure of the cell membrane as a fluid structure with various protein and carbohydrate components floating freely in the membrane. All the exchanges between the cell and its environment have to pass through the cell membrane. The cell membrane is selectively permeable to ions (e.g. hydrogen, sodium), small molecules (oxygen, carbon dioxide) and larger molecules (glucose and amino acids) and controls the movement of substances in and out of the cells. It performs many important functions within the cell such as osmosis, diffusion, transport of nutrients into the cell, processes of ingestion and secretion.

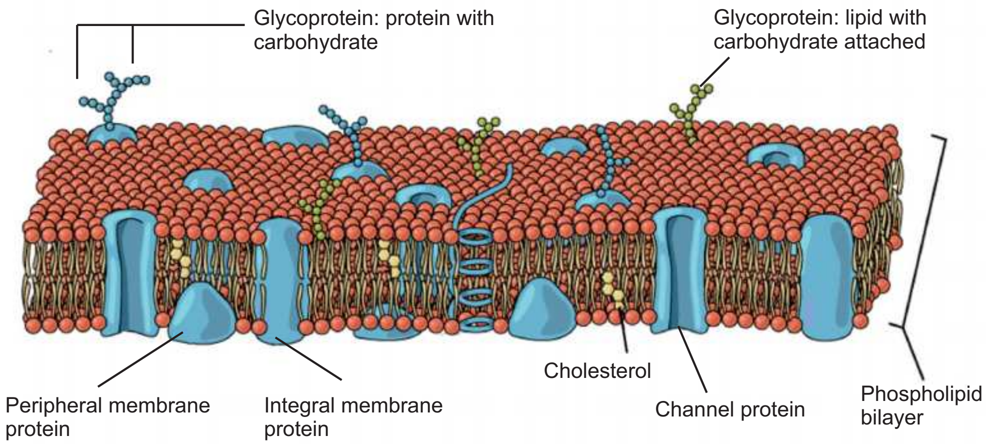


Figure 4.12 Section of cell-membrane

Movement across the membranes:

Movement of substances across cell membranes is necessary as it allows cells to acquire oxygen and nutrients, excrete waste products and control the concentration of required substances in the cell (e.g oxygen, water, hormones, ions, etc). This movement occurs by diffusion, osmosis, facilitated diffusion and active transport.

1. Diffusion:

Diffusion is the movement of substances from a region of high concentration to low concentration. It is therefore said to occur down a concentration gradient.

Diffusion is a passive process which means it does not require any energy input. It can occur across a living or non-living membrane and can occur in a liquid or gas medium. Examples diffusion of carbon dioxide, oxygen, water and other small molecules that are able to dissolve within the lipid bilayer.

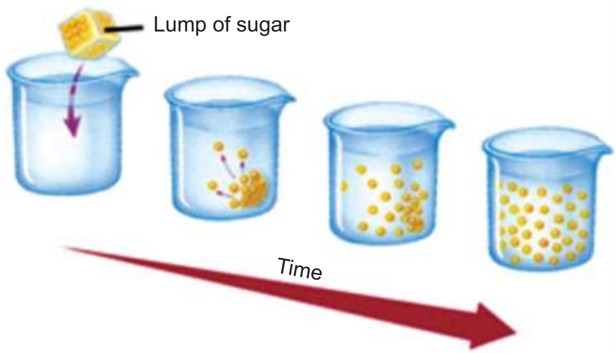


Fig 4.13 Diffusion:
The diagram shows the movement of dissolved particles within a liquid until eventually becoming randomly distributed.

2. Osmosis:

Movement of water always occurs down a concentration gradient, i.e., from dilute solution to concentrated solution. Osmosis is also a passive process and does not require any input of energy. Cell membranes allow molecules of water to pass through, but they do not allow molecules of most dissolved substances, e.g. salt and sugar, to pass through it.

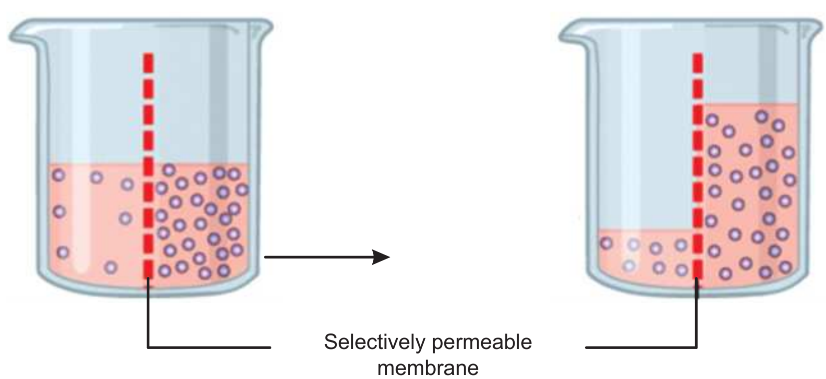


Fig 4.14 Osmosis

In biological systems, osmosis is vital to plant and animal cell survival. Figure 4.15 demonstrates how osmosis affects red blood cells and plant cell, when they are placed in three different solutions with different concentrations.

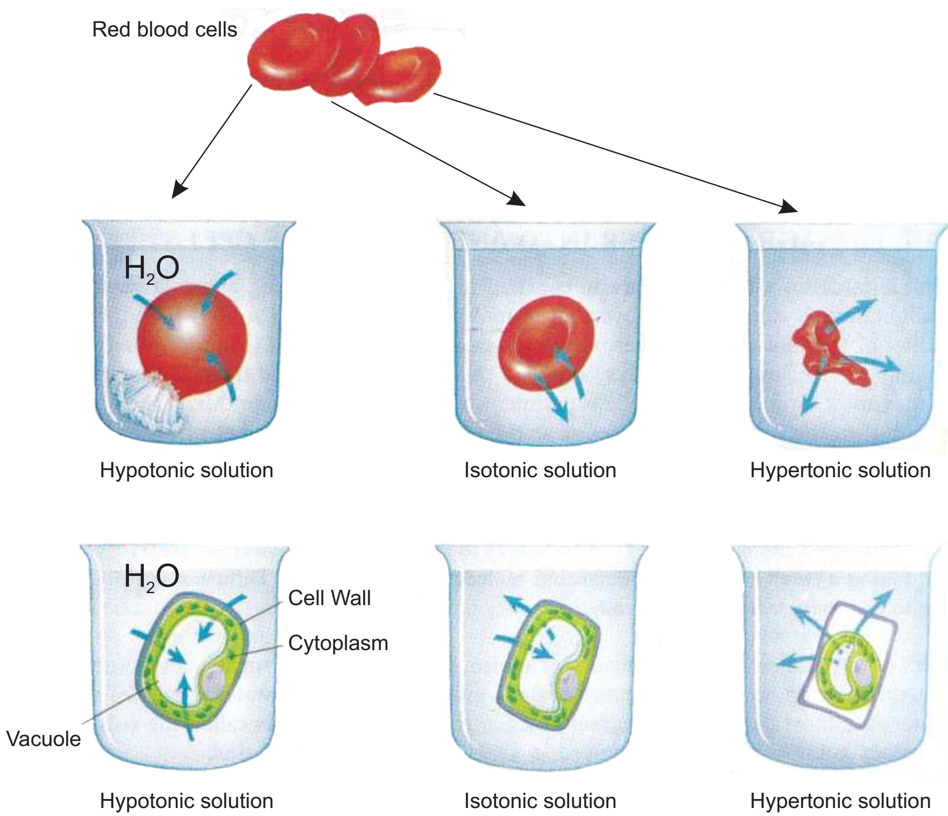


Figure 4.15 The effect of hypertonic, isotonic and hypotonic solutions on red blood cells and plant cell.

Plant cells use osmosis to absorb water from the soil and transport it to the leaves. In hypertonic conditions a plant cell loses water and cytoplasm shrinks and shrinkage of cytoplasm is called **plasmolysis**. Osmosis in the kidneys keeps the water and salt levels in the body and blood at the correct levels.

Activity: Predicting the direction of osmosis

Apparatus:

- Beaker
- Large potato
- Potato peeler/scalpel
- Pins
- Concentrated sucrose/sugar solution. To obtain this, add 100g of sugar to 200ml of water.

Procedure:

1. Peel off the skin of a large sized potato with a scalpel/potato peeler.
2. Cut its one end to make the base flat.
3. Make a hollow cavity in the potato almost to the bottom of the potato.
4. Add the concentrated sugar solution into the cavity of the potato, filling it about half way. Mark the level by inserting a pin at the level of the sugar solution (insert the pin at an angle into the cavity at the level) (A).
5. Carefully place the potato in the beaker containing water.
6. Observe what happens to the level of the sugar solution in the potato.
7. After 15 to 20 minutes, mark the level by inserting the second pin at the level of the sugar solution (insert as the first pin) (B).

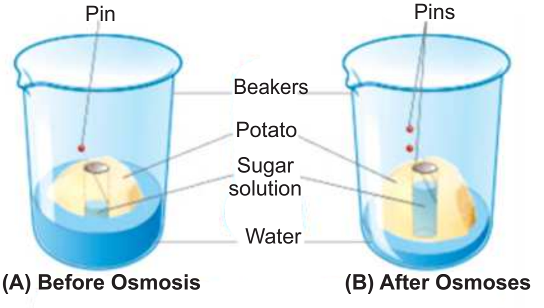


Figure 4.16 Potato Osmoscope

Questions

1. What do you observe happening to the level of the solution inside the potato?
2. What conclusion can you draw based on your observation?
3. What conditions were met in this experiment that makes this type of transport different to diffusion?

3. Facilitated diffusion:

Facilitated diffusion is a special form of diffusion which allows rapid exchange of specific substances. Particles are taken up by carrier proteins which change their shape as a result. The change in shape causes the particles to be released on the other side of the membrane.

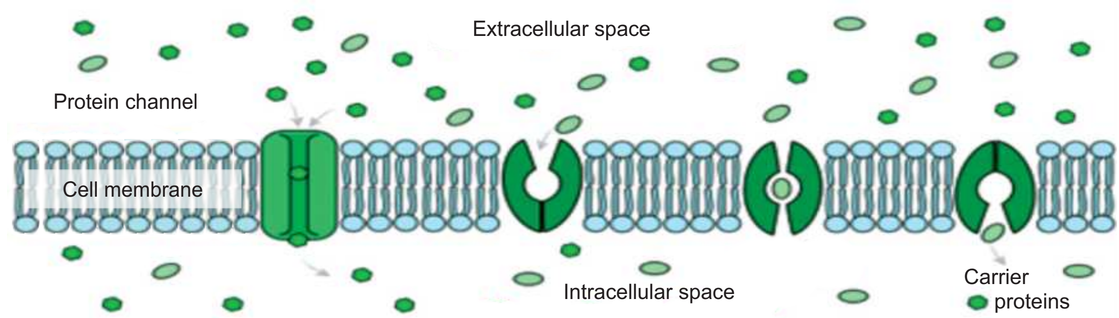


Figure 4.17 Facilitated diffusion in cell membrane, showing ion channels and carrier proteins

4. Active transport:

Active transport is the movement of substances against a concentration gradient, from a region of low concentration to high concentration using an input of energy. In biological systems, the form in which this energy occurs is adenosine triphosphate (ATP). Examples of substances moved include sodium and potassium ions as shown in Figure 4.18.

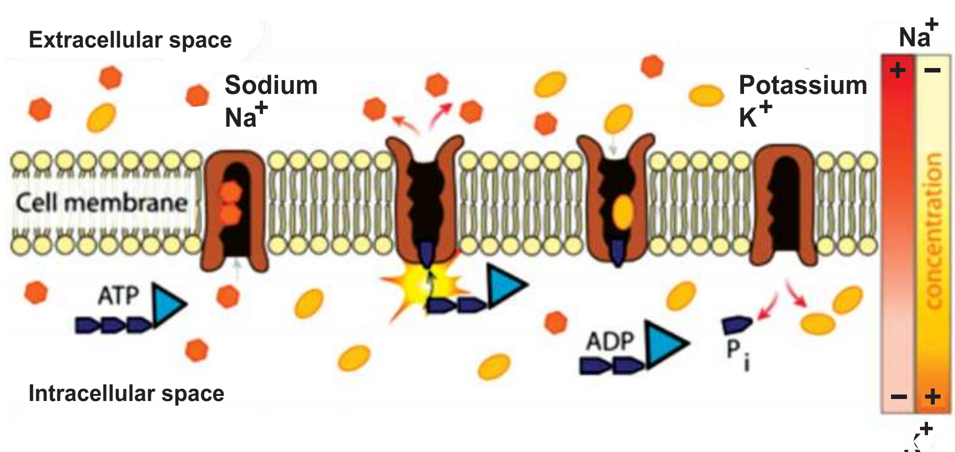


Figure 4.18 The sodium-potassium pump is an example of primary active transport.

ATP and ADP are molecules involved with moving energy within cells.

Cell organelles: We will now look at the key organelles that make up the cell. It is important to bear in mind that structure and function are closely related in all living systems. When studying each organelle, ensure that you observe the specific structures (from micrographs) that allow the organelle to perform its specific function.

Cytoplasm: The cytoplasm is the jelly-like substance that fills the cell. It consists of up to 90% water. It also contains dissolved nutrients and waste products. Its main function is to hold together the organelles which make up the cytoplasm. It also nourishes the cell by supplying it with salts and sugars and provides a medium for metabolic reactions to occur.

Cytoskeleton: A microscopic network of protein consists of microtubules and various filaments that spread out through the cytoplasm, providing both structural support and means of transport within the cell. Microtubules are made of tubulin while filaments made up of active protein.

Nucleus: The nucleus is the largest organelle in the cell and contains the entire cell's genetic information in the form of DNA. The presence of a nucleus is the primary factor that distinguishes eukaryotes from prokaryotes. Nucleus is covered by two phospholipids membranes known as nuclear envelope that separates the nucleus and its contents from the cytoplasm. Nuclear pores are found in the nuclear envelope and help to regulate the exchange of materials (such as RNA and proteins) between the nucleus and the cytoplasm. Inside nuclear envelope, a granular fluid is present called **nucleoplasm**. In nucleus an aggregation of RNA is also present called nucleolus. In non-dividing cell the genetic material is found in the form of net work in the nucleus called chromatin net work.

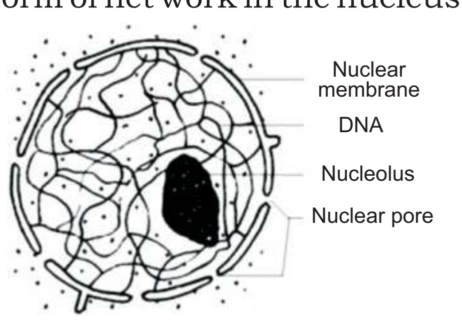


Figure 4.19 Schematic Diagram of nucleus

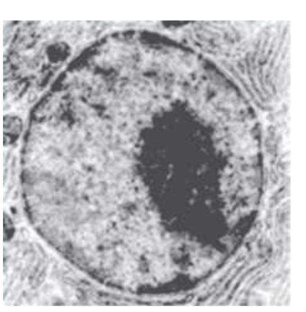


Figure 4.20 Micrograph of nucleus

Mitochondria (Singular; Mitochorion):

A mitochondrion is a membrane bound organelle found in eukaryotic cells. Mitochondria contain two phospholipid bilayers: there is an outer membrane, and an inner membrane. The inner membrane contains many folds called cristae which contain specialized membrane proteins that enable the mitochondria to synthesize ATP. Inside the inner membrane is a jelly-like matrix. The compartment, the compartments of the mitochondrion are shown in figure 4.21

Mitochondria is the site of aerobic respiration. During aerobic respiration energy is produced in the form of ATP. Therefore the Mitochondria is also called 'Power house' of cell.

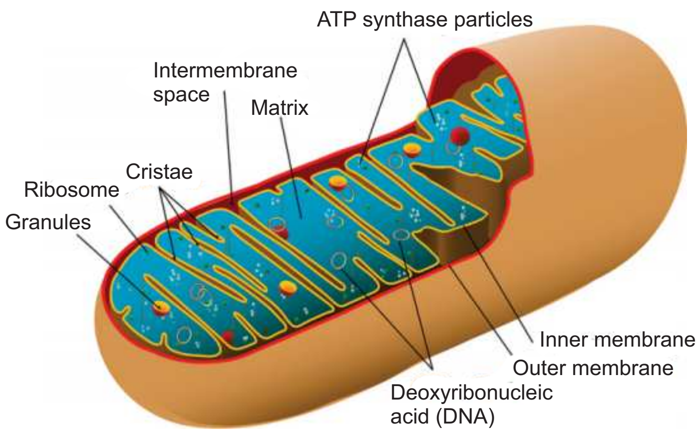


Figure 4.21 Mitochondria

Endoplasmic reticulum:

The endoplasmic reticulum (ER) is an organelle found in eukaryotic cells only. The ER has a double membrane consisting of a network of hollow tubes, flattened sheets, and round sacs. These flattened, hollow folds and sacs are called cisternae. The ER is located in the cytoplasm and is connected to the nuclear envelope. There are two types of endoplasmic reticulum: smooth and rough ER.

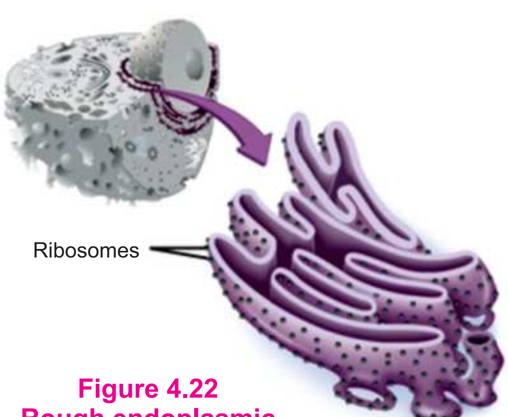


Figure 4.22 Rough endoplasmic reticulum

Smooth Endoplasmic Reticulum: does not have any ribosomes attached. It is involved in the synthesis of lipids, including oils, phospholipids and steroids. It is also responsible for metabolism of carbohydrates, regulation of calcium concentration and detoxification.

Rough Endoplasmic Reticulum: is covered with ribosomes giving the endoplasmic reticulum its rough appearance. It is responsible for protein synthesis and plays a role in membrane production. The folds present in the membrane increase the surface area allowing more ribosomes to be present on the ER, thereby allowing greater protein production.

Ribosomes:

Ribosomes are composed of RNA and protein. They occur in the cytoplasm and are the sites where protein synthesis occurs. Ribosomes may occur singly in the cytoplasm or in groups or may be attached to the endoplasmic reticulum thus forming the rough endoplasmic reticulum.

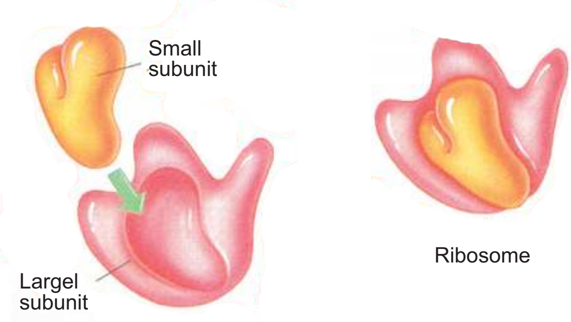


Figure 4.23
Structure of Ribosome

Golgi body:

The Golgi body was discovered by the Italian physician Camillo Golgi. It was one of the first organelles to be discovered and described in detail because its large size made it easier to observe. It is important for proteins to be transported through Golgi body from where they are synthesized to where they are required in the cell. The Golgi body is the sorting organelle of the cell.

The Golgi body consists of a stack of flat membrane-bound sacs called cisternae. The cisternae within the

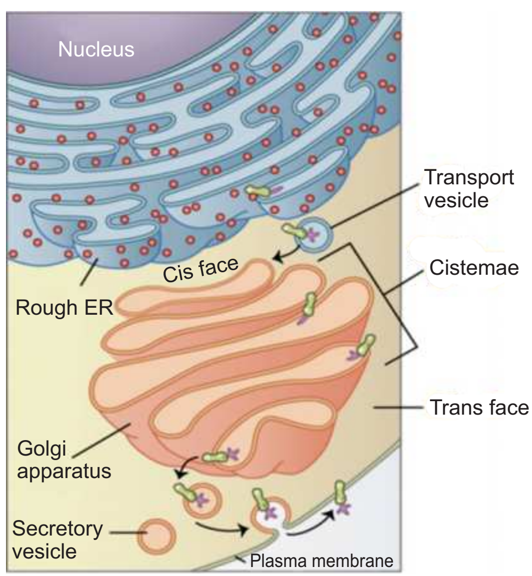


Figure 4.24 Golgi body

Golgi body consist of enzymes which modify the packaged products of the Golgi body.

Proteins are transported from the rough endoplasmic reticulum (RER) to the Golgi. In the Golgi, proteins are modified and packaged into vesicle. The Golgi body therefore receives proteins made in one location in the cell and transfers these to another location within the cell where they are required. For this reason the Golgi body can be considered to be the 'post office' of the cell.

Vesicles and lysosomes:

Vesicles are small, membrane-bound spherical sacs which facilitate the metabolism, transport and storage of molecules. Many vesicles are made in the Golgi body and the endoplasmic reticulum, or are made from parts of the cell membrane. Vesicles can be classified according to their contents and function. Transport vesicles transport molecules within the cell.

Lysosomes are formed by the Golgi body and contain powerful digestive enzymes that can potentially digest the cell. These powerful enzymes can digest cell structures and food molecules such as carbohydrates and proteins. Lysosomes are abundant in animal cells that ingest food through food vacuoles. When a cell dies, the lysosome releases its enzymes and digests the cell.

Vacuoles:

Vacuoles are fluid-filled spaces that occur in the cytoplasm of plant cells, but are very small or completely absent in animal cells. Plant cells generally have one large vacuole that takes up most of the cell's volume in mature cell. A selectively permeable boundary called the tonoplast, surround the vacuole. The vacuole contains cell sap which is a liquid consisting of water, mineral salts, sugars and amino acids. The vacuole plays an important role in hydrolysis, excretion of cellular waste, storage of water, organic and inorganic substances.

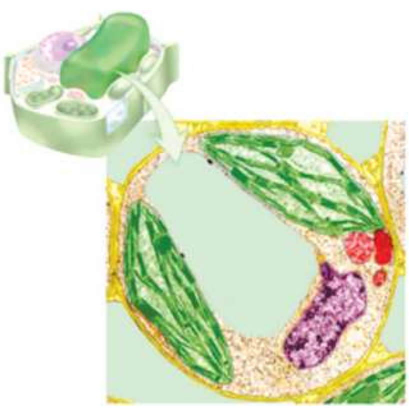


Figure 4.25 A vacuole

Centrioles:

Animal cells contain a special organelle called a centriole. The centriole is a cylindrical tube-like structure that is composed of 27 microtubules arranged in a very particular pattern of triplets in rows. The site where two centrioles arranged perpendicular to each other are referred to as a centrosome. The centrosome plays a very important role in cell division. The centrioles are responsible for organizing the microtubules that position the chromosomes in the correct location during cell division.

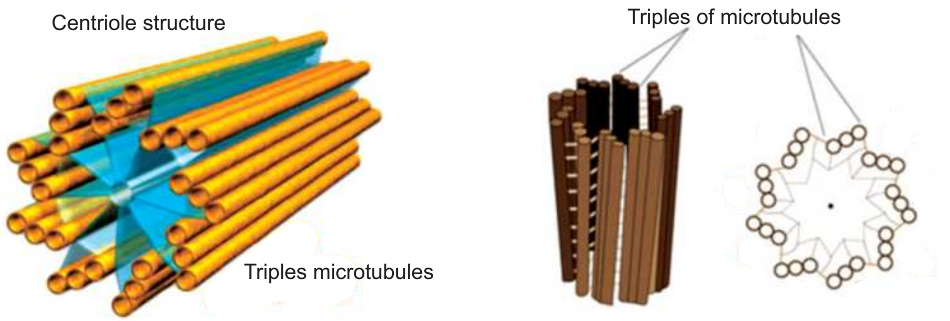


Figure 4.26 Centriole side view and pattern

Plastids

Plastids are large cytoplasmic and major organelles found in the cells of plants and algae. Plastids are the site of manufacture and storage of important chemical compounds used by the cell. Plastids often contain pigments used in photosynthesis, and the types of pigments present can change or determine the cell's colour. There are three different types of plastids:

Chloroplasts: Green-coloured plastids found in plants and algae.

Chromoplasts: Contain red, orange or yellow pigments and are common in ripening fruit, flowers or autumn leaves.

Leucoplasts: Colour less plastids.

The colour of plant flowers such as an orchid is controlled by a specialized organelle in a cell known as the chromoplast.

Chloroplast

The chloroplast is a double-membraned organelle. Within the double membrane is a gel-like substance called stroma. Stroma contains enzymes for photosynthesis. Suspended in the stroma are stack-like structures called grana (singular = granum). Each granum is a stack of thylakoid discs. The chlorophyll molecules (green pigments) are found on the surface of the thylakoid discs. Chlorophyll absorbs energy from the sun for photosynthesis.

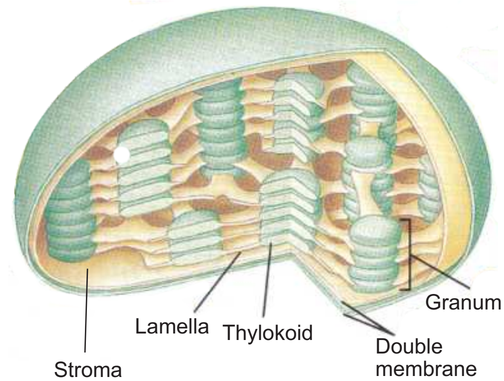


Figure 4.27 Structure of choloroplast

4.3 CELL SIZE AND SHAPE AS THEY RELATE TO SURFACE AREA TO VOLUME RATIO

Cells are microscopic mostly because of this constraint; there are some physiological limits to how big a cell can grow. The scale, or size of a cell compared to other objects, is incredibly small.

The smallest cells are bacteria called mycoplasmas, with diameter between 0.1 μm to 1.0 μm. The bulkiest cells are bird eggs, and the longest cells are some muscle cells and nerve cells. Most cells lie between these extremes. Cell size and shape are related to cell function. Bird eggs are bulky because they contain a large amount of nutrient for the developing young. Long muscle cells are efficient in pulling different body parts together. Lengthy nerve cells can transmit messages between different parts of body. On the other hand, small cell size also has many benefits. For example human red blood cells are only 8 μm in diameter and therefore can move through our tiniest blood vessels i.e. capillaries. Most cells are small in size. In relation of their volumes, large cells have less surface area as compared to small cells. Figure 4.28 Shows this relationship using cube-shaped cells. The figure shows 1 large cell and 27 small cells. In both cases, the total volume is same:

Volume = 30 μm X 30 μm X 30 μm = 27,000 μm^3

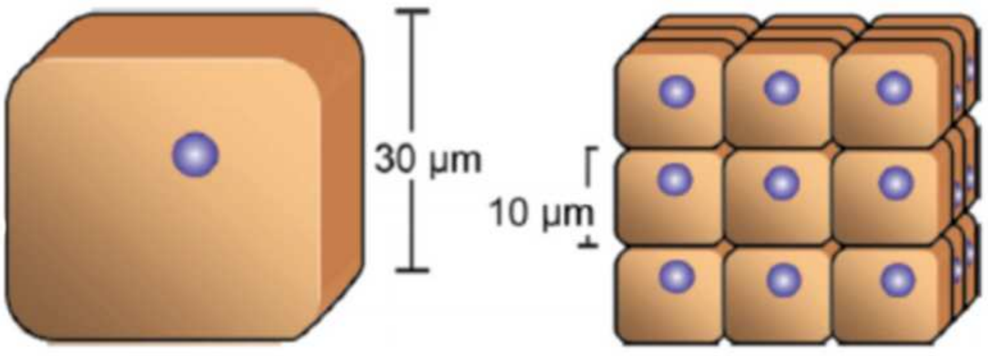
In contrast to the total volume, the total surface areas are very different. Because a cubical shape has 6 sides, its surface area is 6 times the area of 1 side.

The surface areas of cubes are as follows:

Surface area of 1 large cube = 6 X (30 μm X 30 μm) = 5400 μm^2

Surface area of 1 small cube = 6 X (10 μm X 10 μm) = 600 μm^2

Surface area of 27 small cubes = 27 X 600 μm^2 = 16, 200 μm^2



Surface area of one large cube = 5400 μm^2

Total surface area of 27 small cubes = 16,200 μm^2

Figure 4.28 Surface-area to volume ratio too small = decreased rate of chemical exchange ⟶ cell dies

Cell size and volume ratio:

Waste production and demand of nutrients are directly proportional to cell volume. Cell takes up nutrients and excretes wastes through its surface cell membrane. So a large volume cell demands large surface area but as the figure shows, a large cell has a much smaller surface area relative to its volume than smaller cells have. Each internal region of the cell has to be served by part of the cell surface. As a cell grows bigger, its internal volume enlarges and the cell membrane expands. Unfortunately, the volume increases more rapidly than does the surface area, and so the relative amount of surface area available to pass materials to a unit volume of the cell steadily decreases. Hence we conclude that the membranes of small cells can serve their volumes more easily than the membrane of a large cell.

In Life Sciences it is important to note that whenever a structure has an increased surface area, there is an increase in the functioning of that structure.

Activity 1: Examining plant cells under the microscope

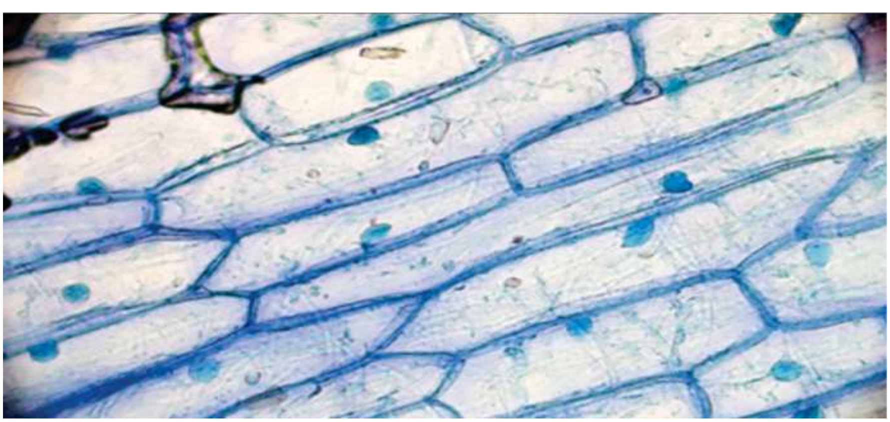
To study the microscopic structures of plant cells.

Apparatus:

- Onion
- Brushes
- Forceps
- Watch glass
- Blade
- Tissue paper
- Dropper
- Petri dish containing water
- Slides and coverslips
- Compound microscope
- Iodine solution

Procedure:

1. Peel off the outer most layer of an onion carefully, using a pair of forceps.
2. Place the peeled layer in a watch glass containing water. Make certain that the onion peel does not roll or fold.
3. Using a scalpel or a thin blade, cut a square piece of the onion peel (about $1cm^2$).
4. Remove the thin transparent skin from the inside curve of a small piece of raw onion and place it on a drop of iodine solution on a clean slide.
5. Cover the peel with a coverslip ensuring that no bubbles are formed.
6. Using a piece of tissue paper wipe off any excess iodine solution remaining on the slide.
7. Observe the onion skin under low power of the microscope and then under high power.
8. Draw a neat diagram of 5-10 cells of the typical cells you can see.



Onion cells stained with methylene blue.

Activity 2: Examining animal cells under the microscope

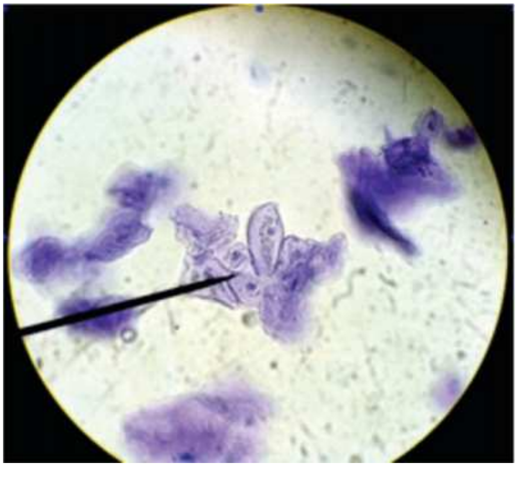
To study the microscopic structures of human cheek cells under a compound microscope.

Apparatus:

- Cotton bud
- Dropper
- Forceps
- Clean slide
- Water
- Microscope
- Methylene blue
- Tissue paper

Procedure:

1. Place a drop of water on a clean glass slide.
2. Using a clean ear bud, wipe the inside of your cheek. The ear bud will collect a moist film.
3. Spread the moist film on a drop of water on a clean glass slide, creating a small smear on the slide.
4. Use a coverslip to cover the slide gently.
5. Place one or two drops of stain on the side of the cover slip.
6. Use a piece of tissue to remove the excess dye.
7. Observe the cheek cells under low power magnification and then under high power magnification.



Cheek epithelial cells

Questions

1. What are the shapes of epidermal cells of the onion peel and the human cheek cells?
2. Why is iodine used to stain the onion peel?
3. What is the difference between the arrangement of cells in onion cells and in human cheek cells?
4. Why is a cell considered the structural and functional unit of living things?

4.4 ANIMAL AND PLANT TISSUES

We know the levels of organization where a group of similar cells that work together to perform a common function is known as a tissue. For instance, the cells in the small intestine that absorb nutrients look very different from the muscle cells needed for body movement.

(A) Animal tissues:

Humans and other large multicellular animals are made up of four basic types tissue: **epithelial** tissue, **connective** tissue, **muscular** tissue and **nervous** tissue.

1. Epithelial tissue:

Epithelial tissue covers the surface of the body, lines the spaces inside the body and forms glands. For instance, the outer layer of your skin is an epithelial tissue and the lining of small intestine are made up of epithelial tissues.

Epithelial cells are polarized, means that they have a top and a bottom side.

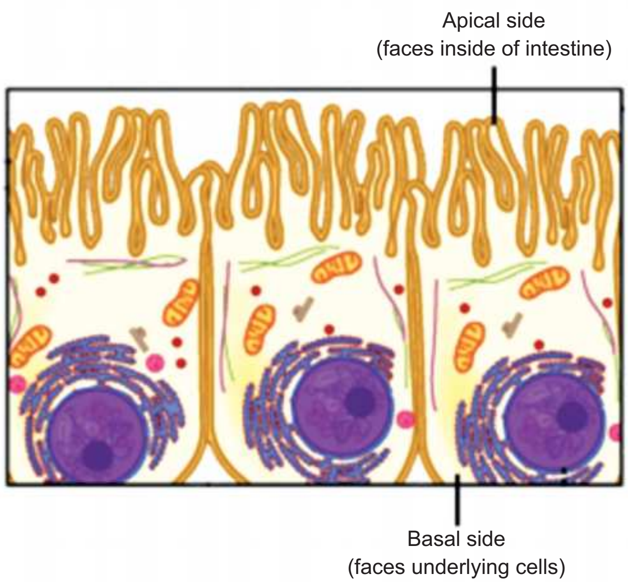
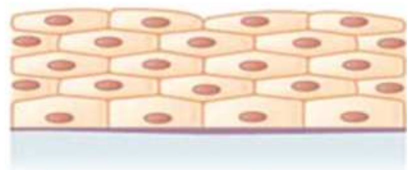
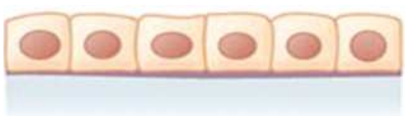
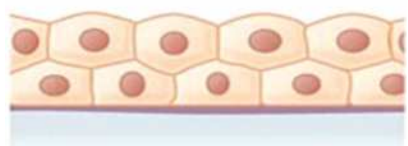
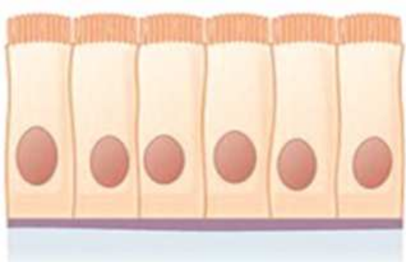
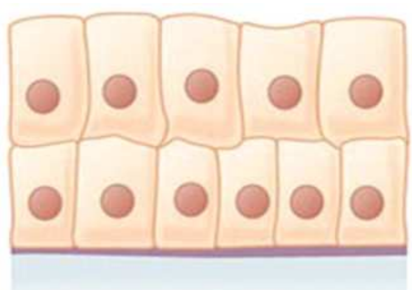


Figure 4.29 Epithelial tissue

There are different types of epithelial tissue depending on their function in a particular location. The simplest classification of these tissues is based on the number of cell layers.

When the epithelium is composed of a single layer of cells, it is called **simple epithelial tissue** and those containing two or more layers of cells are called **stratified epithelial tissues**.

	Simple	**Stratified**
Squamous	 Simple squamous spithelium	 Startified squamous epithelium
Cubical	 Simple cuboidal epithelium	 Stratified cuboidal epithelium
Columnar	 Simple columnar epithelium	 Stratified columnar epithelium

Simple squamous epithelium is found in the alveoli of lungs, and its structure is important for the exchange of gases between the blood and lungs. **Simple cuboidal epithelia** line the lumen of collecting ducts in the kidney and are present in the thyroid gland around the follicles that secrete thyroid hormones.

Simple columnar epithelia are found in the female reproductive system and in the digestive tract.

Stratified epithelia consist of more than one layer of cells and only one layer is in direct contact with the basement membrane.

Stratified squamous epithelia are found in skin, with many dead, keratinized cells providing protection against water and nutrient loss. **Stratified cuboidal epithelia** are found surrounding the ducts of many glands, including mammary glands in the breast and salivary glands in the mouth. **Stratified columnar epithelia** are rare, found predominantly in some organs of the reproductive system. **Transitional epithelia** are a special subset of stratified epithelia. They are exclusively found in the excretory system.

2. Connective tissue:

This tissue which connects or bind the different types of cells called connective tissues. They also bind other tissues of the body with each other. Connective tissue holds structures in the body together, such as tendons.

Cartilage is a type of supporting connective tissue. It is a dense connective tissue. Cartilage has limited ground substance and can range from semisolid to a flexible matrix.

Figure 4.30 Cartilage presant in pina of ear

Bone is another type of supporting connective tissue. Bone can either be compact (dense) or spongy (cancellous), and contains the osteoblasts or osteocytes cells.

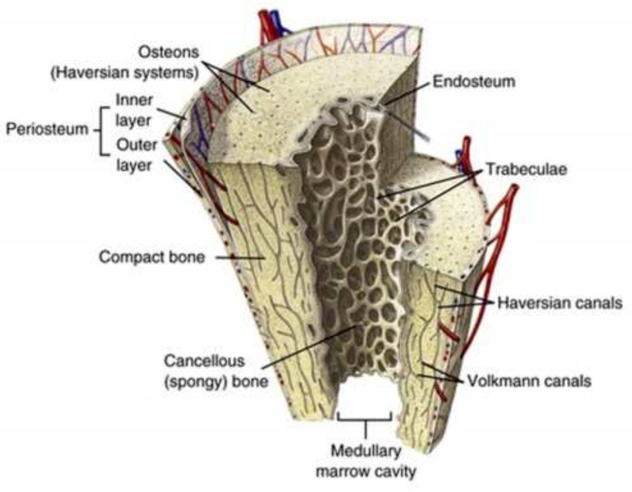


Figure 4.31 Longitudinal section of bone

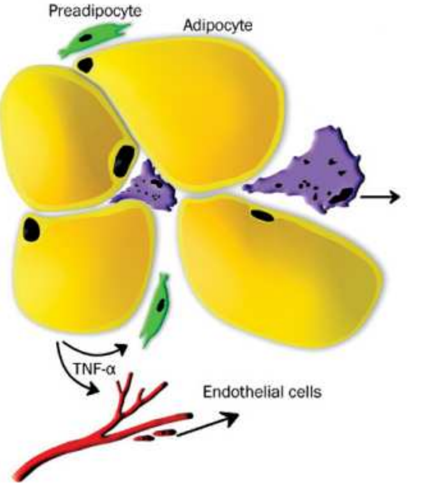


Figure 4.32 Adipose tissue

Adipose is another type of supporting connective tissue that provides cushions and stores excess energy and fat.

Blood referred to as connective tissue. It is a type of fluid connective tissue.

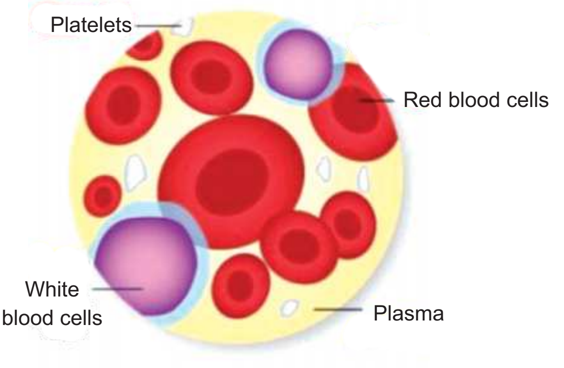


Figure 4.33 Blood cells

3. Muscle tissues:

Muscle tissue contains the cells that are responsible for the contraction of muscles. There are three types of muscular tissues i.e. cardiac, smooth, and skeletal.

Skeletal muscle, which is also called striated (striped) muscle, is what we refer to as muscle in everyday life. Skeletal muscle is attached to bones by tendons. For instance, the muscles in your legs and your arms are skeletal muscle.

Cardiac muscle is found only in the walls of the heart. Like skeletal muscle, cardiac muscle is striated, or striped. But it's not under voluntary control, so thankfully! you don't need to think about making your heart beat.

Smooth muscle is found in the walls of blood vessels, as well as in the walls of the digestive tract, the uterus, the urinary bladder, and various other internal structures. Smooth muscle is un-striped, (unstriated), it is involuntary, not under conscious control. That means you don't have to think about moving food through your digestive tract!

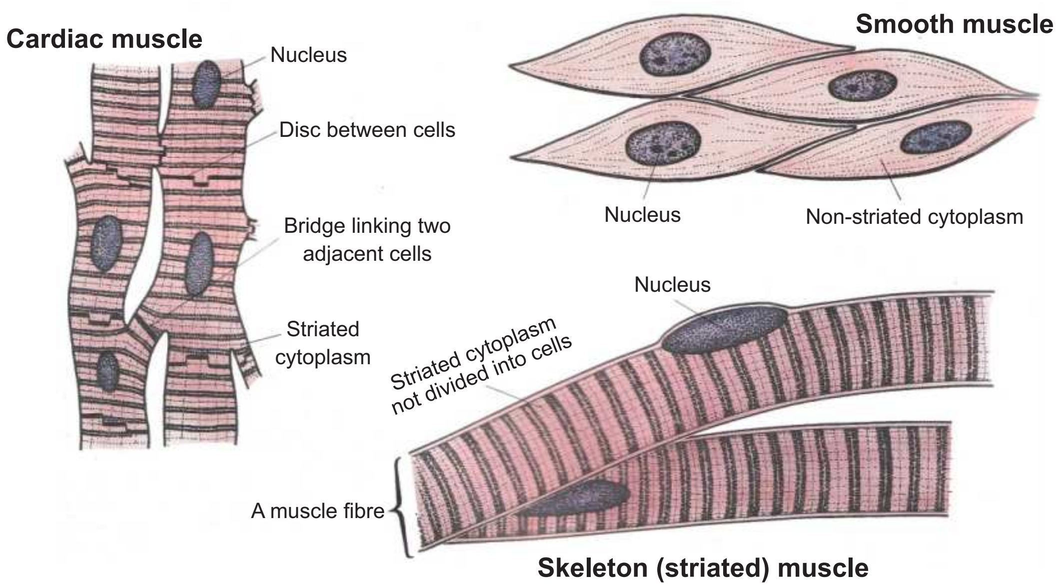


Figure 4.34 Types of msucles

4. Nervous tissues:

Nervous tissue is composed of neurons, which transmit information to other cells. Nervous tissue is found in the brain, spinal cord, and nerves. It is responsible for coordinating and controlling many body activities. It stimulates muscle contraction, creates an awareness of the environment, and plays a major role in emotions, memory, and reasoning. To do all these things, cells in nervous tissue need to be able to communicate with each other by way of electrical nerve impulses.

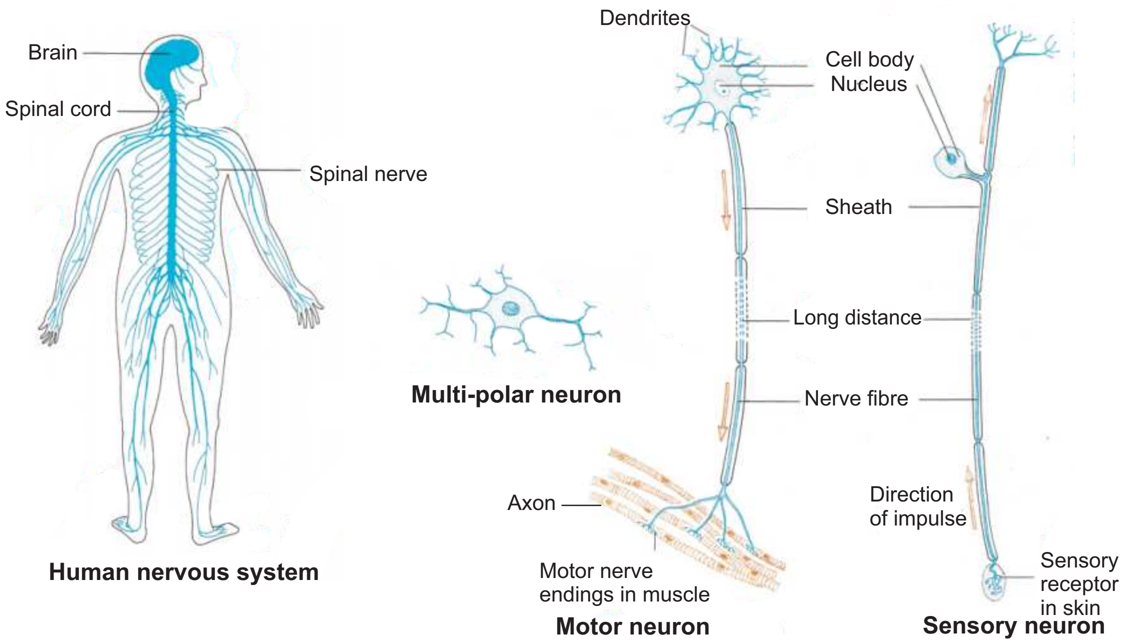


Figure 4.35 Human nervous system and various types of neuron cells

(B) Plant tissues

As same in animals, plant cells are grouped into tissues with characteristic functions such as photosynthesis, transport etc. There are two major categories of tissues in plants i.e. Meristematic tissues and Permanent tissues.

Plant tissue

- Meristematic – Cells are capable of cell division
- Permanent – Mature cells are incapable of cell division
  - Simple – Tissue composed of a single cell type
    - Epidermis
    - Parenchyma
    - Collenchyma
    - Sclerenchyma
    - (Parenchyma, Collenchyma) → Chlorenchyma
  - Complex – Tissue composed of more than one cell type
    - Xylem
      - Xylem vessels
      - Tracheids
    - Phloem
      - Sieve tubes
      - Companion cells

1. Meristematic Tissues:

These tissues are composed of cells, which have the ability to divide. The cells are thin walled, have large nucleus and number of small vacuoles. Usually they do not have inter-cellular spaces, so the cells are arranged compactly.

Two main types of meristematic tissues are recognized in plants.

(i) **Apical meristems** tissues are present at the apex of roots and stems. According to their position they are Apical meristems. Stem and root increase in length by the division of cells of these tissues. This type of growth is called **primary growth**.

(ii) **Lateral meristems** are located on the lateral sides of roots and shoot. By dividing, they are responsible for increase in grith of plant parts. This growth is called secondary growth.

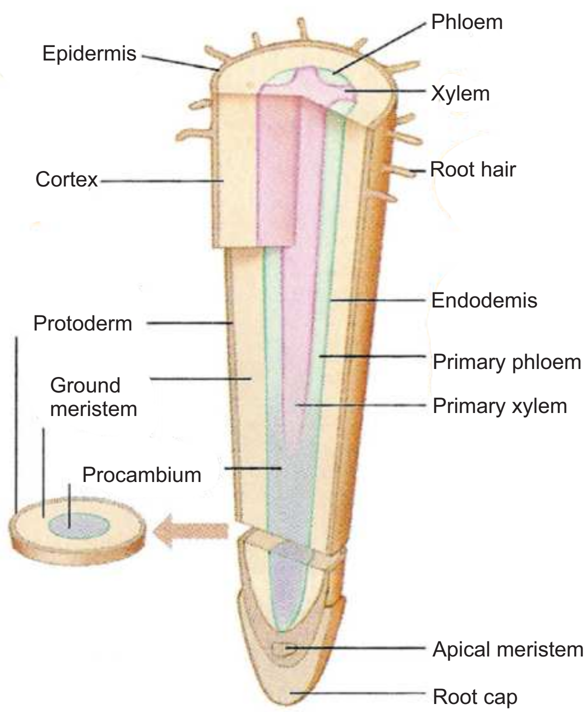


Figure 4.36 ***Apical meristem at root tip, Vascular and cork cambium***

2. Permanent Tissues :

Permanent tissues originate from meristematic tissue. The cells of these tissues do not have the ability to divide and may have intercellular spaces in between cells. They are further classified into following types: either on the basis of position or composition. There are two types of permanent tissues i.e. (a) Simple permanent tissue (b) Compound or complex tissue.

(A) Simple permanent tissue:

Simple permanent tissues are made up of only one type of cell.

(i) Epidermal Tissues :

Epidermal tissues are composed of a single layer of cells and they cover plant body. They act as a barrier between environment and internal plant tissues. In roots, they are also responsible for the absorption of water and minerals. On stem and leaves they secrete cutin (the coating of cutin is called cuticle) which prevents evaporation.

Epidermal tissues also have some specialized structure that perform specific functions; for example **root hairs** and **stomata**.

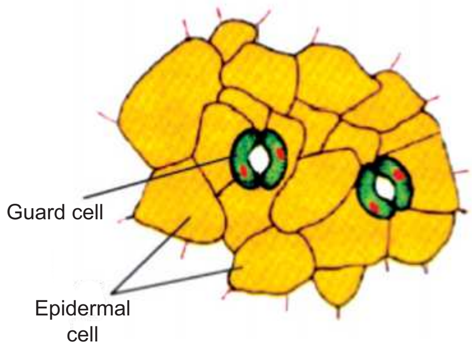


Figure 4.37 Epidermal tissue

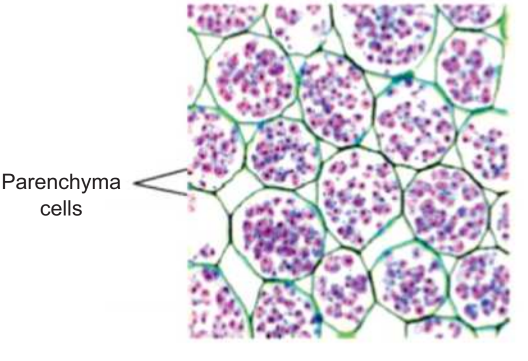


Figure 4.38 Ground tissue

(ii) Ground Tissues:

Ground tissues are simple tissues made up of **parenchyma cells**. Parenchyma cells are the most abundant cells in plants. Overall they are spherical but flat at point of contact. They have thin primary cell walls and have large vacuoles for storage of food. In leaves, they are called **mesophyll** and are the sites of photosynthesis. In other parts, they are the sites of respiration and protein synthesis.

(iii) Supporting Tissues:

These tissues provide strength and flexibility to plants. They are further of two types.

(a) Collenchyma Tissues:

They are found in cortex (beneath epidermis) of young stems and in the midribs of leaves and in petals of flowers. They are made of elongated cells with unevenly thickened primary cell walls. They are flexible and function to support the organs in which they are found.

Most parenchyma cells can develop the ability to divide and differentiate into other types of cells and they do so during the process of repairing an injury.

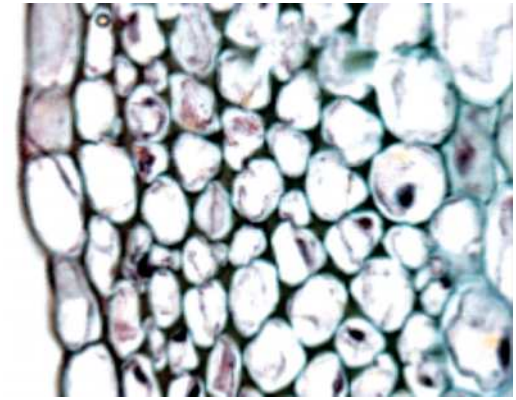


Figure 4.39 Collenchyma tissue

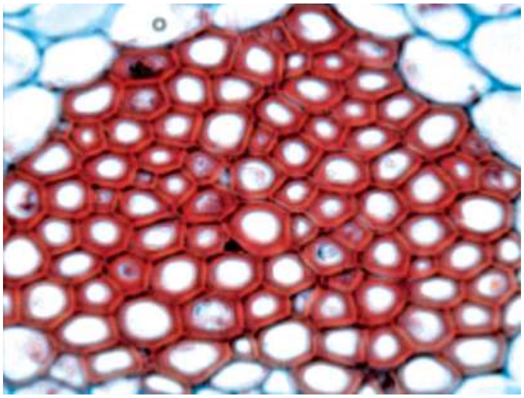


Figure 4.40 Schlerenchyma tissue

(b) Sclerenchyma Tissues :

They are composed of cells with rigid secondary cell walls. Their cell walls are hardened with lignin, which is the main chemical component of wood. Mature sclerenchyma cells cannot elongate and most of them are dead.

(B) Compound (Complex) Tissues:

A plant tissue composed of more than one type of cell is called a compound or complex tissue. Xylem and phloem tissues, found only in vascular plants, are examples of compound tissues.