SLO 4: Cells and Tissues

4.1 Microscopy and the Emergence of Cell Theory

4.1.1 Define 'Magnification' And 'Resolution' Of The Microscope

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.

4.1.2 Compare Light Microscopy And Electron 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.

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.

4.1.3 Calculate The Total Magnification Of A Specimen Observed Under A Compound Light Microscope By Applying The Formula:

Total Magnification = Eyepiece Magnification × Objective Lens Magnification

4.1.4 Differentiate Among SEM and TEM

Scanning Electron Microscope (SEM)
In SEM, electrons are reflected from the metal-coated surfaces. SEM is used to study the structure of cell surfaces. A beam of electrons moves back and forth across the surface of a cell or tissue, creating a detailed image of the 3D surface.

Transmission Electron Microscope (TEM)
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.

4.1.5 Determine Whether An Image Is From A Light Microscope, Scanning Electron Microscope Or Transmission Electron Microscope

1. Light Microscope (LM)

- Visual Look: Can be in color (if stained) or shows natural colors of the specimen.
- Resolution: Lowest. You can see the whole cell and large organelles (Nucleus, Chloroplast, Vacuole), but not the internal details of those organelles.
- Magnification: Up to 1,000x – 1,500x.
- Key Indicator: If you see a purple/pink stained slide or a green plant cell where the mitochondria are just "tiny dots," it is a Light Microscope.

2. Scanning Electron Microscope (SEM)

- Visual Look: 3D (Three-Dimensional). It looks like a photograph of the surface of an object.
- Resolution: High. You can see the texture, bumps, and "landscape" of a specimen.
- Magnification: Up to 100,000x.
- Key Indicator: If the image looks like a "sculpture" or shows the outside of a pollen grain, an insect's eye, or the surface of a hair, it is an SEM. The background is usually dark/shadowy.

3. Transmission Electron Microscope (TEM)

- Visual Look: 2D (Two-Dimensional) Cross-section. It looks like a "flat" slice through a cell.
- Resolution: Highest. You can see the inner ultra-structure (e.g., the cristae inside mitochondria, the grana inside chloroplasts, or the bilayer of the cell membrane).
- Magnification: Up to 500,000x+.
- Key Indicator: If you are "inside" the cell seeing the internal details of a ribosome or the DNA strands in a nucleus, it is a TEM.

4.1.7 State The Postulates Of Cell Theory

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.

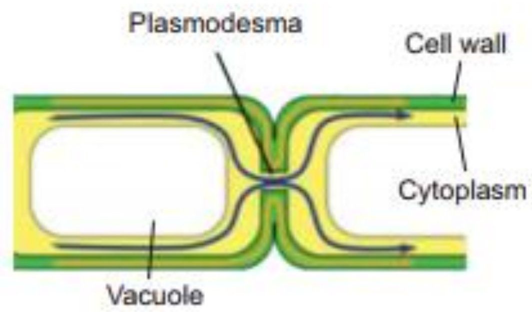
4.2 Cellular Organelles

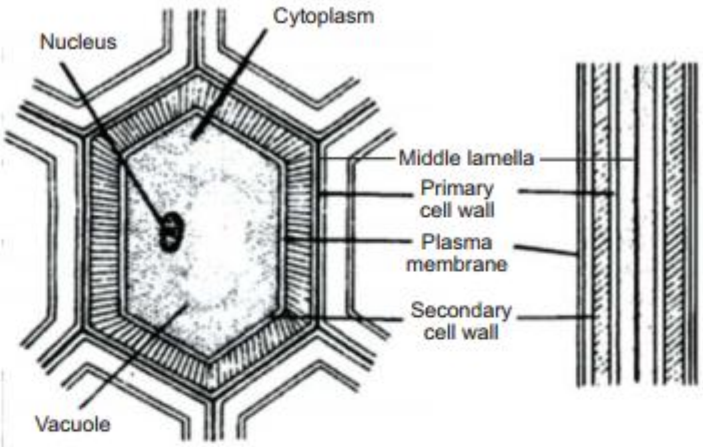
4.2.1 Explain Structure, Composition And Functions Of The Sub-Cellular Components

Cell Wall

A cell wall is a tough, rigid non-living and permeable protective layer. It is located next to cell 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. Plant cell wall is composed mainly of strong fibers of cellulose. It may consist up to three layers that help to support the plant.

- 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 alongside the cell membrane. It is made up of a thick and tough cellulose which is held together by a hard, water proof lignin. It is only found in cells which provide mechanical support in plants, i.e., Some cells of xylem like tracheid and vessels.



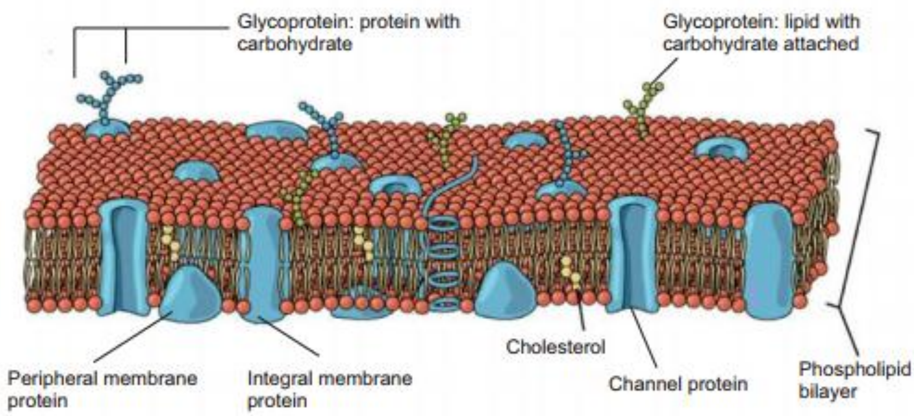


The openings in the cell wall are called plasmodesma which contain strands of cytoplasm that connect adjacent cells. This allows cells to interact with one another, allowing molecules to travel between plant cells. The main function of the wall is to protect the inner parts of the plant cell; it gives 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.

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.

Plasma Membrane

The cell membrane is the outer most living boundary of all cells. Plasma membrane physically separates the intracellular space (inside the cell) from the extracellular environment (outside the cell). It surrounds and protects the cytoplasm. It is composed of a double layer (bilayer) of special lipids called phospholipids.



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.

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.

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 network in the nucleus called chromatin network.

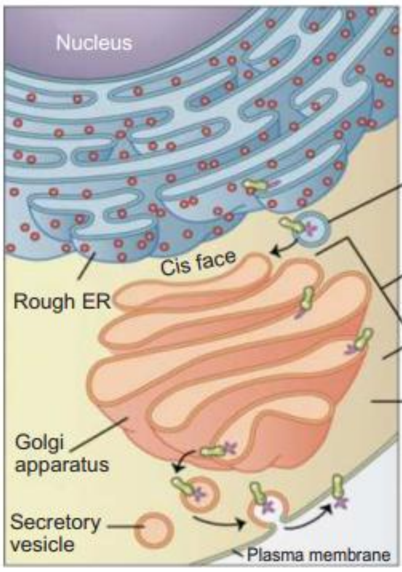
Cytoplasm

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.

Golgi Bodies



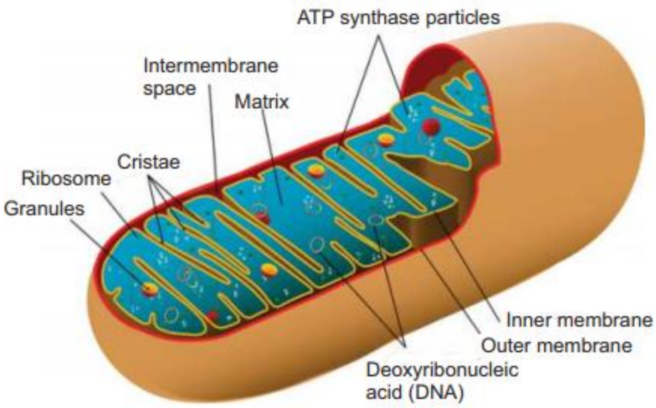
The Golgi body was discovered by the Italian physician Camillo Golgi. It was one of the first organelles to be discovered and described in detail because its large size made it easier to observe. It is important for proteins to be transported through Golgi body from where they are synthesized to where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

Mitochondria

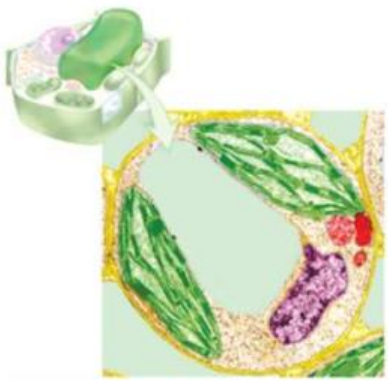
A mitochondrion is a membrane bound organelle found in eukaryotic cells. Mitochondria contain two phospholipid bilayers: there is an outer membrane, and an inner membrane. The inner membrane contains many folds called cristae which contain specialized membrane proteins that enable the mitochondria to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

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.



Vacuole

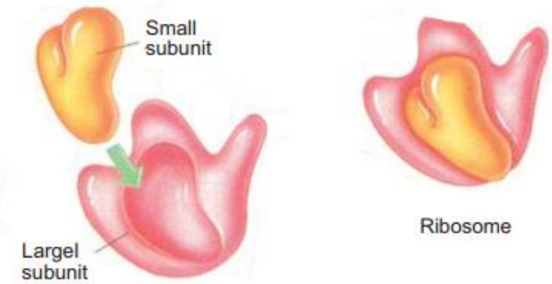
Vacuoles are fluid-filled spaces that occur in the cytoplasm of plant cells, but are very small or completely absent in animal cells. Plant cells generally have one large vacuole that takes up most of the cell's volume in mature cell. A selectively permeable boundary called the tonoplast, surround the 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.



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.

Endoplasmic Reticulum



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.

Smooth Endoplasmic Reticulum:

It 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:

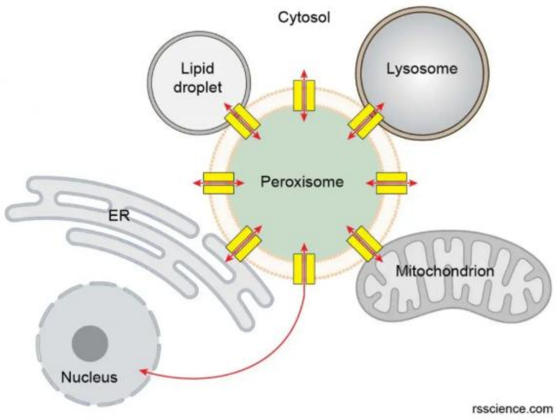
It is covered with ribosomes giving the endoplasmic reticulum its rough appearance. It is responsible for protein synthesis and plays a role in membrane production. The folds present in the membrane increase the surface area allowing more ribosomes to be present on the ER, thereby allowing greater protein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

Lysosomes

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.

Peroxisomes

Peroxisomes are essential single membrane-bound organelles involved in oxidative metabolism. While they resemble lysosomes in appearance, they differ significantly in their enzymatic content and origin. They are small, spherical or ovoid vesicles (0.1–1.5 µm) with a granular matrix surrounded by a single lipid bilayer. They are Enzymatic Battery; they contain over 50 enzymes, primarily oxidases and catalase.

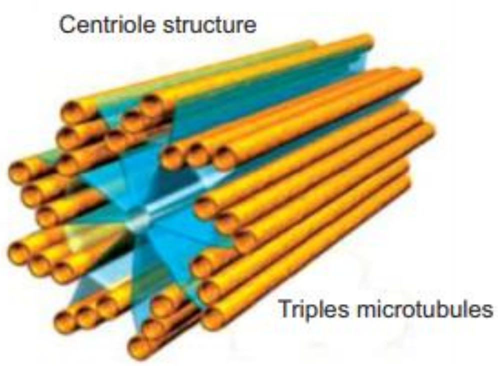


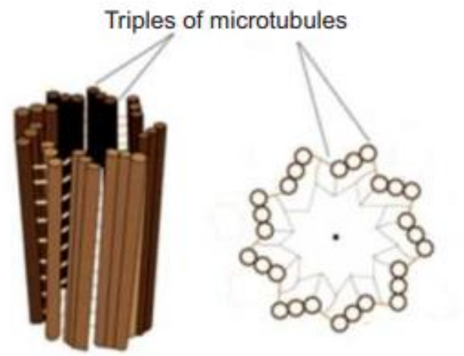
Peroxisomes use oxygen to strip hydrogen from various organic molecules, producing hydrogen peroxide because H_2O_2 is toxic, the enzyme catalase immediately converts it into harmless water and oxygen. They also break down very long-chain fatty acids. They are abundantly found in the liver and kidneys, where they detoxify harmful substances like alcohol and drugs.

In germinating seeds, specialized peroxisomes convert stored fatty acids into carbohydrates (sugars) through the glyoxylate cycle to provide energy for growth. In green leaves, they assist chloroplasts and mitochondria in photorespiration, recycling by-products of carbon fixation.

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.





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 color. There are three different types of plastids:

- Chloroplasts: Green-colored plastids found in plants and algae.
- Chromoplasts: Contain red, orange or yellow pigments and are common in ripening fruit, flowers or autumn leaves.
- Leucoplasts: Color less plastids.

4.2.2 Compare:

Prokaryotic And Eukaryotic Cells

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).

Cellular Structures	Prokaryotic cell	Eukaryotic cell
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 organelles	Absent	Present
Ribosomes	Smaller 70S	Larger 80S
Permeability of nuclear membrane	Not present	Selective
Cell Size	1-10 µm	1-1000 µm
Flagella	Submicroscopic in size, composed of only on	Microscopic in size; membrane bound
Organelles present	Microtubules (rare), Vesicles	Lysosomes, Peroxisome, Microtubules, Endoplasmic reticulum, Mitochondria, Vesicles, Golgi Apparatus, Chloroplasts (plants), Plasma membrane, Vacuoles

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 center 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

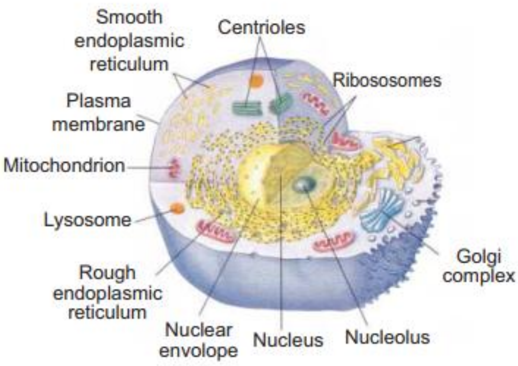


Figure 4.8 Animal cell

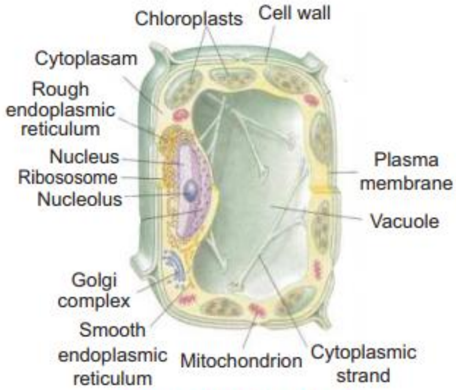


Figure 4.9 Plant cell

4.2.3 Evaluate The Overall Effect Of A Malfunctioned Organelle On Cellular Function

Cell wall:
Malfunction causes loss of rigidity and protection, making the cell prone to bursting under osmotic pressure or mechanical stress.

Plasma membrane:
Malfunction disrupts selective permeability, leading to loss of homeostasis, uncontrolled ion/nutrient flow, and potential cell lysis or shrinkage.

Nucleus:
Malfunction impairs DNA replication and gene expression, halting proper protein synthesis, cell regulation, and division.

Cytoplasm:
Malfunction disrupts the medium for metabolic reactions and organelle suspension, severely reducing biochemical efficiency and cellular organization.

Cytoskeleton:
Malfunction leads to loss of cell shape, impaired intracellular transport, motility, and defective cell division.

Golgi bodies:
Malfunction prevents proper modification, sorting, and packaging of proteins/lipids, causing secretion defects and accumulation of dysfunctional molecules.

Mitochondria:
Malfunction causes severe ATP shortage, crippling energy-dependent processes and often triggering cell death pathways.

Vacuole:
Malfunction impairs storage, waste detoxification, and turgor pressure, resulting in loss of cell firmness and toxic buildup (especially critical in plant cells).

Ribosomes:
Malfunction reduces or corrupts protein synthesis, affecting nearly all cellular structures, enzymes, and functions.

Endoplasmic reticulum:
Malfunction causes protein misfolding, lipid synthesis failure, and calcium imbalance, inducing ER stress and cellular dysfunction.

Lysosomes:
Malfunction leads to accumulation of undigested waste and macromolecules, causing cellular toxicity and storage disease-like effects.

Peroxisomes:
Malfunction results in buildup of reactive oxygen species and toxic metabolites, increasing oxidative damage and disrupting lipid breakdown.

Centrioles:
Malfunction disrupts microtubule organization, spindle formation, and cell division, leading to mitotic errors, aneuploidy, or motility defects (in ciliated cells).

Plastids:
Malfunction (especially in chloroplasts) reduces photosynthesis or storage capacity, causing energy and nutrient deficits in plant cells.

4.3 Cell Specialization

4.3.1 Define 'Stem Cells' As Unspecialized Cells
Stem cells are unspecialized cells that can both reproduce themselves indefinitely and — under appropriate signals — turn into various specialized cell types (e.g., muscle cells, nerve cells, blood cells, bone cells, etc.) whenever needed by the body.

4.3.2 Describe Cell Specialization And Its Importance For The Efficient Functioning Of Complex Organisms
Cell specialization, also known as cell differentiation, is the process by which unspecialized cells, such as stem cells, develop into specialized cells with distinct structures, shapes and functions to perform specific roles in the body. This occurs through differential gene expression, where all cells contain the same genetic information (DNA), but only certain genes are activated in each cell type while others are silenced, leading to the production of specific proteins that determine the cell's structure and function.

- Cell specialization enables division of labor in multicellular organisms, which is essential for their efficient functioning and survival.
- In complex organisms, this allows the formation of tissues, organs and organ systems that work together in a coordinated manner, supporting large body size, complex structures and advanced physiological processes such as rapid response, homeostasis, nutrient distribution and reproduction.
- Cell specialization transforms a single fertilized egg into a highly organized, efficient and functional organism capable of complex life activities.
- Without specialization, multicellular organisms would remain limited to simple forms like colonial organisms (e.g., Volvox), lacking true tissue-level organization, efficient resource utilization, effective defense mechanisms or adaptability to environmental changes.

4.3.3 Relate Structure Of The Following Specialized Cells With Their Functions:
A. Root hair cells – for absorption of water and minerals,
B. Xylem vessels – for conduction and support,
C. Mesophyll cells – for photosynthesis and gaseous exchange,
D. Epidermal cells with cuticle – for protection and regulation of water loss,
E. Red blood cells – for transport of oxygen,
F. Nerve cells – for conduction of nerve impulse.

4.3.4 Assess The Potential Impacts On The Functioning Of Multicellular Organisms If The Cells (A – F) Mentioned In SLO 4.3.3 Were Not Specialized
A. Root hair cells — Extremely slow and inefficient absorption of water and minerals → severe dehydration, nutrient deficiency, wilting, and plant death.
B. Xylem vessels — Poor water/mineral conduction and weak mechanical support → inadequate supply to leaves, collapse of tall structures, reduced photosynthesis, and plant instability.
C. Mesophyll cells — Drastically reduced photosynthesis and slow gaseous exchange → minimal energy/carbohydrate production, starvation, stunted growth, and eventual plant death.

D. Epidermal cells with cuticle — Uncontrolled water loss and no protection from damage/pathogens → rapid desiccation, infections, physical injury, and failure to survive dry conditions.
E. Red blood cells — Inefficient oxygen transport and poor capillary passage → widespread tissue hypoxia, reduced respiration, organ failure (especially brain/heart), and organism death.
F. Nerve cells — Slow or impossible rapid/long-distance impulse conduction → loss of coordination, reflexes, sensory/motor functions, homeostasis, and inability to respond or survive threats.

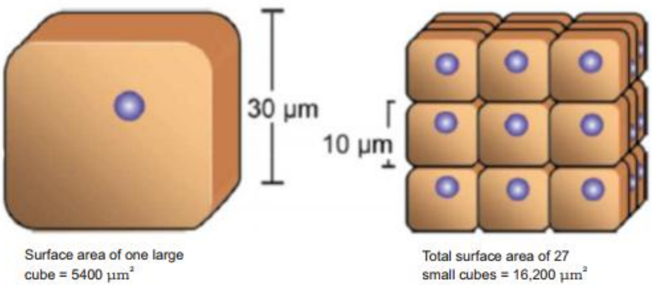
4.4 Surface Area To Volume Ratio

4.4.1 Calculate The Surface Area To Volume Ratio Of Different-Sized Cells (Cubes) Using Appropriate Formulas And Measurements

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 µm3

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.



4.4.2 Evaluate The Relationship Between Surface Area To Volume Ratio And Cell Size

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 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.

4.4.3 Assess The Efficiency Of Cellular Processes Based On The Surface Area-To Volume Ratio Of Cells

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.

4.5 Active And Passive Transport Of Matter

4.5.1 Define ‘Tonicity’ Of The Solution

The relative concentration of solutes dissolved in a solution which determines the direction and extent of osmosis across a semi-permeable membrane.

4.5.2 Describe Different Types Of Solution Based On The Types Of Tonicities

Isotonic Solution:
The solute concentration is equal inside and outside the cell. There is no net movement of water, and the cell volume remains stable.

Hypotonic Solution:
The external solution has a lower solute concentration (higher water potential) than the cell's cytoplasm. Water enters the cell, causing it to swell. Plant cell becomes Turgid (firm), as the cell wall prevents bursting.

Hypertonic Solution:
The external solution has a higher solute concentration (lower water potential) than the cell's cytoplasm. Water leaves the cell. Plant cell undergoes Plasmolysis, where the cell membrane shrinks away from cell wall.

4.5.3 Analyze The Effects On Plant And Animal Cells When Placed In Hypotonic, Hypertonic And Isotonic Solutions

Solution Type	Animal Cell	Plant Cell
Hypotonic	Hemolysis: Water enters the cell. Lacking a cell wall, the membrane cannot withstand the pressure and the cell bursts.	Turgid: Water enters the large vacuole. Rigid cell wall exerts back-pressure, prevent bursting and making the cell firm.
Isotonic	Normal / Stable: Water moves in and out at equal rates. The cell maintains its biconcave shape.	Flaccid (Limp): There is no net pressure against the cell wall. The plant may begin to wilt if all cells are in this state.
Hypertonic	Crenation (Shrinking): Water leaves the cell. The cell membrane shrivels, giving it a notched or wrinkled appearance.	Plasmolysis: Water leaves the vacuole. The Cytoplasm and cell membrane shrink away from the rigid cell wall.

4.5.5 Compare Different Types Of Membranes

Feature	Permeable	Partially Permeable	Impermeable
Definition	Allows all substances (solutes, solvents, molecules of any size/charge) to pass through freely without restriction.	Allows some substances to pass while restricting others (based on size, charge, solubility, or specific transport mechanisms).	Allows no substances to pass through (completely blocks everything).
What can pass	Everything: water, ions, small/large molecules, gases, solutes (no selectivity).	water/solvent freely; small uncharged molecules/gases easily; larger/charged molecules/ions blocked or require channels/carriers	Nothing: no molecules, ions, or water can cross.
Examples in biology	Plant cell wall (cellulose); filter paper or cotton cloth in experiments.	Plasma membrane (cell membrane); dialysis tubing; Visking tubing; tonoplast (vacuole membrane).	Rubber sheet; plastic sheet; some artificial barriers; certain dead tissues or synthetic films

4.5.6 Predict The Direction Of Movement Of Molecules Through Permeable, Partially Permeable And Impermeable Membranes

Molecules move passively (by diffusion or osmosis) down their concentration gradient (from high concentration to low concentration) until equilibrium is reached, but the direction and possibility depend entirely on the membrane type and the properties of the molecules (size, charge, solubility).

4.5.7 Compare The Phenomena Of Diffusion, Facilitated Diffusion, Osmosis, Active Transport, Endocytosis And Exocytosis

Diffusion

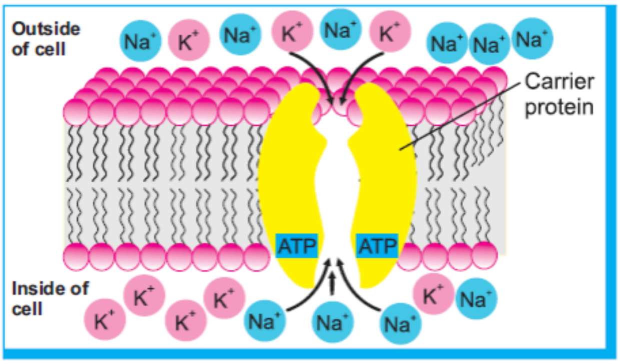
Diffusion is the movement of substances from a region of high concentration to low concentration. It is therefore said to occur down a concentration gradient. Diffusion is a passive process which means it does not require any energy input. It can occur across a living or non-living membrane and can occur 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.

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.

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. 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. 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.

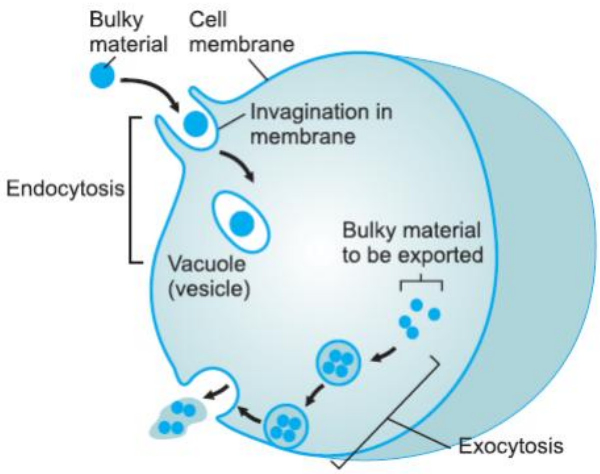


Active transport

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). For example, movement of sodium and potassium ions.

Endocytosis

It is the process of cellular ingestion of bulky materials by the in-folding of cell membrane. 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.



Exocytosis

It is the process through which bulky material is exported. This process adds new membrane which replaces the part of cell membrane lost during endocytosis.

4.5.8 Analyze The Factors That Affect Rate Of Diffusion In Cells

Surface area

A larger surface area (e.g., through folds, microvilli, or flattened cell shape) increases the number of molecules that can diffuse across the membrane at the same time, directly increasing the rate of diffusion.

Temperature

Higher temperature increases the kinetic energy of molecules, causing them to move faster and collide more frequently with the membrane, thereby speeding up the rate of diffusion.

Concentration Gradient

A steeper concentration gradient (greater difference between high and low concentration sides) provides a stronger driving force, resulting in a faster net rate of diffusion down the gradient.

Distance

Shorter diffusion distance (e.g., thin cell walls, flattened cells, or thin alveolar membranes) reduces the time molecules take to travel across, significantly increasing the overall rate of diffusion.

4.5.9 Describe The Significance Of Passive Transport And Active Transport

Passive transport

Passive transport is the movement of substances across the cell membrane down their concentration gradient (from high to low concentration) without using energy (ATP). It is significant because it is energy-efficient, rapid for small/uncharged molecules, and essential for maintaining homeostasis, nutrient uptake, waste removal, and basic cellular exchanges in all living organisms.

Facilitated Diffusion: Transport of Glucose

Facilitated diffusion is a type of passive transport where glucose (a large, polar molecule) moves down its concentration gradient across the plasma membrane with the help of specific carrier proteins (e.g., GLUT transporters) without energy expenditure. Its significance lies in enabling efficient, rapid uptake of glucose into cells (e.g., red blood cells, muscle cells) for immediate energy production via respiration, while preventing energy waste on molecules that can move passively.

Diffusion: Gaseous Exchange in Plants and Animals

Simple diffusion is passive movement of gases (O_2 and CO_2) down their concentration gradients across thin, permeable membranes (no protein required). In animals, it occurs in alveoli (lungs) for O_2 entry into blood and CO_2 exit; in plants, it occurs through stomata and mesophyll air spaces for CO_2 entry during photosynthesis and O_2 exit. Its significance is providing a fast, energy-free mechanism for essential gas exchange, supporting aerobic respiration in animals and photosynthesis in plants without ATP cost.

Osmosis: Water Absorption by Root Hair Cell

Osmosis is the passive diffusion of water across a partially permeable membrane (plasma membrane) from high water potential (low solute) to low water potential (high solute). In root hair cells, soil water (higher water potential) enters the cell (lower water potential due to solutes) by osmosis, creating turgor pressure. Its significance is driving massive water uptake for transpiration, maintaining turgidity, supporting plant structure/growth, and enabling upward transport of minerals via xylem.

Active transport

Active transport is the movement of substances across the cell membrane against their concentration gradient (from low to high concentration) using energy (usually ATP). It is significant because it allows cells to accumulate essential substances (ions, nutrients) at higher concentrations than in the environment, maintain electrochemical gradients, regulate internal conditions, and perform specialized functions critical for survival, nerve signaling, nutrient absorption, and plant mineral uptake.

Sodium-Potassium Pump in Nerve Cells:

This primary active transport uses ATP to pump 3 Na^+ out and 2 K^+ into the neuron against gradients, maintaining resting membrane potential (~ –70 mV), enabling action potential generation, nerve impulse conduction, and rapid signaling. Its significance is crucial for nervous system function, coordination, reflexes, and muscle control; disruption leads to loss of excitability.

Uptake of Glucose in Intestinal Cells of Humans:

In small intestine enterocytes, secondary active transport via SGLT1 (sodium-glucose symporter) uses Na^+ gradient (created by Na^+/K^+ pump) to co-transport glucose against its gradient from lumen (low after digestion) into cell (high). Its significance is allowing efficient absorption of dietary glucose even when luminal concentration is low, ensuring energy supply to body tissues.

Mineral Ions into Root Hair Cells of Plants:

Active transport (via carrier proteins/pumps using ATP) moves mineral ions (e.g., nitrates, phosphates, K^+) against concentration gradients from soil (low) into root hair cells (high). Its significance is enabling plants to accumulate essential nutrients scarce in soil for growth, enzyme function, photosynthesis, and osmoregulation, despite unfavorable gradients.

4.5.10 Exemplify The Importance Of Turgor Pressure In Plants

Turgor pressure is the pressure exerted by water against the cell wall when the central vacuole is full.

Maintains cell rigidity and plant support

Turgor pressure keeps cells firm and turgid, providing structural support to non-woody (herbaceous) plants and young stems/leaves. Without it (e.g., in wilting due to water loss), cells become flaccid, causing the plant to droop and collapse, losing its upright posture and mechanical strength.

Drives cell expansion and plant growth

During growth, turgor pressure pushes against the flexible young cell walls, stretching and enlarging them irreversibly as new cell wall material is laid down. This is the main force behind elongation of stems, roots, and leaves, enabling rapid increase in plant size.

Facilitates opening and closing of stomata

Guard cells surrounding stomata become turgid when water enters (via osmosis), causing them to bow outward and open the stomatal pore for CO_2 uptake during photosynthesis. When turgor decreases (water loss), guard cells become flaccid and the pore closes, reducing water loss through transpiration and helping conserve water in dry conditions.

4.6 Tissues (Types Of Plant And Animal Tissues)

4.6.1 Describe Tissue As A Group Of Cells With Similar Size, Shape And Function

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.

4.6.2 Differentiate Between Simple And Compound Plant Tissues

Feature	Simple Tissues	Compound (Complex) Tissues
Cell Composition	Made up of only one type of cell that are structurally and functionally similar.	Made up of more than one type of cell working together as a single unit.
Function	storage, photosynthesis basic support.	transport (conduction) of water and food.
Examples	Parenchyma, Collenchyma, and Sclerenchyma.	Xylem and Phloem.
Found in	throughout the plant body	in the vascular bundles (veins) of the plant.

4.6.3 Compare Major Plant Tissues

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.

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.

1. 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.
2. 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.

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:

Simple permanent tissue:

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

1. 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.
2. 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.
3. Supporting tissues provide strength and flexibility to plants. They are further of two types.
    a. Collenchyma tissues 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.
    b. Sclerenchyma tissues 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.

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 main types of cell are found in xylem tissue i.e. vessel and tracheid. Vessels have thick secondary cell walls. Their cells lack end walls and join together to form long tubes. Tracheid are made up of slender cells with overlapping ends.

Phloem Tissue
Phloem tissue is responsible for the conduction of dissolved organic matter (food) between different parts of plant body. Phloem tissue mainly contains sieve tube cells and 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 are parenchymatous, narrow, elongated cells, and are closely associated with the sieve tube. Conduction with the sieve tube is done through the pores present on the walls of these cells. They help the sieve tubes in conduction of food materials and make proteins for sieve tube cells.

4.6.4 Compare Major Animal Tissues
Humans and other large multicellular animals are made up of four basic types tissue:

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. 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.

1. When the epithelium is composed of a single layer of cells, it is called simple epithelial tissue.
2. Those containing two or more layers of cells are called stratified epithelial tissues.
3. 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.
4. 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.
5. Simple columnar epithelia are found in the female reproductive system and in the digestive tract.
6. Stratified epithelia consist of more than one layer of cells and only one layer is in direct contact with the basement membrane.
7. Stratified squamous epithelia are found in skin, with many dead, keratinized cells providing protection against water and nutrient loss.
8. Stratified cuboidal epithelia are found surrounding the ducts of many glands, including mammary glands in the breast and salivary glands in the mouth.
9. Stratified columnar epithelia are rare, found predominantly in some organs of the reproductive system.
10. Transitional epithelia are a special subset of stratified epithelia. They are exclusively found in the excretory system.

Connective Tissues

This tissue which connects or binds 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.

1. 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.
2. Bone is another type of supporting connective tissue. Bone can either be compact (dense) or spongy (cancellous), and contains the osteoblasts or osteocytes cells.
3. Adipose is another type of supporting connective tissue that provides cushions and stores excess energy and fat.
4. Blood referred to as connective tissue. It is a type of fluid connective tissue.

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.

1. 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.
2. 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.
3. 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!

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.