CHAPTER

4

Cells And Tissues

Animation 4: Cell Biology
Source and Credit: imm.eday

The wing of a butterfly is a thin sheet of cells, and so is the shiny layer of our eyes. The meat we eat is composed of cells and its contents soon become part of our cells. Our eyelashes, fingernails, orange juice, the wood of our pencil - all are produced by cells. In this chapter we will take a close look at cells and learn about their internal structure. We will also learn how specific cells group together to form tissues.

Recalling:

All organisms are composed of cells. Some are composed of a single cell, and some, like us, are composed of many cells.

4.1 Microscopy And The Emergence Of Cell Theory

The use of microscope is known as microscopy. The first compound microscope was developed by Zacharias Janssen, in Holland in 1595. It was simply a tube with lenses at each end and its magnification ranged from 3X to 9X.

Two important terms are used in microscopy i.e. magnification and resolving power. **Magnification** is the increase in the apparent size of an object and it is an important factor in microscopy. **Resolving power** or **resolution** is the measure of the clarity of an image. It is the minimum distance at which two objects can be seen as separate objects. Human naked eye can differentiate between two points, which are at least 0.1 mm apart. This is known as the resolution of human eye. If we place two objects 0.05 mm apart, human eye would not be able to differentiate them as two separate objects. Magnification and resolution can be increased with the help of lenses.

4.1.1 Light microscopy and electron microscopy

Now two types of microscope i.e. light microscope (LM) and electron microscope (EM) are used in microscopy.

Light Microscope

A light microscope works by passing visible light through a specimen. It uses two glass lenses. One lens produces an enlarged image of the specimen and the second lens magnifies the image and projects it into viewer's eye or on to photographic film. A photograph taken through a microscope is called a **micrograph**.

Animation 4.1: Microscope
Source & Credit: emaze

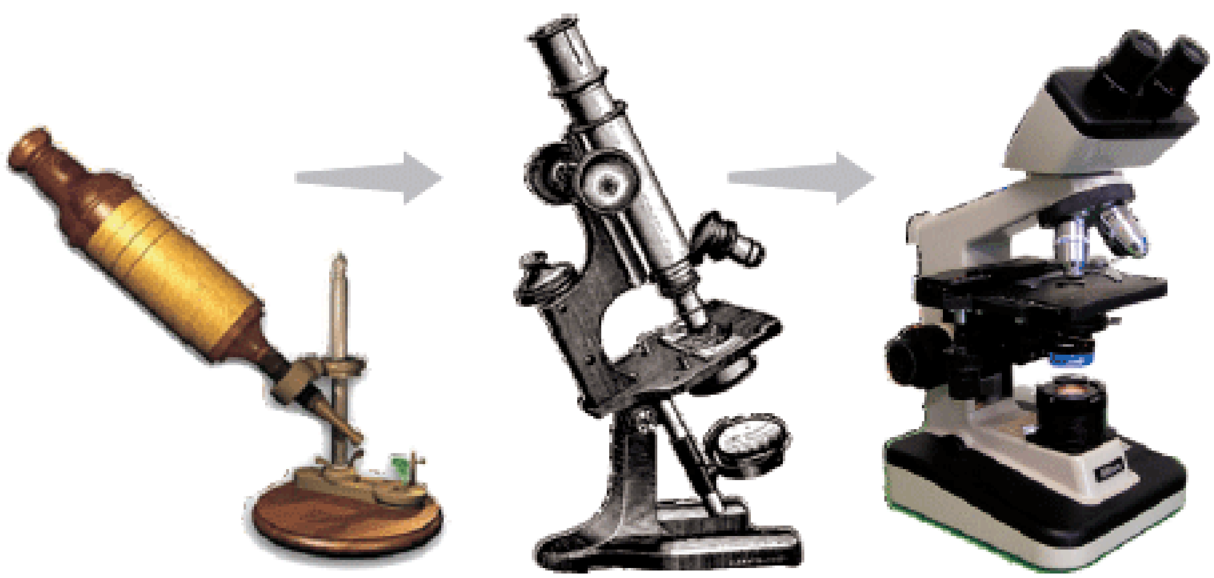


Figure 4.1: Light microscopes: From earlier (left) to the latest (right)

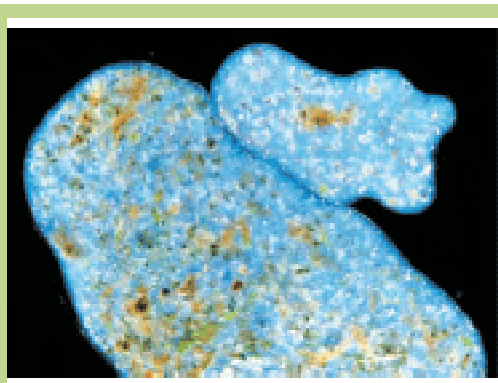
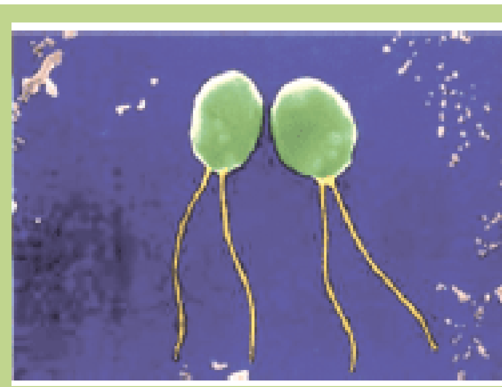



Figure 4.2: Light microscopic view; amoebae (left), unicellular algae (right)

When we see a micrograph on the page of a book, we see some words like "LM 109X" printed along the edge of the micrograph. It tells us that the photomicrograph was taken through a light microscope and that the image has been magnified 109 times.

A light microscope can magnify objects only about 1500 times without causing blurriness i.e. its magnification is **1500X**. Its resolving power is **0.2 micrometer** (μm) and 1μm = 1/1000 mm. In other words, the LM cannot resolve (distinguish) objects smaller than 0.2 μm. It is about the size of the smallest bacterium. The image of bacterium can be magnified many times, but light microscope cannot show the details of its internal structure.

Electron Microscope

It is the most advanced form of microscope. In EM, object and lens are placed in a vacuum chamber and a beam of electrons is passed through object. Electrons pass through or are reflected from object and make image. Electromagnetic lenses enlarge and focus the image onto a screen or photographic film.

Electron microscope has much higher resolving power than light microscope. The most modern EM can distinguish objects as small as **0.2 nanometer** (nm) and 1 nm = 1/1000,000 mm. It is a thousand-fold improvement over LM. EM can magnify objects about 250,000 times. Under special conditions EM can detect individual atoms. Cells, organelles and even molecules like DNA and protein are much larger than single atoms.

Biologists use two types of electron microscopes i.e. **Transmission Electron Microscope (TEM)** and **Scanning Electron Microscope (SEM)**. In TEM, electrons are transmitted through the specimen. TEM is used to study the internal cell structure (Figure 4. 3).

EM has revolutionized the study of cells and organelles but it cannot be used to study life processes, because the specimen must be held in a vacuum chamber i.e. all air must be removed. To study the life processes e.g. movement of Amoeba a light microscope is better.

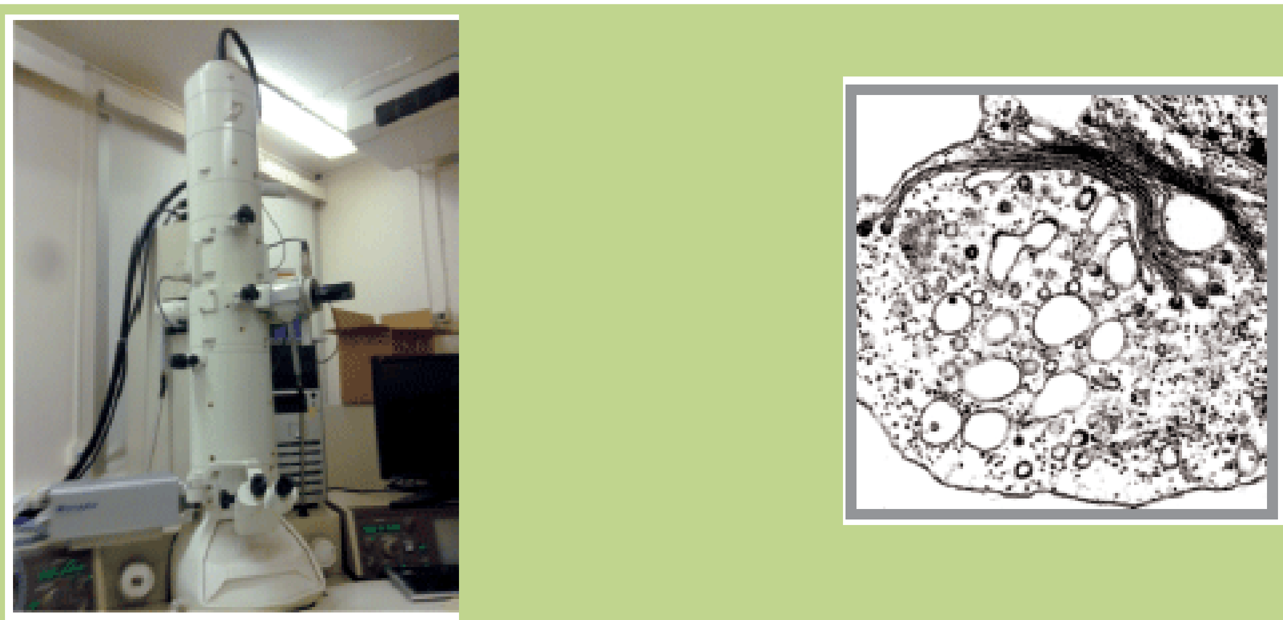


Figure 4.3: TEM (left) and view of an animal cell (right) through it

Which type of microscope would you use to study: (a) the change in shape of a human white blood cell; (b) the surface texture of human hair; (c) the detailed structure of a mitochondrion in the cell of human liver?

(a) LM; (b) SEM; (c) TEM

In SEM, electrons are reflected from the metal-coated surfaces. SEM is used to study the structure of cell surfaces (Figure 4.4).

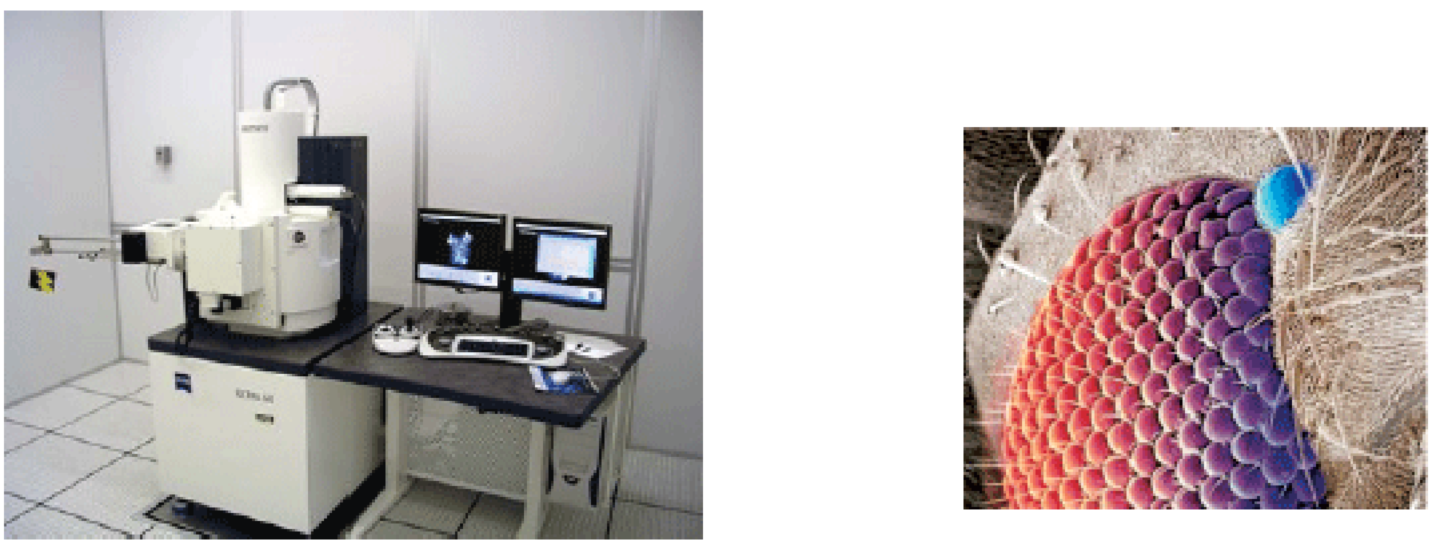


Figure 4.4: SEM (left) and view of mosquito's head and eye (right) through it

4.1.2 History of the formulation of cell theory

In the history of biology, ancient Greeks were the first who organized the data of natural world. **Aristotle** presented 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 microscopes were first used in 17th century, no one knew with certainty that living organisms do share a fundamental unit i.e. cell.

Cells were first described by a British scientist, **Robert Hooke** in 1665. He used his self-made light microscope to examine a thin slice of cork. Hooke observed a "honeycomb" of tiny empty compartments. He called the compartments in cork as "cellulae". His term has come to us as cells (Figure 4.5). The first living cells were observed a few years later by Dutch naturalist **Antonie van Leeuwenhoek**. He observed tiny organisms (from pond water) under his microscope and called them as "animalcules".

Figure 4.5: Robert Hooke

Robert Hooke was a chemist, mathematician and physicist. His remarkable engineering abilities enabled him to invent and improve many mechanical devices, including timepieces, the quadrant, and the Gregorian telescope. His observation about the section of cork is also illustrated here.

For another century and a half, the general importance of cells was not appreciated by biologists. In 1809, **Jean Baptist de-Lamarck** proposed that "no body can have life if its parts are not cellular tissues or are not formed by cellular tissues".

In 1831, a British botanist **Robert Brown** discovered nucleus in the cell. In 1838, a German botanist **Matthias Schleiden** studied plant tissues and made the first statement of cell theory. He stated that all plants are aggregates of individual cells which are fully independent. One year later, in 1839, a German zoologist **Theodor Schwann** reported that all animal tissues are also composed of individual cells. Thus Schleiden and Schwann proposed cell theory in its initial form.

In 1855 **Rudolf Virchow**, a German physician, proposed an important extension of cell theory. He proposed that all living cells arise from pre-existing cells ("Omnis cellula e celula"). In 1862, **Louis Pasteur** provided experimental proof of this idea.

Cell theory is regarded as one of the most fundamental knowledge in biology. It has wide ranging effects in all fields of research. After the initial presentation of cell theory by Schleiden and Schwann, many details of cells were studied and cell theory was extended. Cell theory, in its modern form, includes the following principles;

1. All organisms are composed of one or more cells.
2. Cells are the smallest living things, the basic unit of organization of all organisms.
3. Cells arise only by divisions in previously existing cells.

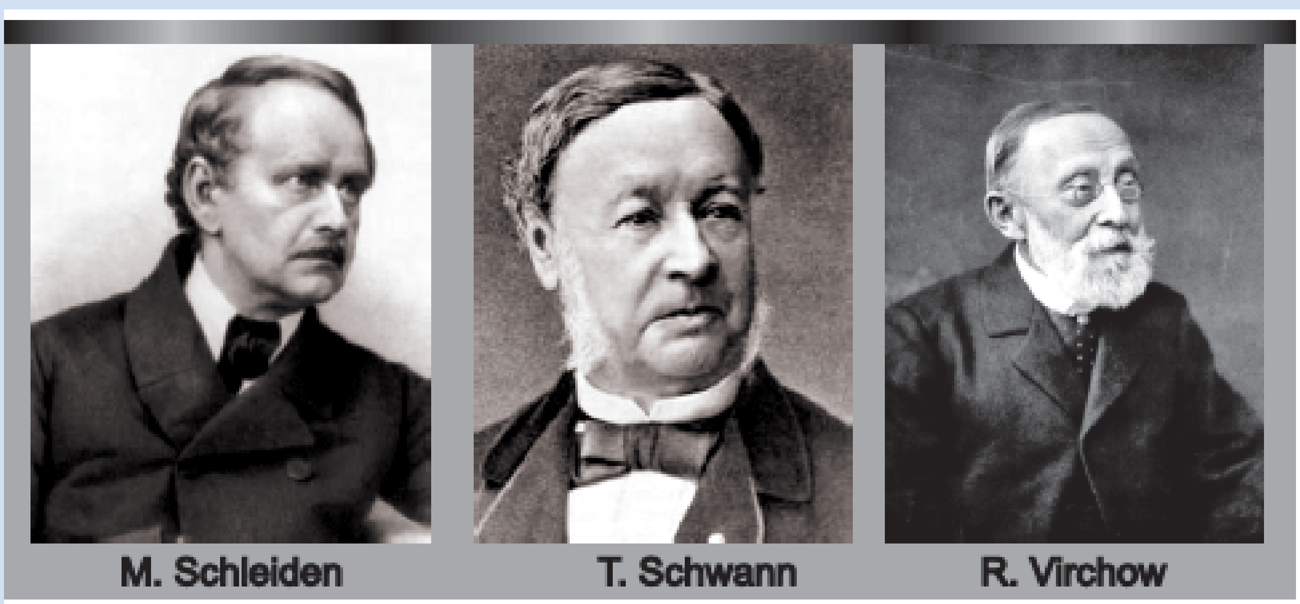
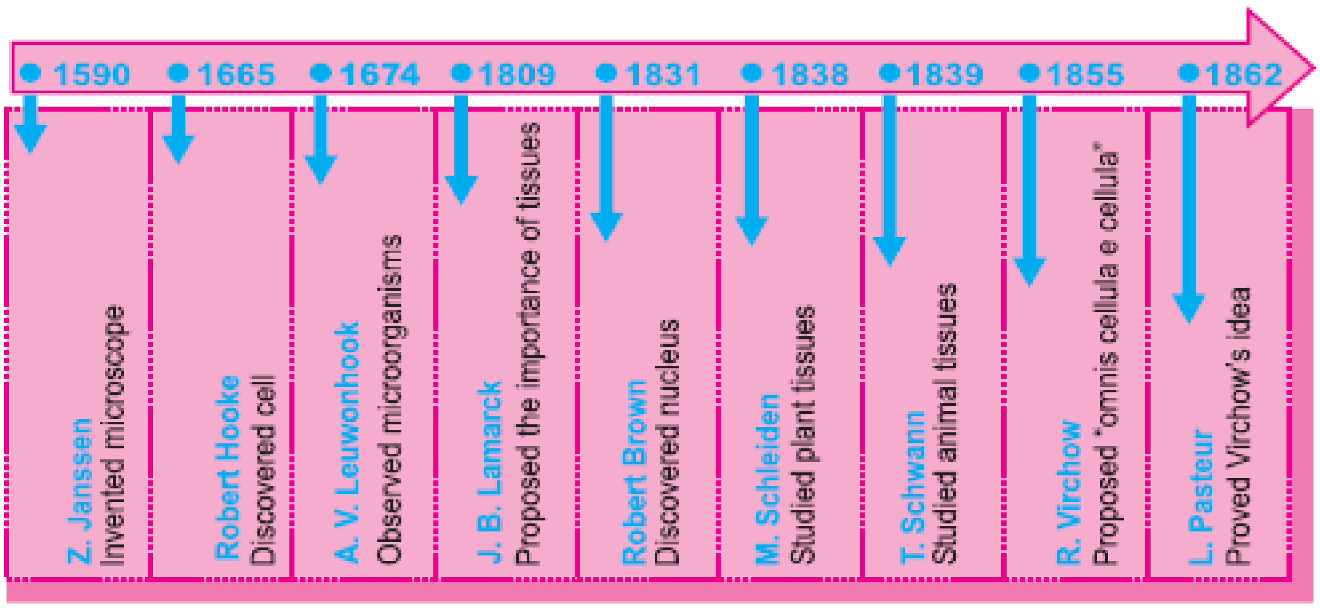


Figure 4.6: Three great German biologists

Sub-cellular or Acellular Particles: According to the first principle of the cell theory all organisms are composed of one or more cells. Virus, prions and viroids are not composed of cells; rather they are sub-cellular or acellular particles. They do not run any metabolism inside them. They show some characteristics of living organisms i.e. they can increase in number and can transmit their characters to next generations. We know that such acellular particles are not classified in any of the five kingdoms of organisms.



History of the formulation of cell theory

4.2 Cellular Structures And Functions

We are well familiar with the basic organization of a eukaryotic cell. Here we will get some detailed learning about cellular structure and functions. A cell is made by the assemblage of organelles. There are some structures in cell that are not organelles, but are still very important for cell. These structures are **cell wall, cell membrane, cytoplasm, and cytoskeleton.**

4.2.1 Cell Wall

We know that not all living organisms have cell walls around their cells, e.g. animals and many animal-like protists. Cell wall is a non-living and strong component of cell, located outside plasma membrane. It provides shape, strength, protection and support to the inner living matter (protoplasm) of cell.

Plant cells have a variety of chemicals in their cell walls. The outer layer of plant cell wall is known as **primary wall** and cellulose is the most common chemical in it. Some plant cells, for example xylem cells, also have **secondary walls** on the inner side of primary wall. It is much thicker and contains lignin and some other chemicals. There are pores in the cell walls of adjacent cells, through which their cytoplasm is connected. These pores are called **plasmodesmata**.

Fungi and many protists have cell walls although they do not contain cellulose. Their cell walls are made of a variety of chemicals. For example, **chitin** is present in the cell wall of fungi. Prokaryotes have a cell wall composed of **peptidoglycan** that is a complex of amino acids and sugars.

Animation 4.2: Cell Wall
Source and Credit: gifsoup

4.2.2 Cell Membrane

All prokaryotic and eukaryotic cells have a thin and elastic cell membrane covering the cytoplasm. Cell membrane functions as a semi-permeable barrier, allowing a very few molecules across it while fencing the majority of chemicals inside cell. In this way, cell membrane maintains the internal composition of cell.

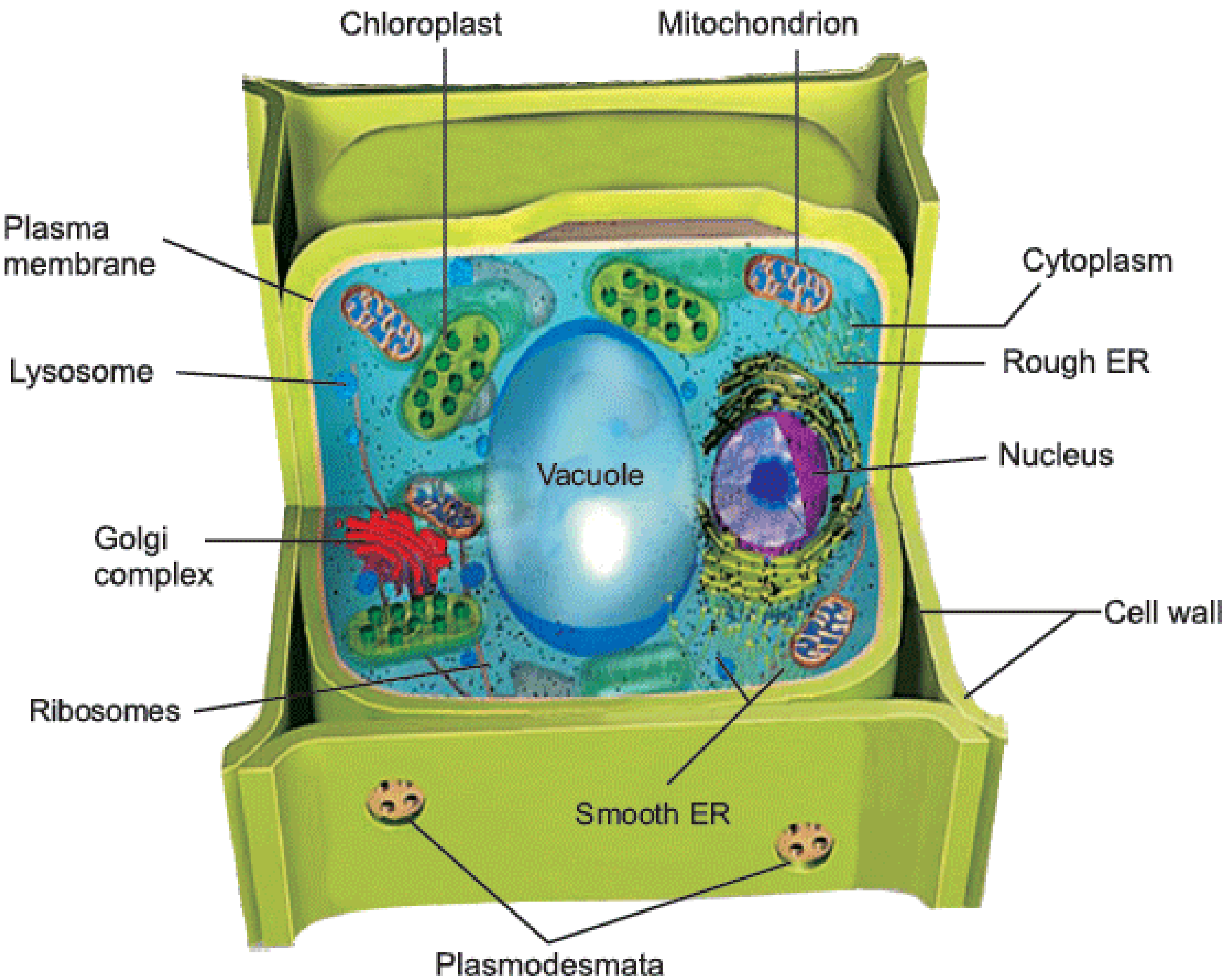


Figure 4.7: The ultra-structure of a plant cell

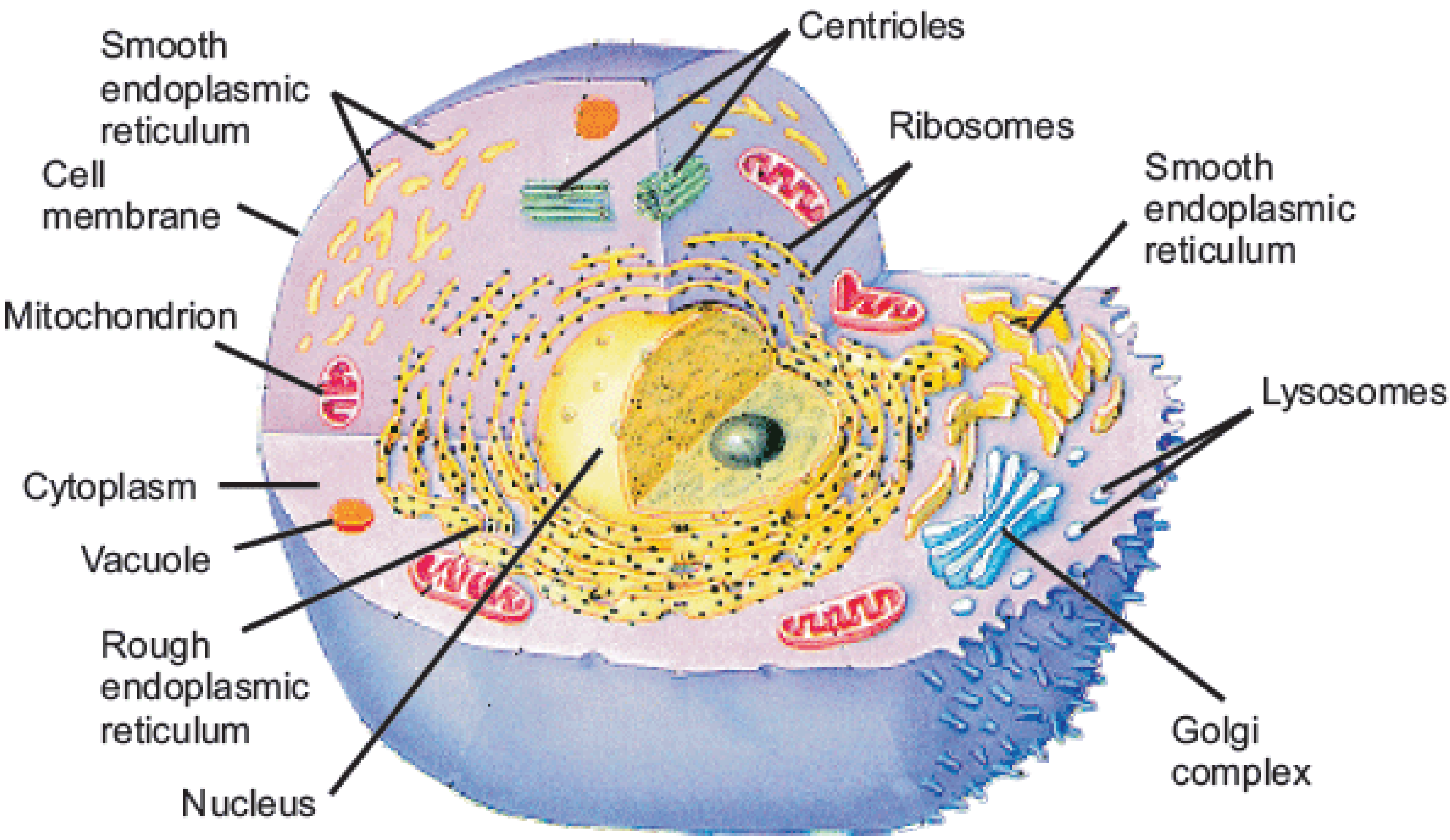


Figure 4.8: The ultra-structure of an animal cell

In addition to this vital role, cell membrane can also sense chemical messages and can identify other cells.

Chemical analysis reveals that cell membrane is mainly composed of **proteins** and **lipids** with small quantities of carbohydrates. Electron microscopic examinations of cell membranes have led to the development of **fluid-mosaic model** of cell membrane (Figure 4.9).

According to this model, there is a lipid bilayer in which the protein molecules are embedded. The lipid bilayer gives fluidity and elasticity to membrane. Small amounts of carbohydrates are also found in cell membranes. These are joined with proteins or lipids of membrane.

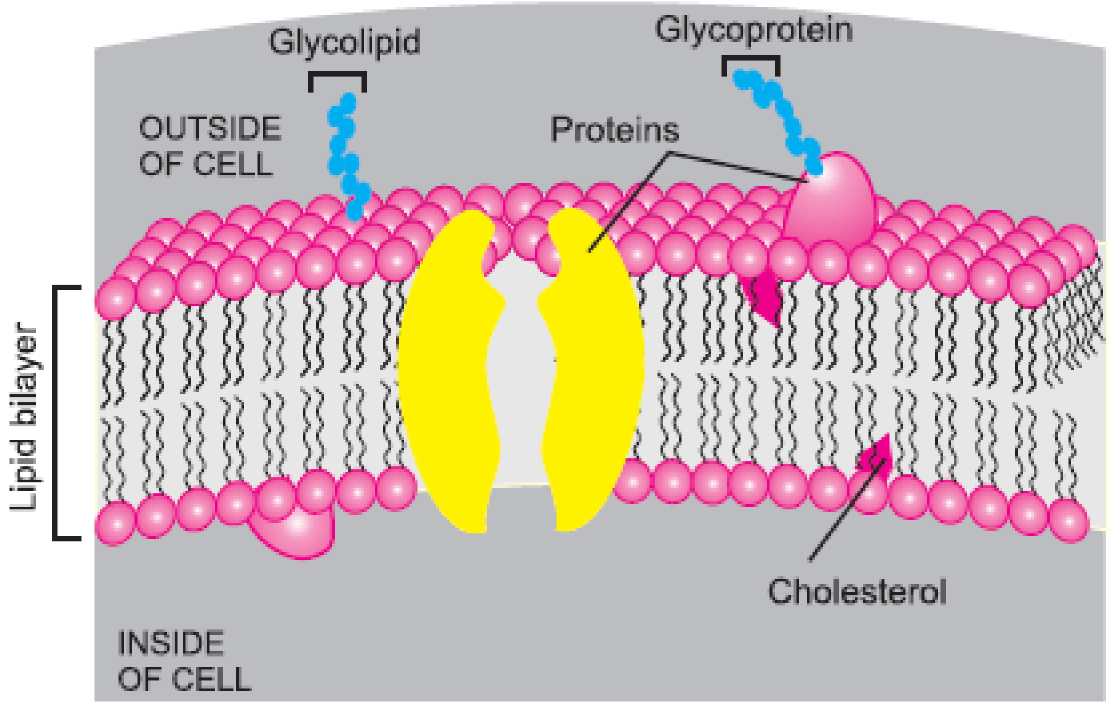


Figure 4.9: The fluid- mosaic model of cell membrane

In eukaryotic cells, cholesterol is also present in lipid bilayer. In eukaryotic cell many organelles e.g. mitochondria, chloroplasts, Golgi apparatus, and endoplasmic reticulum are also bounded by cell membranes.

When we talk about all the membranes of a cell, we say them as cell membranes.
When we talk about only the outer membrane of cell, we say it as plasma membrane.

4.2.3 Cytoplasm

Cytoplasm is the semi-viscous and semi-transparent substance between plasma membrane (cell membrane) and nuclear envelope. It contains water in which many organic molecules (proteins, carbohydrates, lipids) and inorganic salts are completely or partially dissolved.

Cytoplasm provides space for the proper functioning of organelles and also acts as the site for various biochemical (metabolic) reactions. For example, Glycolysis (breakdown of glucose during cellular respiration) occurs in cytoplasm.

4.2.4 Cytoskeleton

Cytoskeleton is a network of microfilaments and microtubules. Microtubules are made of **tubulin** protein and are used by cells to hold their shape. They are also the major component of cilia and flagella. Microfilaments are thinner and are made of **actin** protein. They help cells to change their shapes.

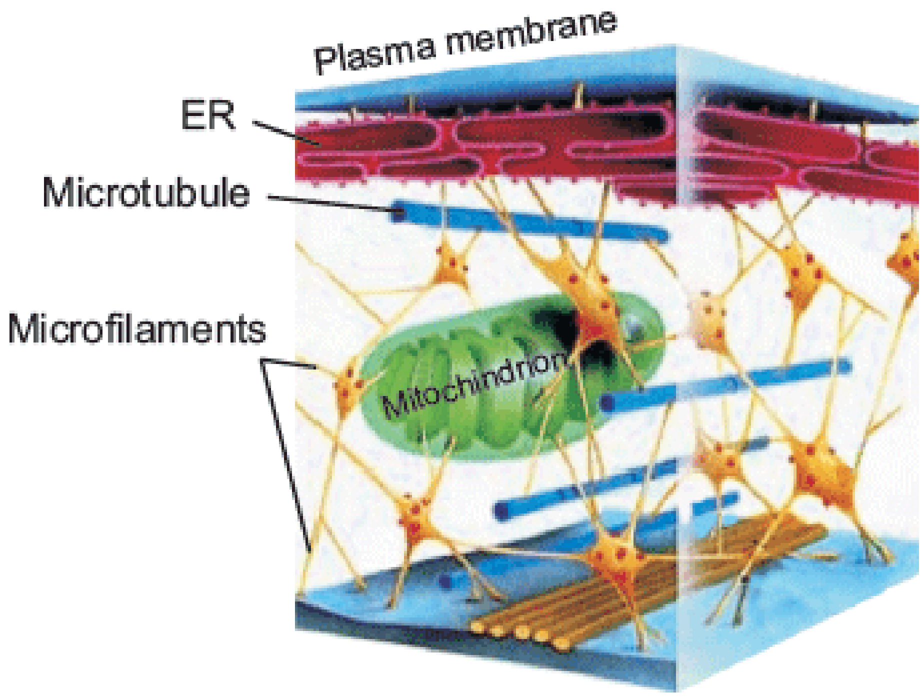


Figure 4.10: Cytoskeleton

4.2.5 Cell Organelles

Organelles are small structures within cells that perform dedicated functions. There are about a dozen types of organelles commonly found in eukaryotic cells. We will go through the basic facts about important cell organelles.

4.2.6 Nucleus

A prominent nucleus occurs in eukaryotic cells. In animal cells it is present in the centre while in mature plant cells, due to the formation of large central vacuole, it is pushed to side. Nucleus is bounded by a double membrane known as **nuclear envelope.** Nuclear envelope contains many small pores that enable it to act as a semi-permeable membrane. Inside nuclear envelope, a granular fluid i.e. **nucleoplasm** is present. Nucleoplasm contains one or two nucleoli (singular; nucleolus) and chromosomes (Figure 4.11).

Nucleolus is a dark spot and it is the site where ribosomal RNA are formed and assembled as ribosomes. **Chromosomes** are visible only during cell division while during interphase (non-dividing phase) of cell they are in the form of fine thread-like structures known as **chromatin**. Chromosomes are composed of Deoxyribonucleic acid (DNA) and proteins.

The prokaryotic cells do not contain prominent nucleus. Their chromosome is made of DNA only and is submerged in cytoplasm.

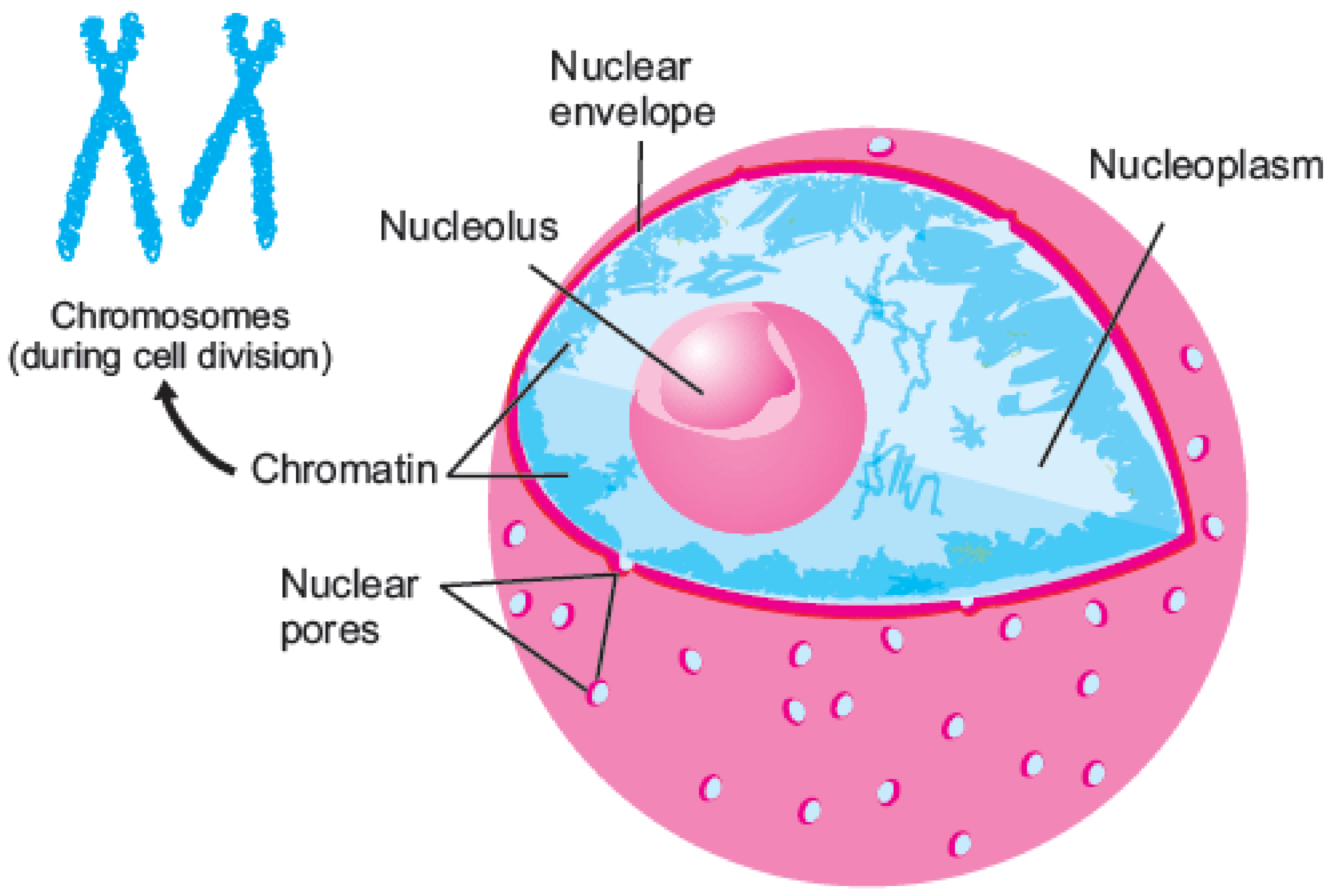


Figure 4.11: Structure of Nucleus

Animation 4.3: Nucleus
Source and Credit: Ameoba sisters

Ribosomes

Ribosomes are tiny granular structures that are either floating freely in cytoplasm or are bound to endoplasmic reticulum (ER). Each ribosome is made up of almost equal amounts of proteins and ribosomal RNA (rRNA). Ribosomes are not bound by membranes and so are also found in prokaryotes. Eukaryotic ribosomes are slightly larger than prokaryotic ones.

Ribosomes are the sites of protein synthesis. Protein synthesis is extremely important to cells, and so large numbers of ribosomes are found throughout cells. When a ribosome is not working, it disassembles into two smaller units (Figure 4.12) .

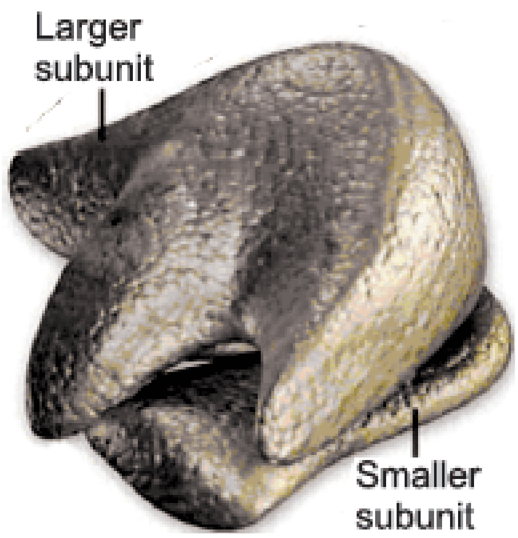


Figure 4.12: Ribosome

Animation 4.4: Ribosomes
Source and Credit: Nature

Animation 4.5: Ribosomes
Source and Credit: nature

Mitochondria

Mitochondria (singular: mitochondrion) are double membrane-bounded structures found only in eukaryotes. These are the sites of aerobic respiration, and are the major energy production centres. The outer membrane of a mitochondrion is smooth but the inner membrane forms many infoldings, called **cristae** (singular crista) in the inner mitochondrial matrix. This serves to increase the surface area of inner membrane on which membrane-bound reactions can take place (Figure 4.13). Mitochondria have their own DNA and ribosomes. The ribosomes of mitochondria are more similar to bacterial ribosomes than to eukaryotic ribosomes.

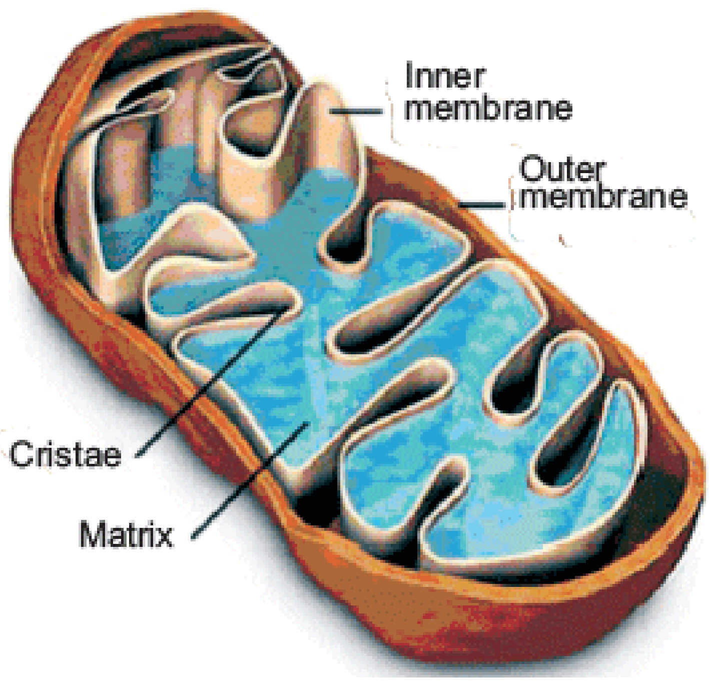


Figure 4.13: Mitochondrion

Animation 4.6: Mitochondria
Source and Credit: ibiblio

Plastids

Plastids are also membrane-bound organelles that only occur in the cells of plants and photosynthetic protists (algae). They are of three type i.e chloroplasts, leucoplasts and chromoplasts.
Like mitochondria, **chloroplast** is also bound by a double membrane. The outer membrane is smooth while the inner membrane gives rise to sacs called **thylakoids**. The stack of thylakoids is called granum (plural = grana).

Grana float in the inner fluid of chloroplast i.e. **stroma** (Figure 4.14). Chloroplasts are the sites of photosynthesis in eukaryotes. They contain chlorophyll (the green pigment necessary for photosynthesis) and associated pigments. These pigments are present in the thylakoids of grana.
The second type of plastids in plant cells are **chromoplasts**. They contain pigments associated with bright colors and are present in the cells of flower petals and fruits. Their function is to give colors to these parts and thus help in pollination and dispersal of fruit.
Leucoplasts are the third type of plastids. They are colourless and store starch, proteins and lipids. They are present in the cells of those parts where food is stored.

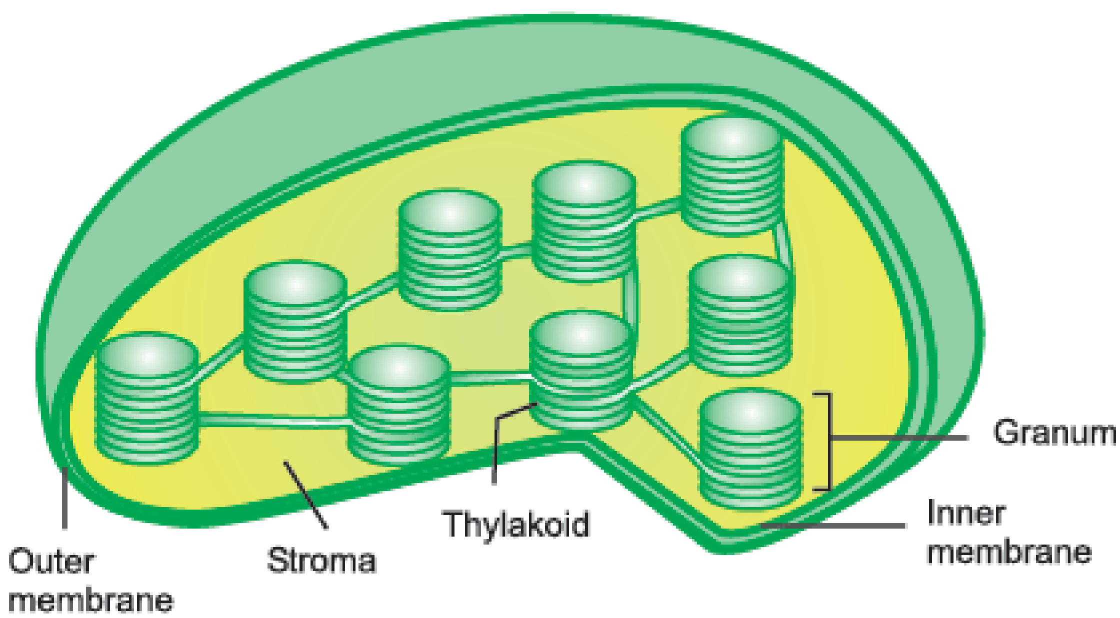


Figure 4.14: Chloroplast

Endoplasmic reticulum (ER)

Endoplasmic reticulum is a network of interconnected channels that extends from cell membrane to nuclear envelope. The network exists in two forms:

Rough Endoplasmic Reticulum (RER) is so-named because of its rough appearance due to numerous ribosomes that are attached to it (Figure 4.15). Due to the presence of ribosomes, RER serves a function in protein synthesis.

Smooth Endoplasmic Reticulum (SER) lacks ribosomes and is involved in lipid metabolism and in the transport of materials from one part of cell to other. It also detoxifies the harmful chemicals that have entered cell.

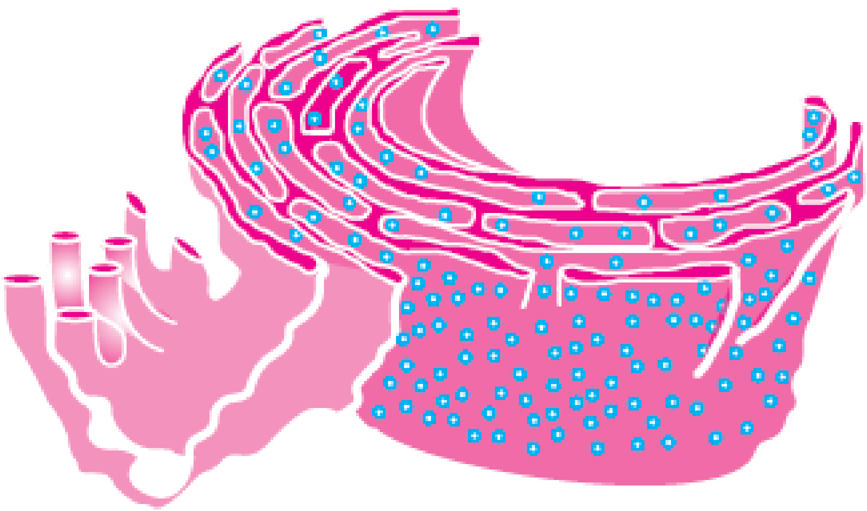


Figure 4.15: Smooth and Rough Endoplasmic Reticulum

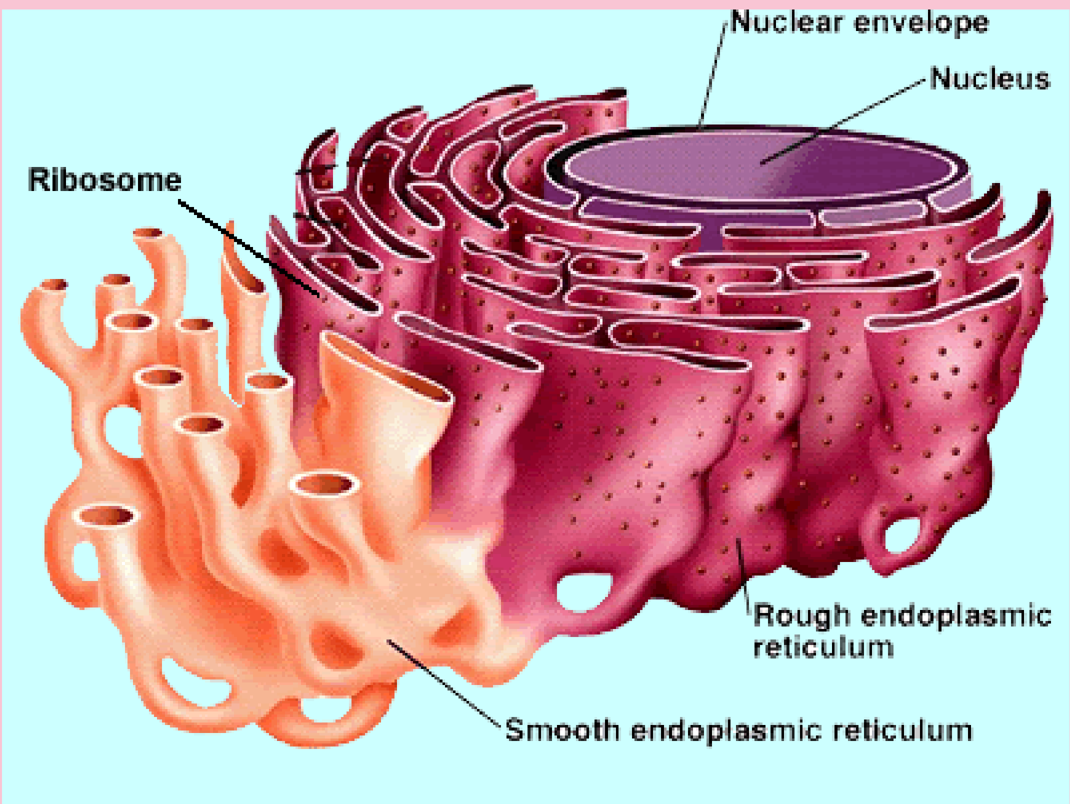


Image 4.1: Endoplasmic reticulum
Source and Credit: dynamicscience

Animation 4.7: Endoplasmic reticulum
Source and Credit: Ameoba sisters

Golgi Apparatus

An Italian physician **Camillo Golgi** discovered a set of flattened sacs **(cisternae)** in cell. In this set, many **cisternae** are stacked over each other. The complete set of cisternae is called Golgi apparatus or Golgi complex. It is found in both plant and animal cells. It modifies molecules coming from rough ER and packs them into small membrane bound sacs called **Golgi vesicles**. These sacs can be transported to various locations in cell or to its exterior, in the form of secretions (Figure 4.17).

Animation 4.8: Golgi Apparatus
Source and Credit: Ameoba sisters

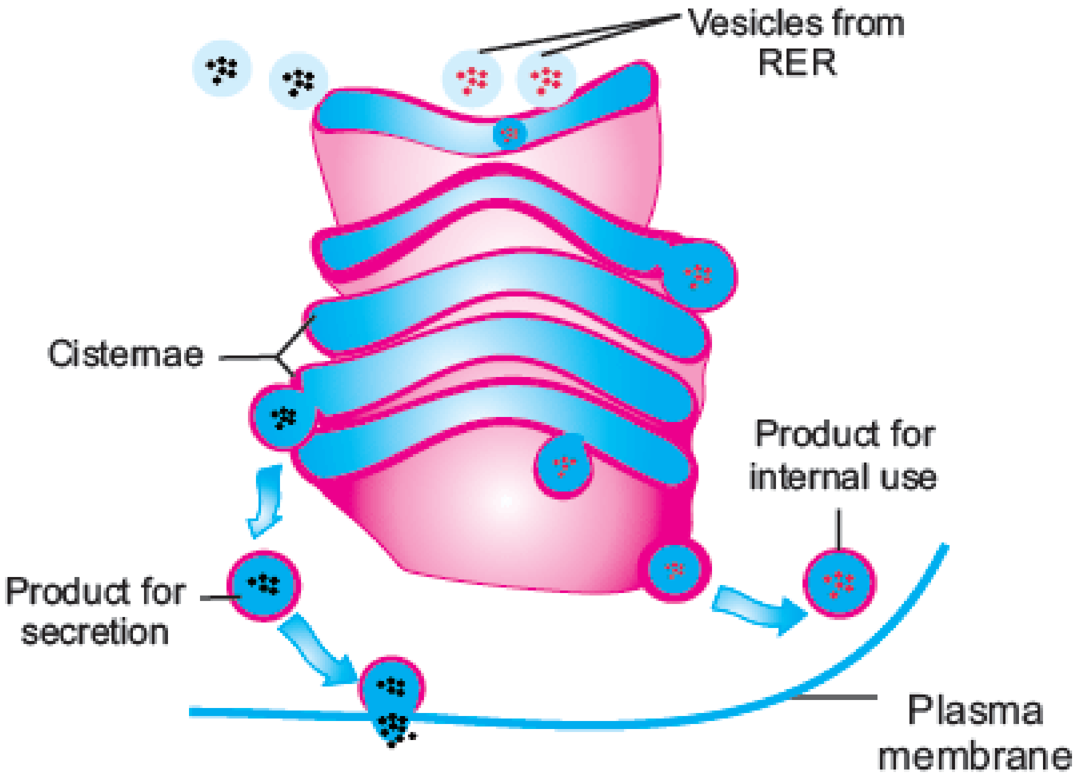


Figure 4.17: Functioning of the Golgi apparatus

De Duve won the 1974 Nobel Prize for physiology and medicine.

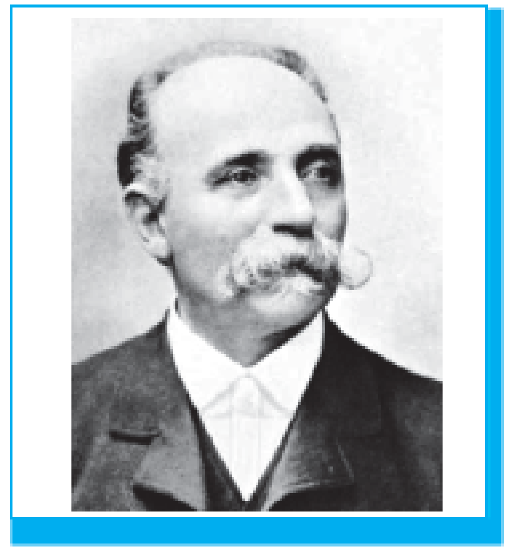


Figure 4.16: Camillo Golgi

In 1906, Golgi was awarded Nobel Prize for physiology and medicine.

Lysosomes

In the mid-twentieth century, a Belgian scientist **Christian René de Duve** discovered lysosomes. These are single-membrane bound organelles. Lysosomes contain strong digestive enzymes and work for the breakdown (digestion) of food and waste materials within cell. During its function, a lysosome fuses with the vacuole that contains the targeted material and its enzymes break down the material.

Let's think; What can happen when a lysosome bursts inside the cell and all its enzymes are released in the cytoplasm?

Animation 4.9: Lysosomes
Source and Credit: Ameoba sisters

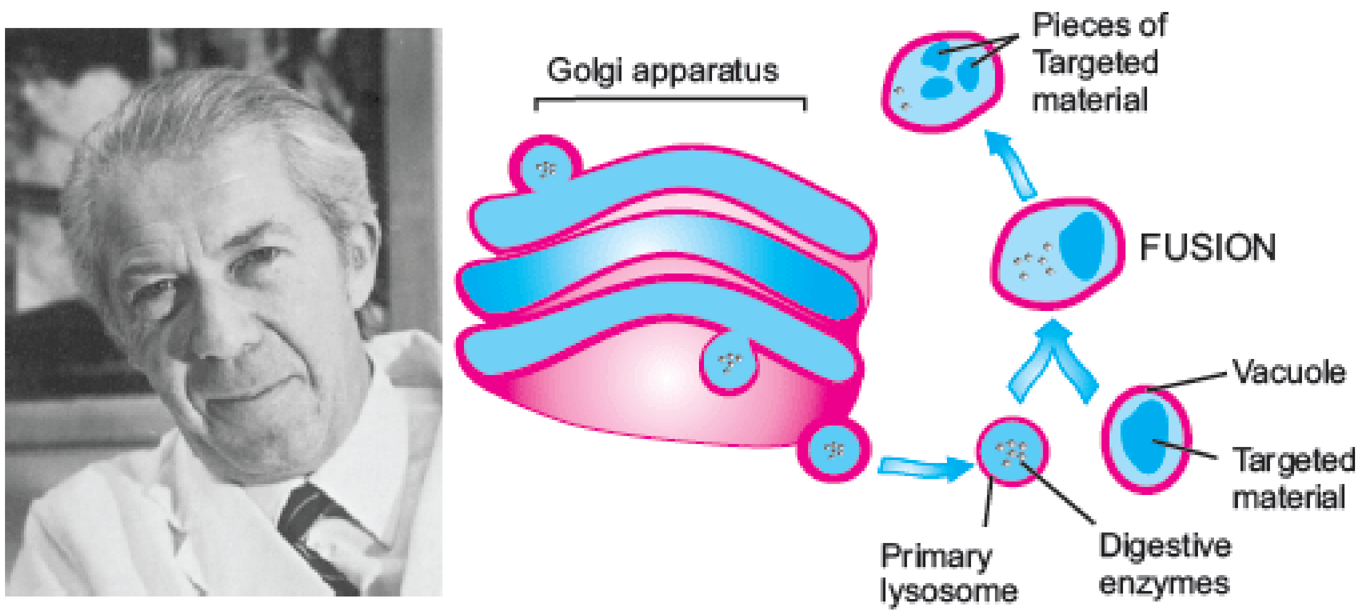


Figure 4.18: De Duve; Formation and Function of lysosome

Centrioles

Animals and many unicellular organisms have hollow and cylindrical organelles known as centrioles. Each centriole is made of nine triplets of microtubules (made up of tubulin protein). Animal cells have two centrioles located near the exterior surface of nucleus. The two centrioles are collectively called a **centrosome**. Their function is to help in the formation of spindle fibers during cell division. In some cells, centrioles are involved in the formation of cilia and flagella.

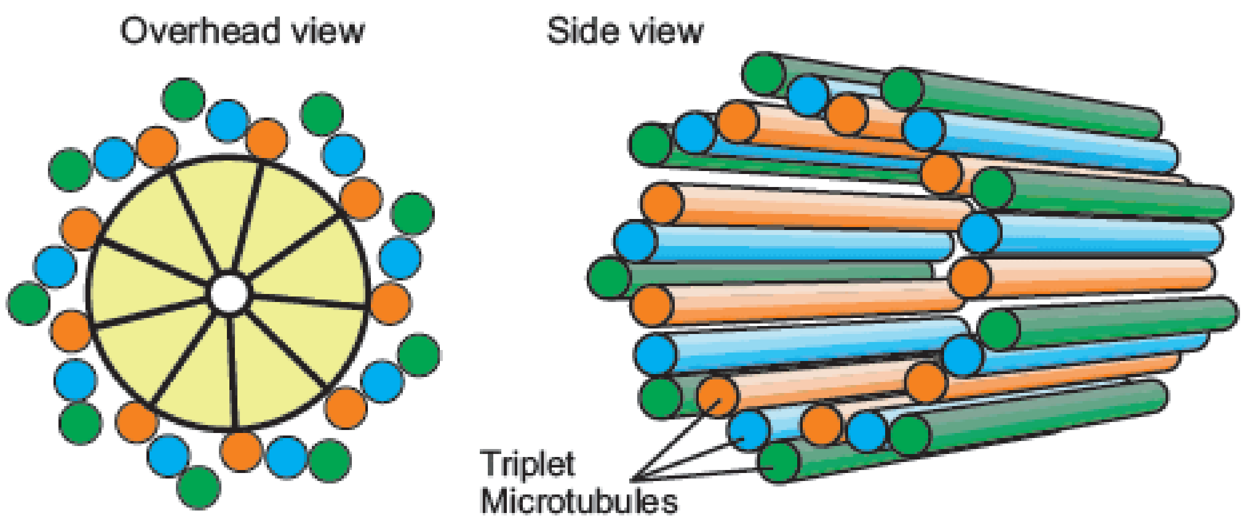
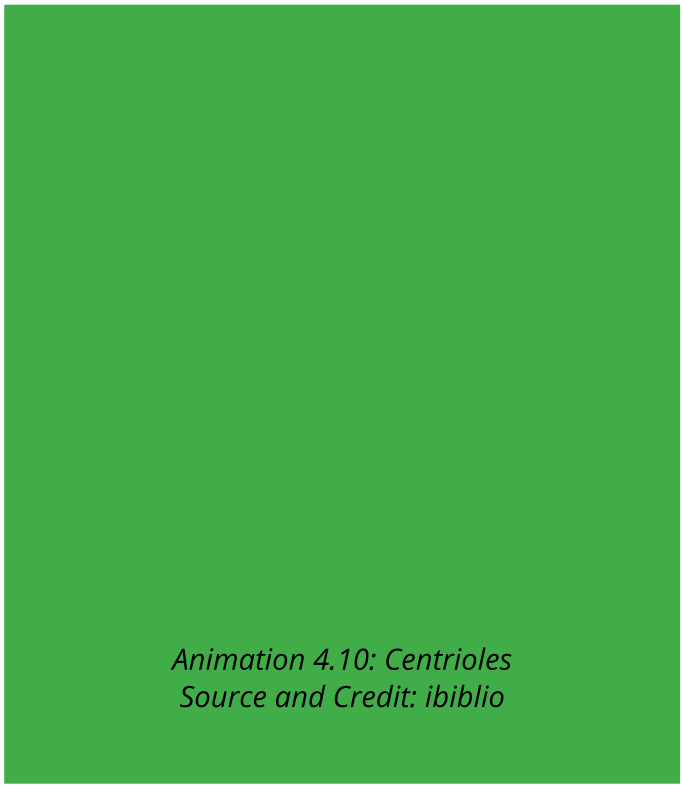


Figure 4.19: A Centriole



Animation 4.10: Centrioles
Source and Credit: ibiblio

Vacuoles

Vacuoles are fluid filled single-membrane bound organelles. Cells have many small vacuoles in their cytoplasm. However, when a plant cells matures its small vacuoles absorb water and fuse to form a single large vacuole in centre. Cell in this state becomes turgid. Many cells take in materials from outside in the form of food vacuole and then digest the material with the help of lysosomes. Some unicellular organisms use contractile vacuole for the elimination of wastes from their bodies.

? Which of the following organelles does not belong to others in the list: mitochondrion, chloroplast, ribosome, lysosome? Why?

Ribosome, because they are not membrane bounded.

Animation 4.11: Vacuole
Source and Credit: Ameoba sisters

4.2.6 Difference between Prokaryotic and eukaryotic cells

Prokaryotes possess prokayotic cells which are much simpler than the eukaryotic cells.The main differences between prokaryotic and eukaryotic cells are given next.

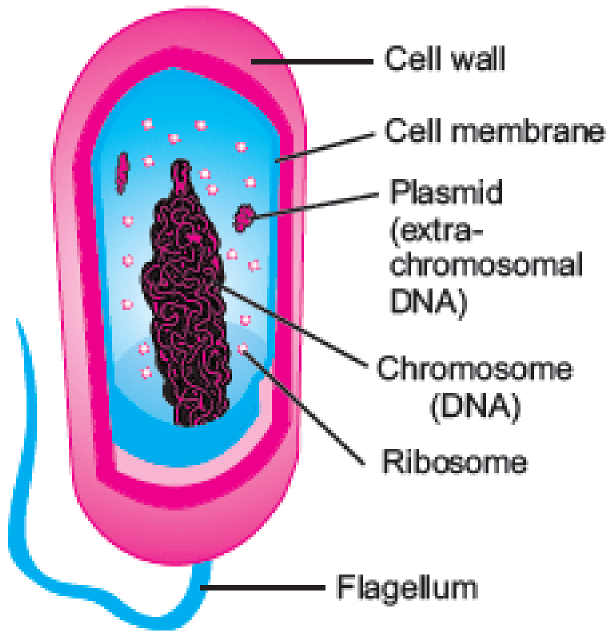


Figure 4.20: A general prokaryotic cell

Animation 4.12: Prokaryote vs. Eukaryote
Source and Credit: Ameoba sisters

Nucleus:	Eukaryotic cells have prominent nucleus (bounded by nuclear envelope) while prokaryotic cells do not have prominent nucleus. Their chromosome consists of DNA only and it floats in cytoplasm near centre. This region is called **nucleoid.**
Other Organelles:	Eukaryotic cells have membrane-bounded organelles like mitochondria, Golgi apparatus, endoplasmic reticulum etc while such membrane-bounded organelles are not present in prokaryotic cells. The ribosomes of eukaryotic cells are larger in size as compared to the ribosomes of prokaryotic cells.
Size:	Eukaryotic cells are, on average, ten times larger than prokaryotic cells.
Cell Wall:	The cell wall of eukaryotic cell is made of cellulose (in plants) or chitin (in fungi). All prokaryotic cells have cell wall, which is made of peptidoglycan (a large polymer of amino acids and sugars).

4.2.7 Relationship Between Cell Function And Cell Structure

The bodies of animals and plants are made of different cell types. Each type performs specific function and all coordinated functions become the life processes of organism. Cells of one type may differ from those of other types in the following respects.

Do you know?
Human body is made of about 200 types of cells.

Size and shape:	• Red blood cells are round to accommodate globular haemoglobin • Nerve cells are long for the transmission of nerve impulse • Xylem cells are tube-like and have thick walls for conduction of water and support
Surface area to volume ratio:	• Root hair cells have large surface area for the maximum absorption of water and salts
Presence or absence of organelles:	• Cells involved in making secretions have more complex ER and Golgi apparatus • Cells involved in photosynthesis have chloroplasts

Individual cells contribute in the functioning of the whole body. It can be explained by the following examples of the cells of human body:

- Nerve cells conduct nerve impulse and thus contribute in coordination in body.
- Muscle cells undergo contraction and share their role in movements in body.
- Red blood cells carry oxygen and white blood cells kill foreign agents and so contribute in the roles of blood in transportation and defence.
- Some skin cells act as physical barriers against foreign materials and some as receptors for temperature, touch, pain etc.
- The cells of bone deposit calcium in their extracellular spaces to make the bone tough and thus contribute to the supporting role of bones.

Cell as an Open System

A cell works as an **open system** i.e. it takes in substances needed for its metabolic activities through its cell membrane. Then it performs the metabolic processes assigned to it. Products and by-products are formed in metabolism. Cell either utilizes the products or transports them to other cells. The by-products are either stored or are excreted out of cell.

4.3 Cell Size And Surface Area To Volume Ratio

Cells vary greatly in size. 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 4.21 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
  and
- Surface area of 27 small cubes = 27 X 600 μm^2 = 16, 200 μm^2

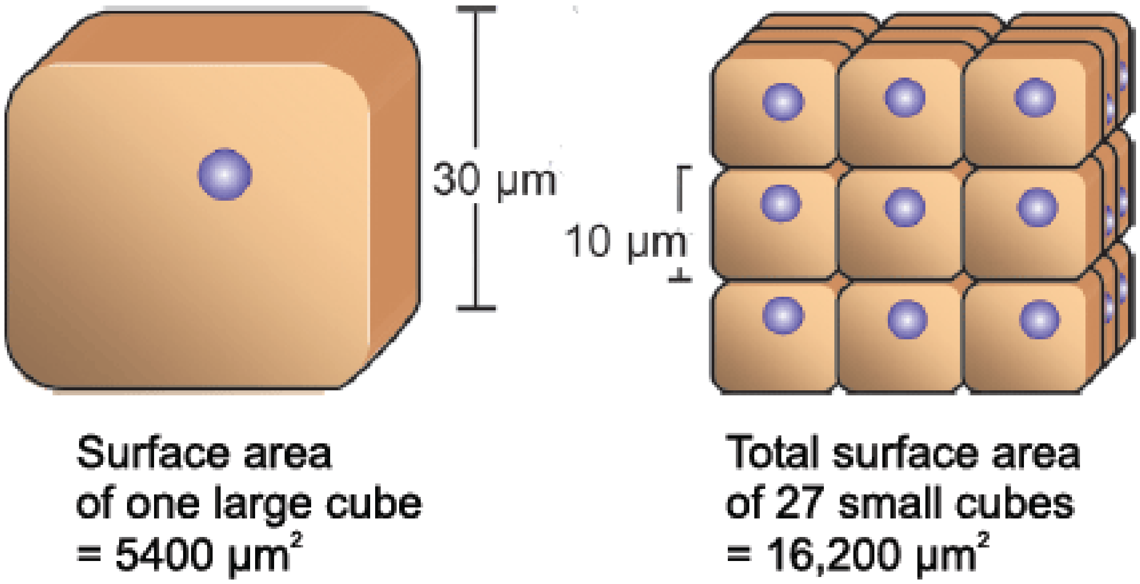


Figure 4.21: Effect of cell size on surface area

Need of nutrients and rate of waste production 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. Hence we conclude that the membranes of small cells can serve their volumes more easily than the membrane of a large cell.

4.4 Passage Of Molecules Into And Out Of Cells

We know that cell membranes act as barriers to most, but not all, molecules. That is why cell membranes are called **semi-permeable** membranes. Cell membranes maintain equilibrium inside cell as well as outside by exchanging matter with cells' environment according to needs. Cell membranes do it through the phenomena of diffusion, facilitated diffusion, osmosis, filtration, active transport, endocytosis and exocytosis.

Diffusion

Diffusion is the movement of molecules from an area of higher concentration to the area of lower concentration i.e. along concentration gradient. The molecules of any substance (solid, liquid or gas) are in motion when that substance is above 0 degrees Kelvin or -273 degrees Centigrade. In a substance, majority of the molecules move from higher to lower concentration, although there are some that move from low to high. The overall (or net) movement is thus from high to low concentration. Eventually, the molecules reach a state of equilibrium where they are distributed equally throughout the area.

Diffusion is one principle method of movement of substances within cells, as well as across cell membrane. Carbon dioxide, oxygen, glucose etc. can cross cell membranes by diffusion. Gas exchange in gills and lungs occurs by this process. Movement of glucose molecules from small intestine lumen into the blood capillaries of villi is another example of diffusion. Because a cell does not expend energy when molecules diffuse across its membrane, the diffusion is type of **passive transport.**

Animation 4.13: Diffusion
Source and Credit: wikipedia

Facilitated diffusion

Many molecules do not diffuse freely across cell membranes because of their size or charge. Such molecules are taken into or out of the cells with the help of transportproteins present in cell membranes. When a transport protein moves a substance from higher to lower concentration, the process is called facilitated diffusion. The rate of facilitated diffusion is higher than simple diffusion. Facilitated diffusion is also a type of passive transport because there is no expenditure of energy in this process (Figure 4.22).

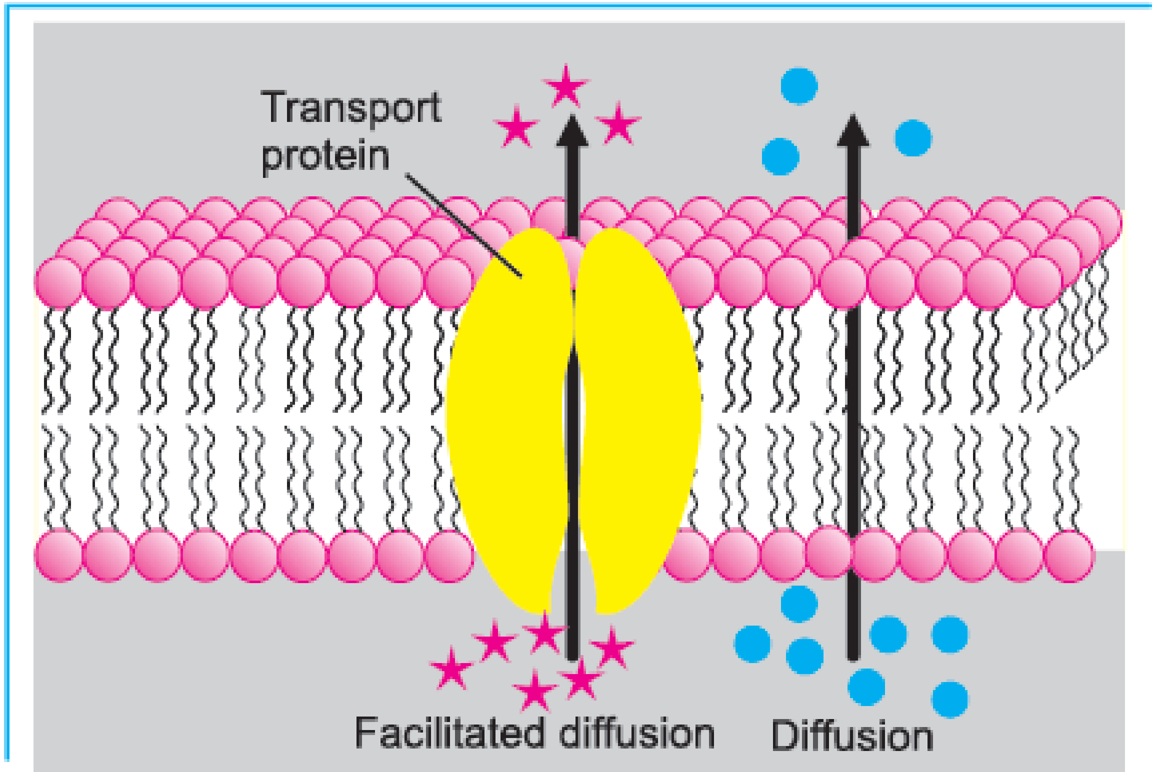


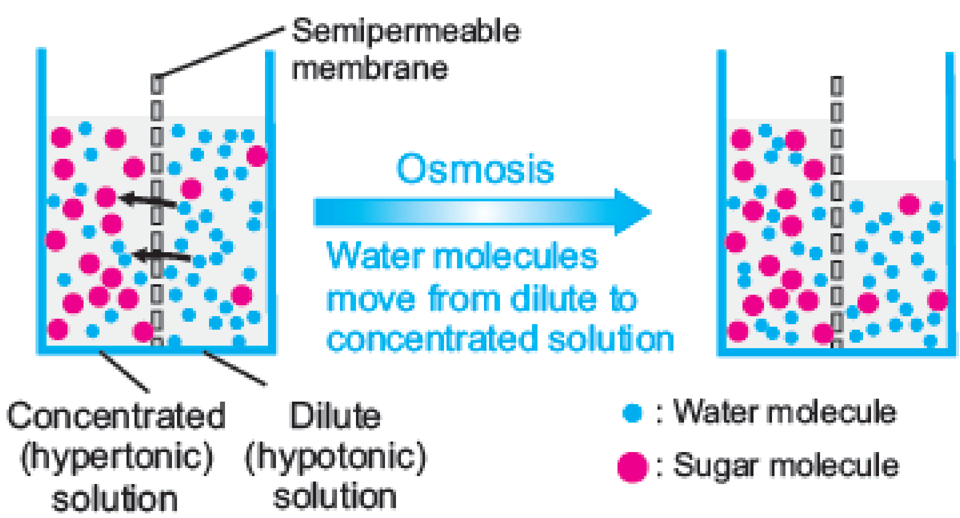
Figure 4.22: Diffusion and facilitated diffusion through cell membrane

Osmosis

Osmosis is the movement of water across a semi-permeable membrane from a solution of lesser solute concentration to a solution of higher solute concentration.

The rules of osmosis can be best understood through the concept of tonicity of solutions. The term tonicity refers to the relative concentration of solutes in the solutions being compared.

- A **Hypertonic solution** has relatively more solute.
- A **Hypotonic solution** has relatively less solute.
- **Isotonic** solutions have equal concentrations of solutes.



Animation 4.14: Osmosis
Source and Credit: majordifferences

Water balance problems

When an animal cell, such as red blood cell, is placed in an isotonic solution, the cell volume remains constant because the rate at which water is entering cell is equal to the rate at which it is moving out. When a cell is placed in a hypotonic solution, water enters and cell swells and may rupture like an over-filled balloon. Similarly, an animal cell placed in a hypertonic solution will lose water and will shrink in size. So in hypotonic environments (e.g. freshwater) animal cells must have ways to prevent excessive entry of water and in hypertonic environments (e.g. seawater) they must have ways to prevent excessive loss of water.

Water balance problems are somewhat different for plant cells because of their rigid cell walls. Most plant cells live in hypotonic environment i.e. there is low concentration of solutes in extracellular fluids than in cells. As a result, water tends to move first inside cell and then inside vacuole. When vacuole increases in size, cytoplasm presses firmly against the interior of cell wall, which expands a little. Due to strong cell wall, plant cell does not rupture but instead becomes rigid. In this condition, the outward pressure on cell wall exerted by internal water is known as **turgor pressure** and the phenomenon is **turgor**. In isotonic environment, the net uptake of water is not enough to make the cell turgid and it is flaccid (loose / not firm). In a hypertonic environment a plant cell loses water and cytoplasm shrinks. The shrinking of cytoplasm is called **plasmolysis.**

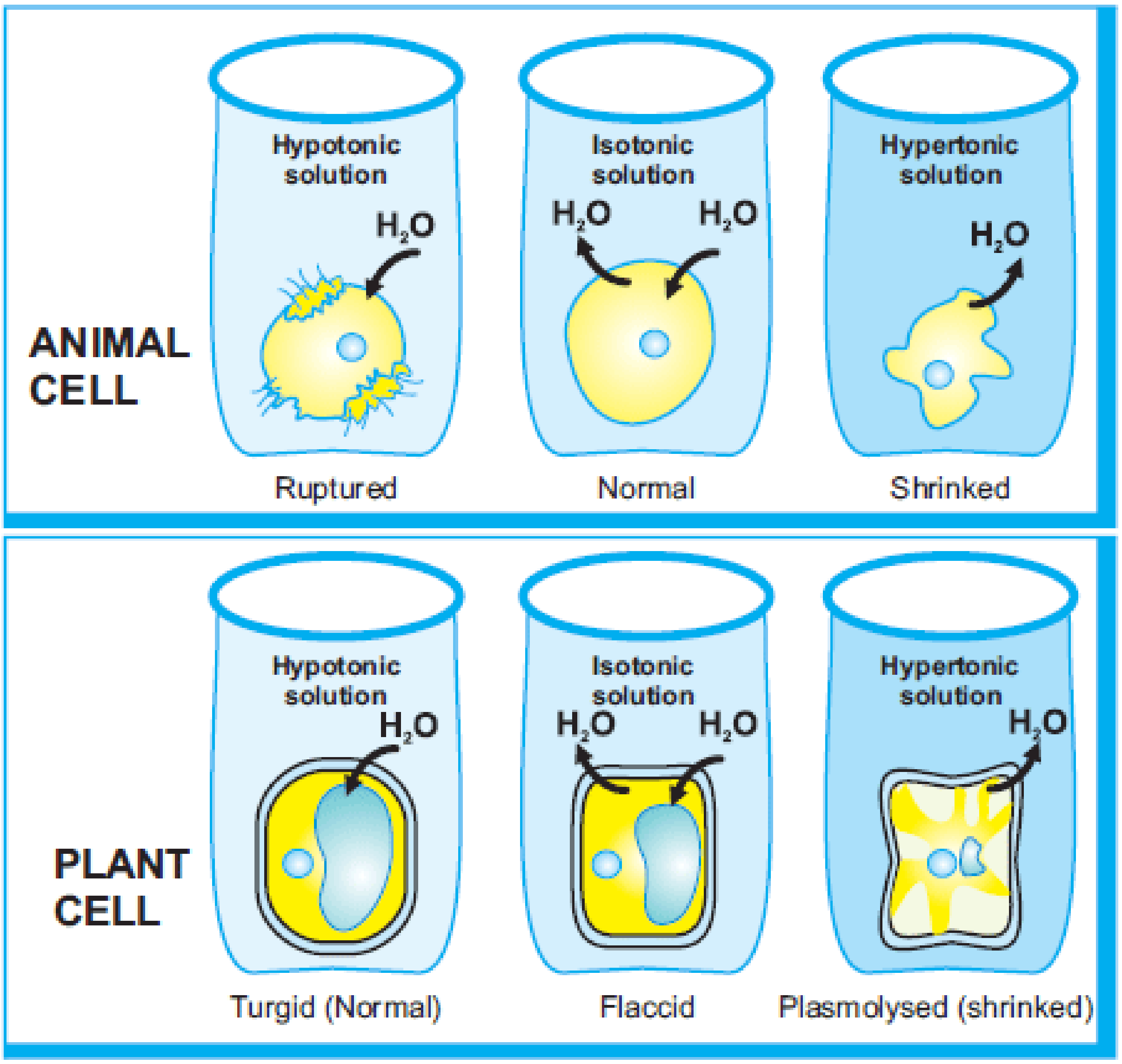


Figure 4.23: Effect of tonicity on animal and plant cell

Osmosis and Guard cells

Stomata (openings) in leaf epidermis are surrounded by guard cells. During daytime guards cells are making glucose and so are hypertonic (have higher concentration of glucose) than their nearby epidermis cells. Water enters them from other cells and they swell. In this form, they assume a rigid bowed shape and a pore is created between them. At night when there is low solute concentration in guard cells, water leaves them and they become flaccid. In this form, both guard cells rest against one another and the opening is closed.

Application of knowledge about semi-permeable membranes

The knowledge about semi-permeable membranes is applied for various purposes. We know that semi-permeable membrane is capable of separating substances. Artificially synthesized semi-permeable membranes are used for the separation of bacteria from viruses, because bacteria cannot cross a semi-permeable membrane. In advanced water-treatment technologies, membrane-based filtration systems are used. In this process, semi-permeable membranes separate salts from water **(reverse osmosis)**.

Filtration

Filtration is a process by which small molecules are forced to move across semipermeable membrane with the aid of hydrostatic (water) pressure or blood pressure.

The turgor of cells is responsible for maintaining shapes of non-woody plants and soft portions of trees and shrubs.

? Explain why it is not enough just to say that a solution is “hypertonoc“.

Hypertonic and hypotonic are relative terms. therefore you must say what the solution is compared to.

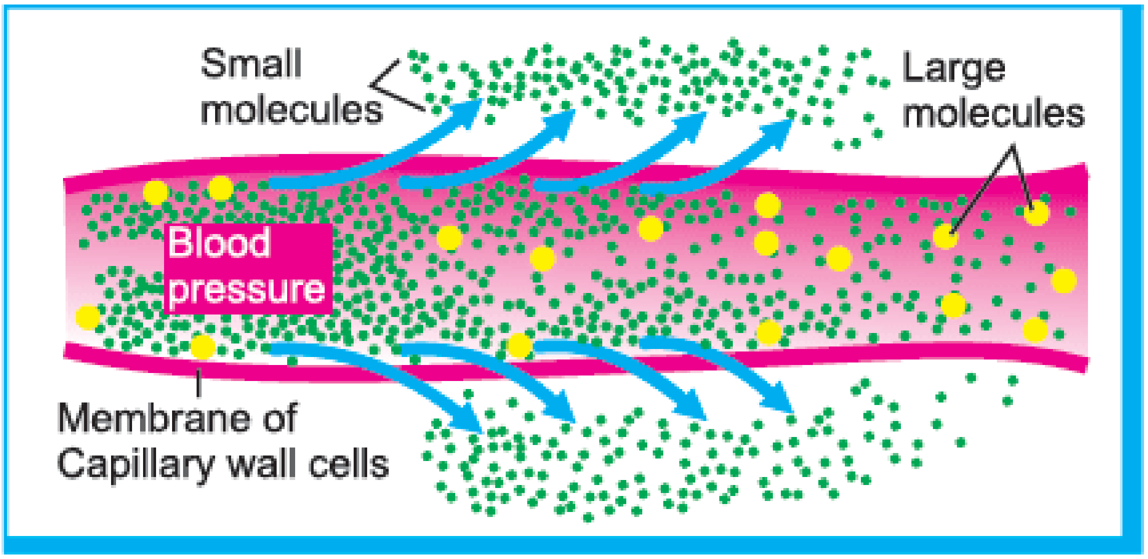


Figure 4.24: Filtration through the cell membrane of capillary wall

Active transport

Active transport is the movement of molecules from an area of lower concentration to the area of higher concentration. This movement against the concentration gradient requires energy in the form of ATP.

In this process, carrier proteins of cell membrane use energy to move the molecules against the concentration gradient. For example, the membranes of nerve cells have carrier proteins in the form of **"sodium-potassium pump"**. In a resting (not conducting nerve impulse) nerve cell, this pump spends energy (ATP) to maintain higher concentrations of K^+ and lower concentrations of Na^+ inside the cell. For this purpose, the pump actively moves Na^+ to the outside of the cell where they are already in higher concentration. Similarly this pumps moves K^+ from outside to inside the cell where they are in higher concentration (Figure 4.25).

? In diffusion and filtration, only small molecules can pass across membrane. Which process would move the molecules faster?

Filtration

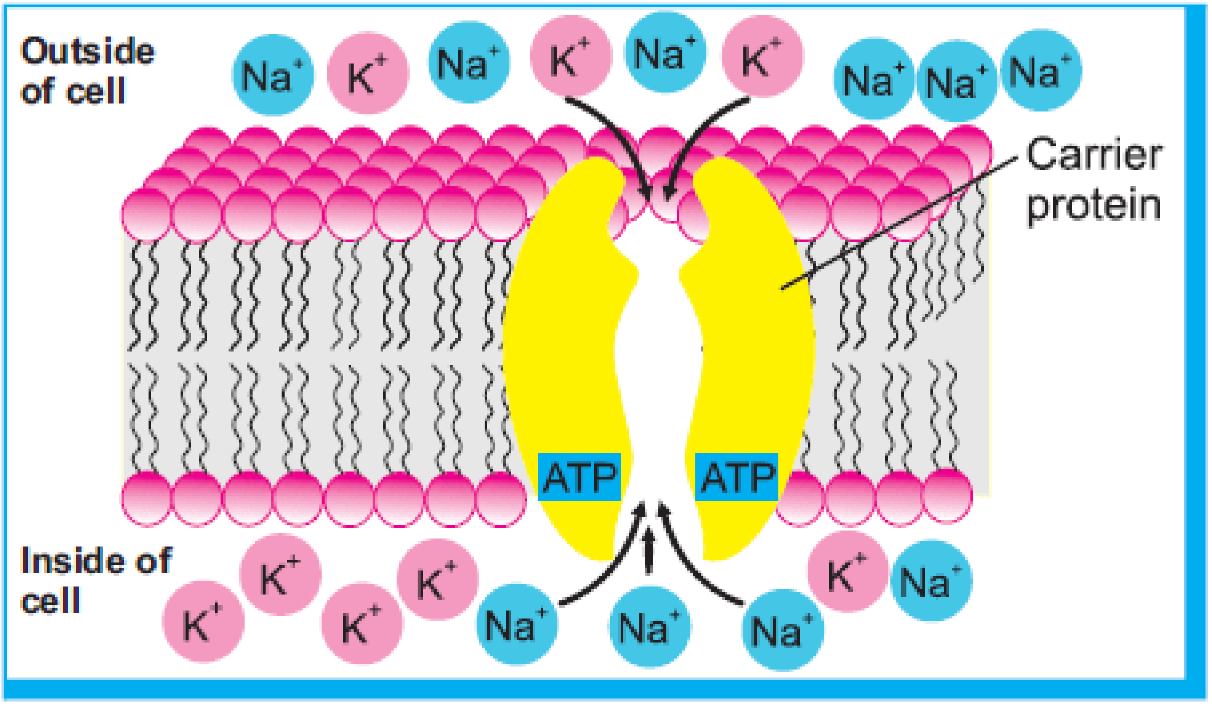


Figure 4.25: Sodium-potassium pump, showing active transport

Endocytosis

It is the process of cellular ingestion of bulky materials by the infolding of cell membrane (see the steps of endocytosis in Figure 4.26).

The two forms of endocytosis are **phagocytosis** (cellular eating) and **pinocytosis** (cellular drinking). In phagocytosis cell takes in solid material while in pinocytosis cell takes in liquid in the form of droplets.

In a colony of cells there are many cells and each cell performs all general functions on its own. Such a group does not get tissue level of organization because cells are not specific and there is no coordination among them.

Exocytosis

It is the process through which bulky material is exported (see the steps in Figure 4.26). This process adds new membrane which replaces the part of cell membrane lost during endocytosis.

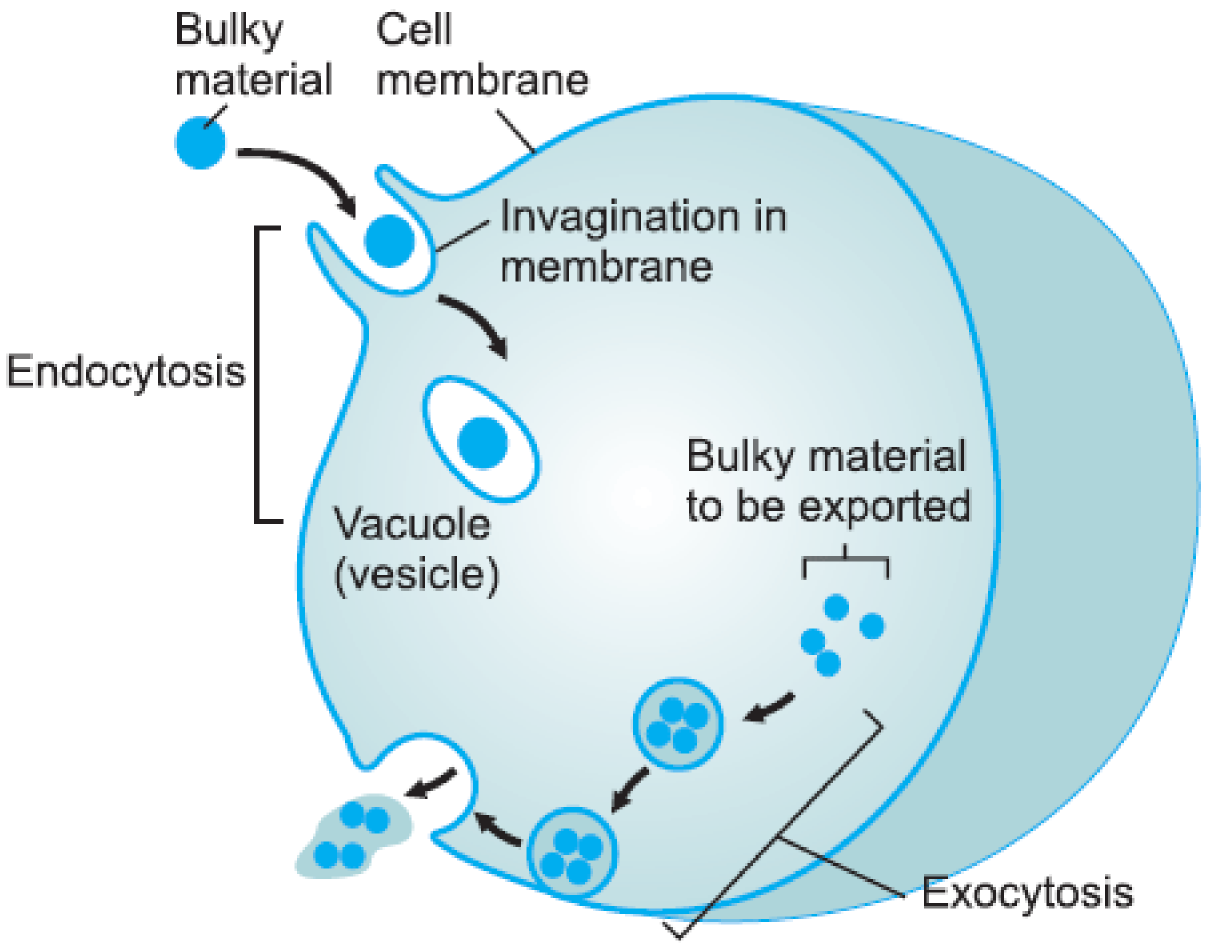


Figure 4.26: Endocytosis and Exocytosis

4.5 Animal And Plant Tissues

We are familiar with the levels of structural organization of life and recognize tissue as a group of similar cells specialized for the performance of a common function. In this topic we will learn about the major types of animal and plant tissues, with reference to their cell specificities, locations and functions.

4.5.1 Animal Tissues

In the bodies of animals, there are four major categories of tissues: epithelial tissue, connective tissue, muscle tissue, and nervous tissue.

Epithelial tissue

Epithelial tissue covers the outside of body and lines organs and cavities. The cells in this tissue are very closely packed together. This tissue has many types on the basis of the shape of cells as well as the number of cell layers. Some types include:

Squamous epithelium consists of a single layer of flat cells. It is found in lungs, heart and blood vessels. Here, it allows the movement of materials across it.

Cuboidal epithelium consists of a single layer of cube-shaped cells. It is found in kidney tubes, small glands etc. where it makes secretions.

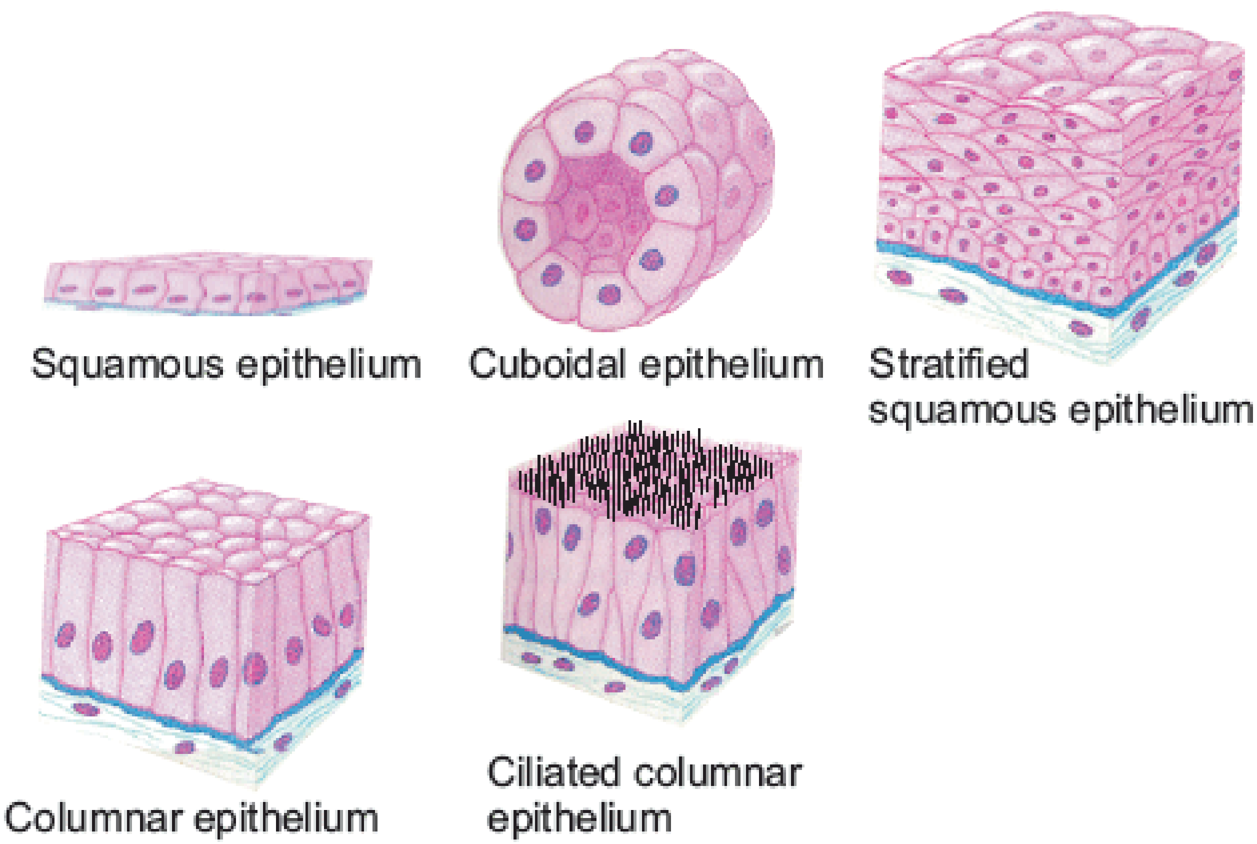


Figure 4.27: Epithelial tissues in animals

Columnar epithelium has elongated cells. It is found in alimentary canal, gall bladder etc. where it makes secretions.

Ciliated columnar epithelium has elongated cells with cilia. It is present in trachea and bronchi and propels mucous.

Stratified squamous epithelium has many layers of flat cells. It is present in the lining of oesophagus and mouth and also over the skin. It protects the inner parts.

Connective tissue

As the name shows, connective tissue serves a “connecting” function. It supports and binds other tissues. Unlike epithelial tissue, connective tissue has cells scattered throughout an extracellular matrix. Common examples of this tissue are cartilage (found around the ends of bones, in external ear, nose, trachea etc.), bone and blood. The adipose tissue (found around kidneys, under skin, in abdomen etc.) is also a type of connective tissue. It provides energy and support organs.

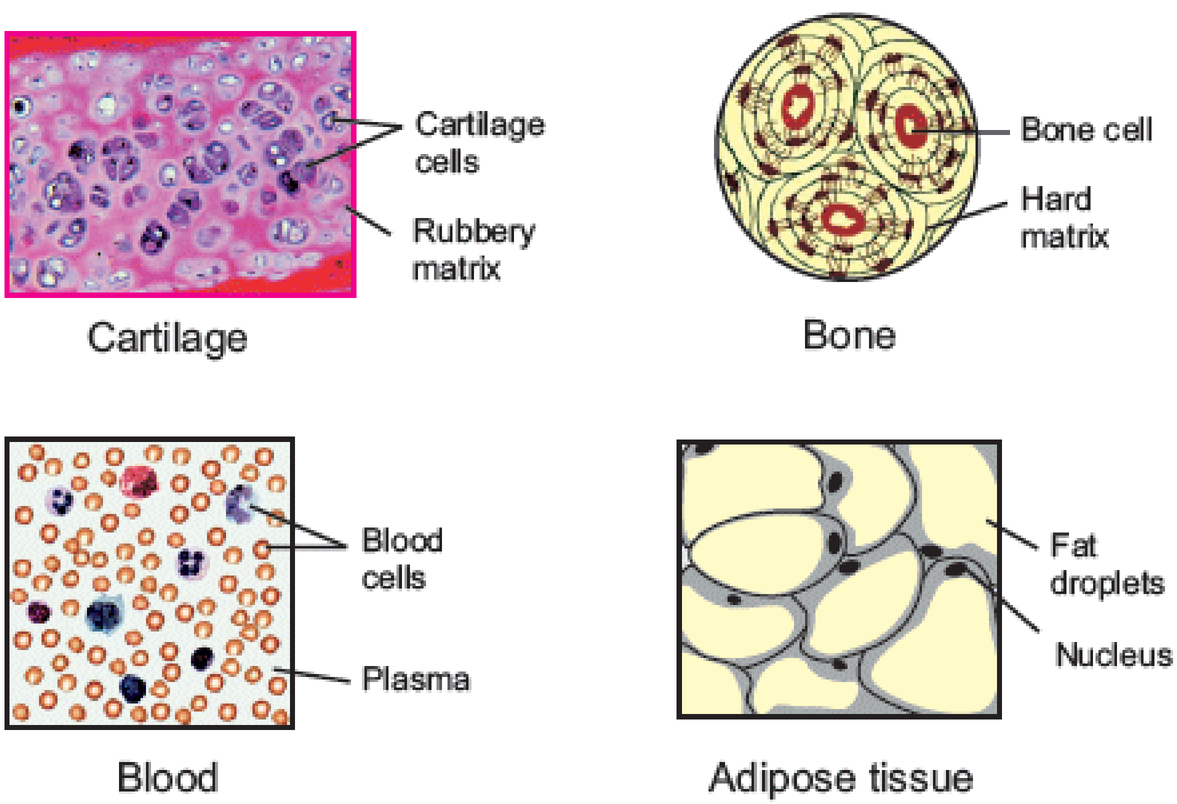


Figure 4.28: Connective tissues in animals

Do you know?

Exercise does not increase the numbers of our skeletal muscle cells; it simply enlarges those already present

Muscle Tissue

Muscle tissue consists of bundles of long cells called muscle fibers. It is the most abundant tissue in an animal. The cells of this tissue have ability to contract. There are three kinds of muscle tissue.

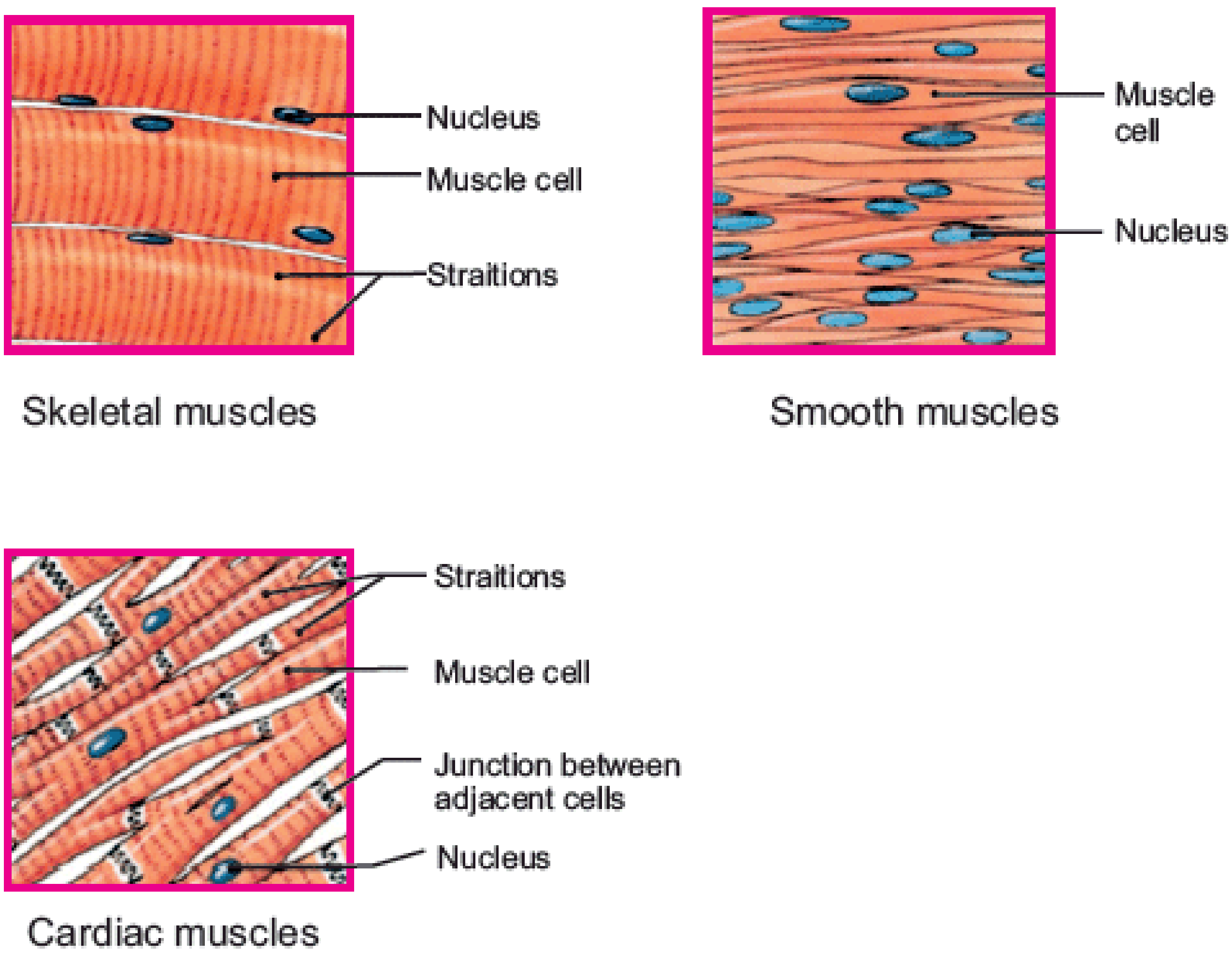


Figure 4.29: Types of muscle tissue

Skeletal muscles or striated muscles are attached to bones. Their cells are striated (striped) and contain many nuclei. They are responsible for the movements of bones.

Smooth muscles are found in the walls of alimentary canal, urinary bladder, blood vessels etc. They contain smooth (non-straited) cells, each with a single nucleus. They are responsible for the movement of substances.

Cardiac muscles are present in the wall of heart. Their cells are also striated but there is a single nucleus in each cell. They produce heartbeat.

Skeletal muscles are voluntary in action i.e. their contraction is under the control of our will. Smooth and cardiac muscles are involuntary in action i.e. their contraction is not under the control of our will.

Nervous tissue

We know that an animal's survival depends on its ability to respond appropriately to the stimuli from its environment. This ability requires the transmission of information among the parts of body. Nervous tissue forms a communication system and performs this task. This tissue is mainly composed of **nerve cells** or **neurons,** which are specialized to conduct messages in the form of **nerve impulses.** Nervous tissue is found in brain, spinal cord and nerves.

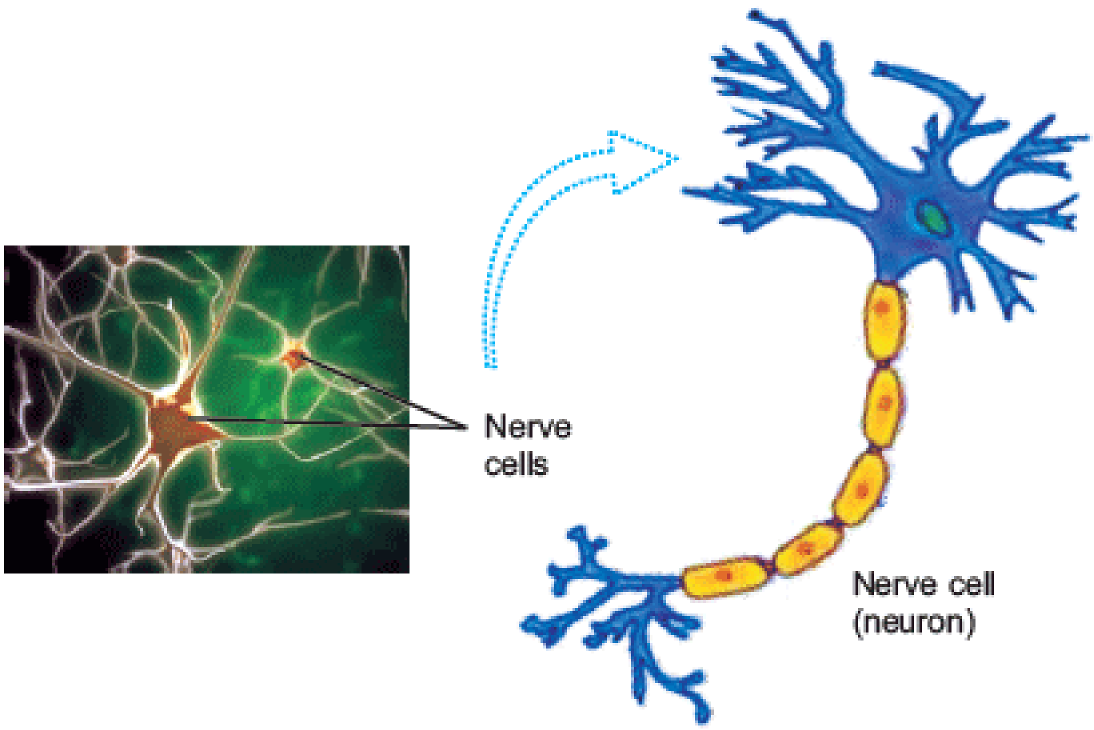


Figure 4.30: Nervous tissue

? When you hear that epithelial tissue has a tightly packed structure what function do you expect?

Barrier and protective function

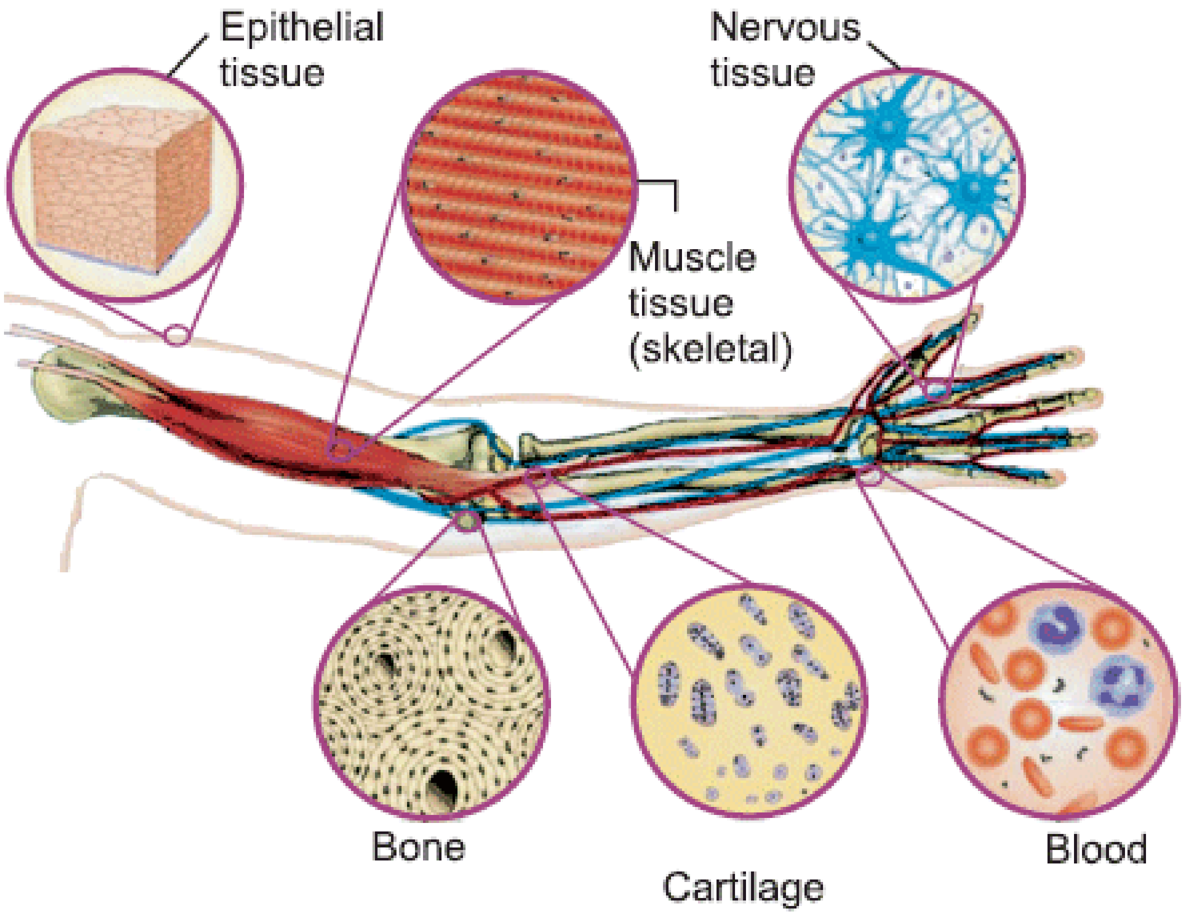


Figure 4.31: Different tissues in human body

4.5.2 Plant Tissues

As in animals, the cells of plants are grouped into tissues with characteristic functions such as photosynthesis, transport etc. There are two major categories of tissues in plants i.e. simple tissues and compound (complex) tissues.

Simple tissues

The tissues which are made of single type of cells, are called simple tissues. They are of two types i.e. meristematic tissues and permanent tissues.

A- Meristematic Tissues

These tissues are composed of cells, which have the ability to divide. The cells are thin walled, have large nucleus and small or no vacuoles. They do not have inter-cellular spaces among them. Two main types of meristematic tissues are recognized in plants.

i. **Apical meristems** are located at the apices (tips) of roots and shoot. When they divide they cause increase in the length of plant. Such 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 growth of plant parts. This growth is called secondary growth. They are further of two types i.e. **vascular cambium** (located between xylem and phloem) and cork cambium (in the outer lateral sides of plant).

Intercalary meristem is in the form of small patches among the mature tissues. These are common in grasses and help in the regeneration of parts removed by herbivores etc.

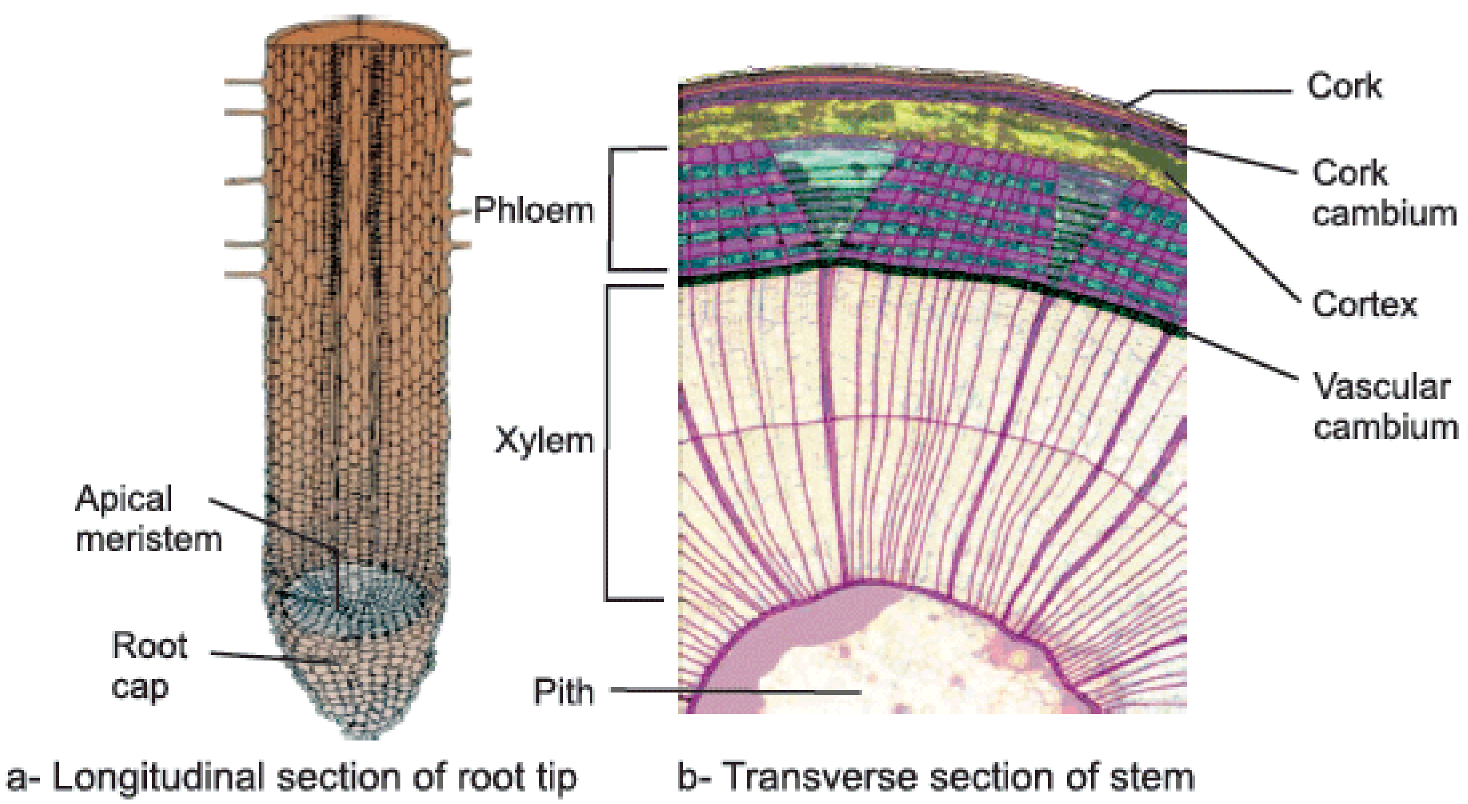


Figure 4.32: a- Apical meristem at root tip and b- Vascular and cork cambium in stem

B- Permanent Tissues

Permanent tissues originate from meristematic tissue. The cells of these tissues do not have the ability to divide. They are further classified into following types:

1. 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**.

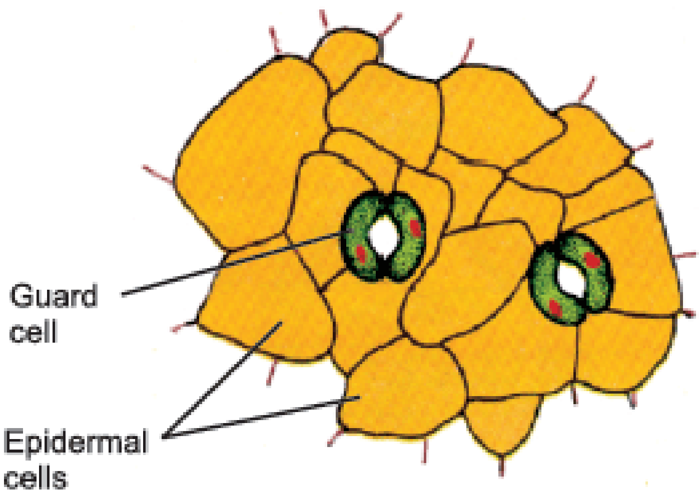


Figure 4.33: Epidermal tissue

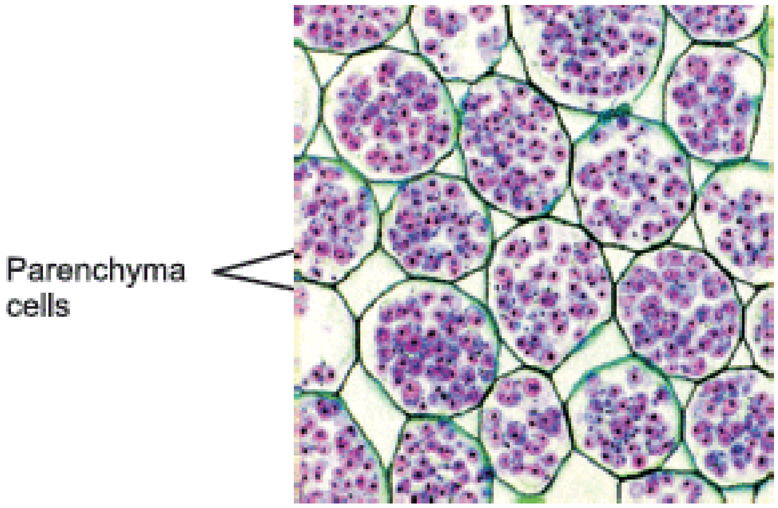


Figure 4.33-b : Ground tissue

2. 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.

Do you know?

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.

3. Support Tissues

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

i. Collenchyma Tissue

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.

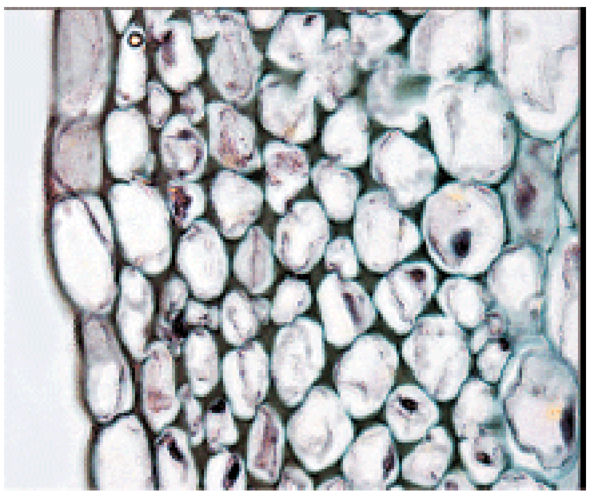


Figure 4.34: Collenchyma tissue

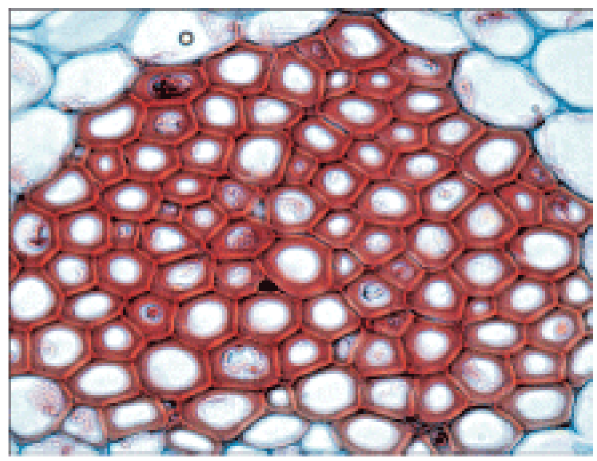


Figure 4.35: Schlerenchyma tissue

ii. Sclerenchyma Tissue

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.

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.

1. Xylem Tissue

Xylem tissue is responsible for the transport of water and dissolved substances from roots to the aerial parts. Due to the presence of lignin, the secondary walls of its cells are thick and rigid. That is why xylem tissue also provides support to plant body. Two types of cell are found in xylem tissue i.e. vessel elements and tracheids. **Vessel elements or cells** have thick secondary cell walls. They lack end walls and join together to form long tubes. **Tracheids** are slender cells with overlapping ends.

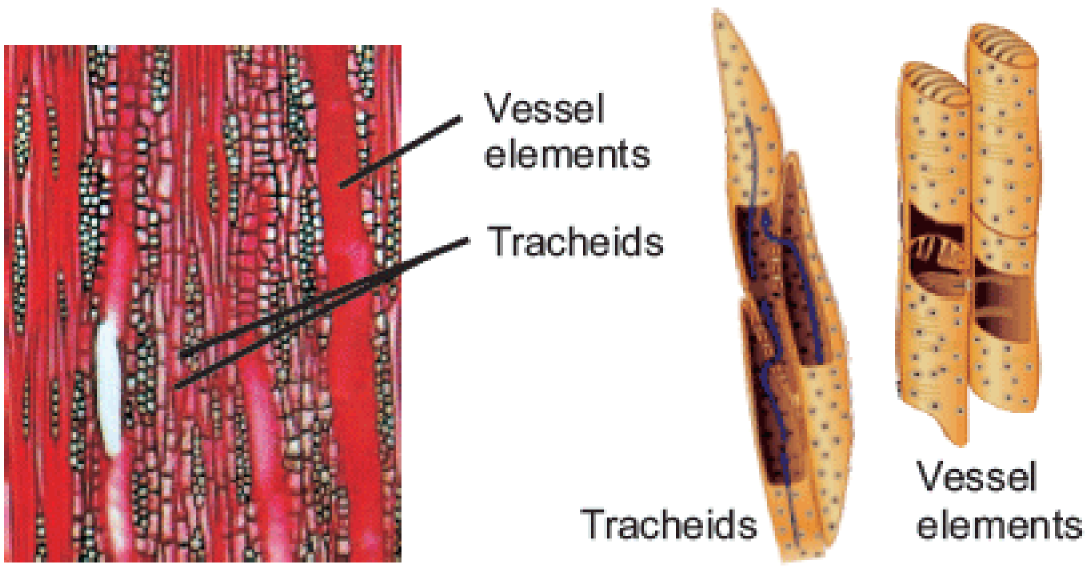


Figure 4.36: Xylem tissue

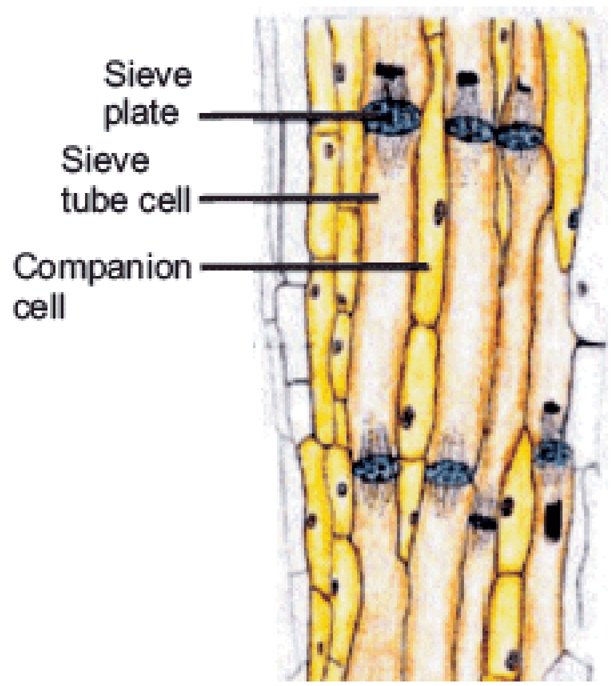


Figure 4.37: Phloem tissue

2. Phloem Tissue

Phloem tissue is responsible for the conduction of dissolved organic matter (food) between different parts of plant body. Phloem tissue contains sieve tube cells ands companion cells. **Sieve tube cells** are long and their end walls have small pores. Many sieve tube cells join to form long sieve tubes. **Companion cells** make proteins for sieve tube cells

? Birds fly by flapping their wings. What do you thing is the type of muscle responsible for wings flapping?

Skeletal

UNDERSTANDING THE CONCEPTS

1. Explain the functions of cell membrane.
2. Describe the structure of cell wall.
3. Discuss nucleus structure and function.
4. Describe the structure and function of endoplasmic reticulum and Golgi apparatus.
5. Describe the formation and function of lysosomes.
6. Explain what would happen when a plant and an animal cell is placed in a hypertonic solution.
7. Describe the internal structure of chloroplast and compare it with that of mitochondrion.
8. Explain the phenomena involved in the passage of matter across cell membrane.
9. Describe how turgor pressure develops in a plant cell.
10. State the relationship between cell function and cell structure.
11. Describe the differences in prokaryotic and eukaryotic cells.
12. Explain how surface area to volume ratio limits cell size.
13. Describe the major animal tissues in terms of their cell specificities, locations and functions.
14. Describe the major plant tissues in terms of their cell specificities, locations and functions.

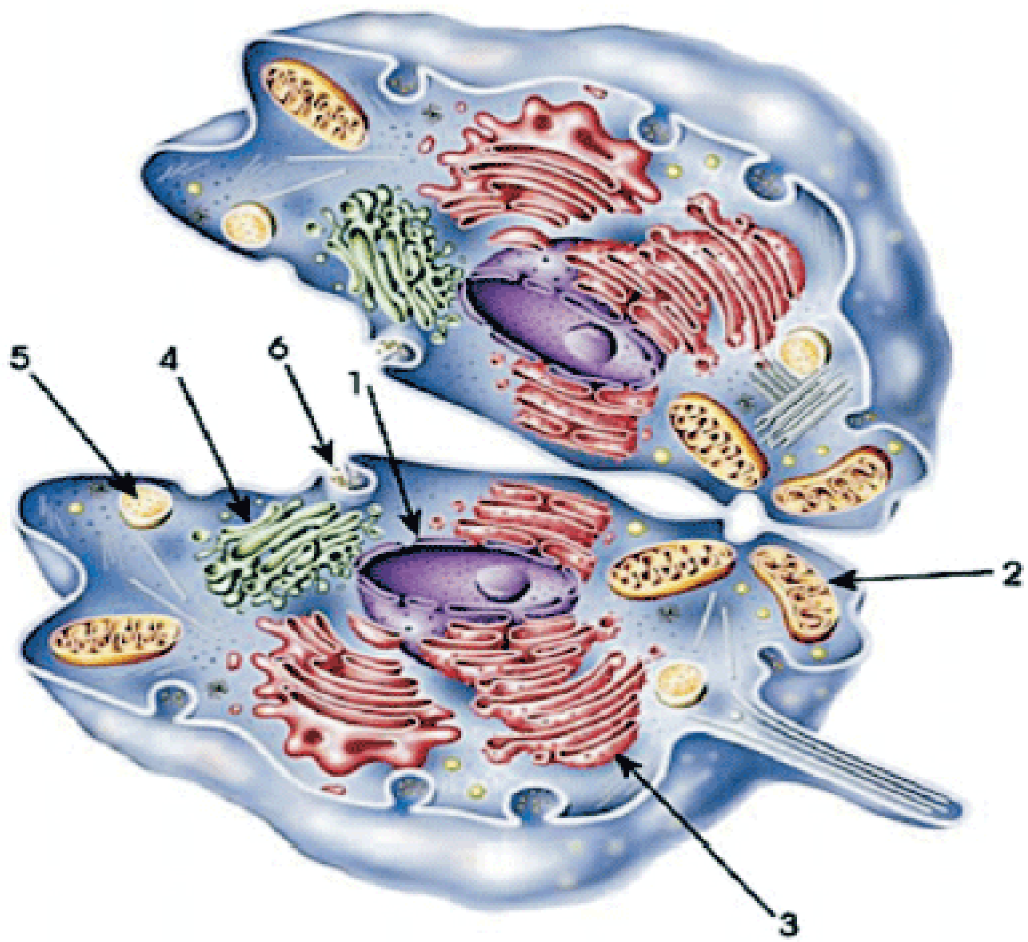
SHORT QUESTIONS

1. State the cell theory.
2. What are the functions of leucoplasts and chromoplasts?
3. Differentiate between diffusion and facilitated diffusion?
4. What is meant by hypertonic and hypotonic solutions?

THE TERMS TO KNOW		
Active transport	Epithelial tissue	Organelle
Cell	Facilitated diffusion	Osmosis
Cell membrane	Golgi apparatus	Passive transport
Cell theory	Hypertonic/Hypotonic solution	Phagocytosis
Cell wall	Isotonic solution	Pinocytosis
Centriole	Leucoplast	Plasmolysis
Chloroplast	Lysosome	Plastid
Chromoplast	Mitochondrion	Ribosome
Connective tissue	Muscle tissue	Selectively permeable
Cytoplasm	Nucleus	Tissue
Diffusion	Endoplasmic reticulum	Turgor pressure

Initiating And Planning

1. Assess the capabilities of animal and plant cell types owing to the presence or absence of chloroplasts and cell wall.
2. Assess the capabilities of prokaryotic and eukaryotic cells owing to the presence or absence of nucleus and mitochondria.
3. Label the six points given in the following diagram of a cell.



4. Justify why a colony of cells does not get tissue level of organization in spite of having many cells.
5. Formulate operational definitions of major variables e.g. Define concentration gradient; define osmosis in terms of hypotonic, hypertonic and isotonic solutions.

ON-LINE LEARNING

1. www.columbia.edu
2. www.agen.ufl.edu/.../lect/lect_15/lect_15.htm
3. http://sps.k12.ar.us/massengale/biology%20I%20page.htm
4. www.cell-research.com