
Cell biology (also **cellular biology** or **cytology**) is a branch of biology studying the structure and function of the cell, also known as the basic unit of life. Cell biology encompasses both prokaryotic and eukaryotic cells and can be divided into many sub-topics which may include the study of cell metabolism, cell communication, cell cycle, biochemistry, and cell composition. The study of cells is performed using several techniques such as cell culture, various types of microscopy, and cell fractionation. These have allowed for and are currently being used for discoveries and research pertaining to how cells function, ultimately giving insight into understanding larger organisms. Knowing the components of cells and how cells work is fundamental to all biological sciences while also being essential for research in biomedical fields such as cancer, and other diseases. Research in cell biology is interconnected to other fields such as genetics, molecular genetics , biochemistry, molecular biology, medical microbiology, immunology, and cytochemistry.

Cell

The **cell** (from Latin *cella*, meaning "small room") is the basic structural, functional, and biological unit of all known organisms. A cell is the smallest unit of life. Cells are often called the "building blocks of life". The study of cells is called cell biology, cellular biology, or cytology.

Cells consist of cytoplasm enclosed within a membrane, which contains many biomolecules such as proteins and nucleic acids.

Most plant and animal cells are only visible under a microscope, with dimensions between 1 and 100 micrometres.

Organisms can be classified as unicellular (consisting of a single cell such as bacteria) or multicellular (including plants and animals).

The number of cells in plants and animals varies from species to species, it has been estimated that humans contain somewhere around 40 trillion (4×1013) cells.

Cells were discovered by Robert Hooke in 1665, Cell theory, first developed in 1839 by Matthias Jakob Schleiden and Theodor Schwann, states that:-

- **all organisms are composed of one or more cells**
- **cells are the fundamental unit of structure and function in all living organisms**
- **all cells come from pre-existing cells**.

Cells are of two types: eukaryotic, which contain a nucleus, and prokaryotic which do not. Prokaryotes are single-celled organisms, while eukaryotes can be either single-celled or multicellular.

Cell organelles

- Cell organelle is a specialized entity or structure present inside a particular type of cell that performs a specific function.
- There are various cell organelles, some are common in most types of cells like cell membranes, nucleus, and cytoplasm. However, some organelles are specific to one particular type of cell-like plastids and cell walls in plant cells.

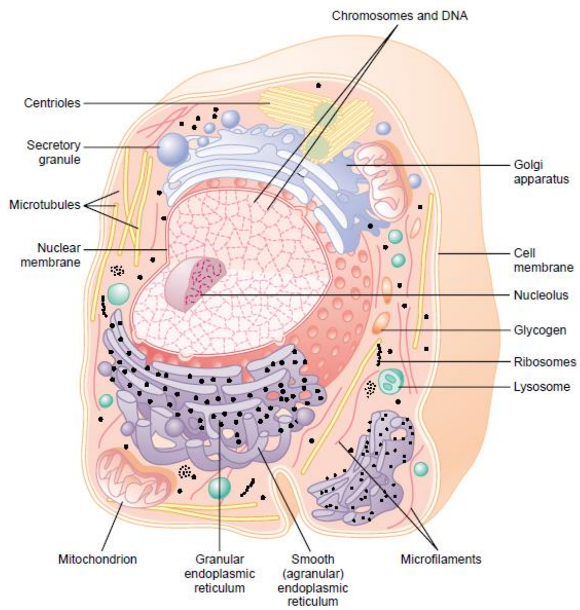


Figure 2–2

Reconstruction of a typical cell, showing the internal organelles in the cytoplasm and in the nucleus.

Cell membrane (Plasma membrane/ Plasmalemma)

Cell membranes protect and organize cells. All cells have an outer plasma membrane that regulates not only what enters the cell, but also how much of any given substance comes in. Unlike prokaryotes, eukaryotic cells also possess internal membranes that encase their organelles and control the exchange of essential cell components. Both types of membranes have a specialized structure that facilitates their gate keeping function.

The cell membrane is a thin, pliable, elastic structure only 7.5 to 10 nanometers thick. It is composed almost entirely of proteins and lipids.
The approximate composition is proteins, 55 per cent; phospholipids, 25 per cent; cholesterol, 13 per cent; other lipids, 4 per cent; and carbohydrates, 3 per cent.

Lipid Barrier of the Cell Membrane Impedes Water Penetration.

Its basic structure is a *lipid bilayer,* which is a thin, double-layered film of lipids—each layer only one molecule thick—that is continuous over the entire cell surface. The basic lipid bilayer is composed of phospholipid molecules. One end of each phospholipid molecule is soluble in water; that is, it is *hydrophilic.* The other end is soluble only in fats; that is, it is *hydrophobic.* The phosphate end of the phospholipid is hydrophilic, and the fatty acid portion is hydrophobic.

Because the hydrophobic portions of the phospholipid molecules are repelled by water but are mutually attracted to one another, they have a natural tendency to attach to one another in the middle of the membrane.

The lipid layer in the middle of the membrane is impermeable to the usual water-soluble substances, such as ions, glucose, and urea. Conversely, fat-soluble substances, such as oxygen, carbon dioxide, and alcohol, can penetrate this portion of the membrane with ease.

The cholesterol molecules in the membrane are also lipid in nature because their steroid nucleus is highly fat soluble.

These molecules, in a sense, are dissolved in the bilayer of the membrane. They mainly help determine the degree of permeability (or impermeability) of the bilayer to water-soluble constituents of body fluids. Cholesterol controls much of the fluidity of the membrane as well.

Cell Membrane Proteins

Membrane Proteins are globular masses floating in the lipid bilayer, most of which are *glycoproteins.* Two types of proteins occur: *integral proteins* that protrude all the way through the membrane, and *peripheral proteins* that are attached only to one surface of the membrane and do not penetrate all the way through.

Many of the **integral proteins** provide structural *channels* (or *pores*) through which water molecules and water-soluble substances, especially ions, can diffuse between the extracellular and intracellular fluids. These protein channels also have selective properties that allow preferential diffusion of some substances over others. Other integral proteins act as *carrier proteins* for transporting substances that otherwise could not penetrate the lipid bilayer. Sometimes these even transport substances in the direction opposite to their natural direction of diffusion, which is called “active transport.” Still others act as *enzymes.*

Integral membrane proteins can also serve as *receptors* for water-soluble chemicals, such as peptide hormones, that do not easily penetrate the cell membrane.

Interaction of cell membrane receptors with specific *ligands* that bind to the receptor causes conformational changes in the receptor protein. This, in turn, enzymatically activates the intracellular part of the protein or induces interactions between the receptor and proteins in the cytoplasm that act as *second messengers,* thereby relaying the signal from the extracellular part of the receptor to the interior of the cell. In this way, integral proteins spanning the cell membrane provide a means of conveying information about the environment to the cell interior.

Peripheral protein molecules are often attached to the integral proteins. These peripheral proteins function almost entirely as enzymes or as controllers of transport of substances through the cell membrane “pores.”

Membrane Carbohydrates—The Cell "Glycocalyx."

Membrane carbohydrates occur almost invariably in combination with proteins or lipids in the form of *glycoproteins* or *glycolipids.* In fact, most of the integral proteins are glycoproteins, and about one tenth of the membrane lipid molecules are glycolipids.The "glyco" portions of these molecules almost invariably protrude to the outside of the cell, dangling outward from the cell surface. Many other carbohydrate compounds, called *proteoglycans*—which are mainly carbohydrate substances bound to small protein cores—are loosely attached to the outer surface of the cell as well.

Thus, the entire outside surface of the cell often has a loose carbohydrate coat called the *glycocalyx.*

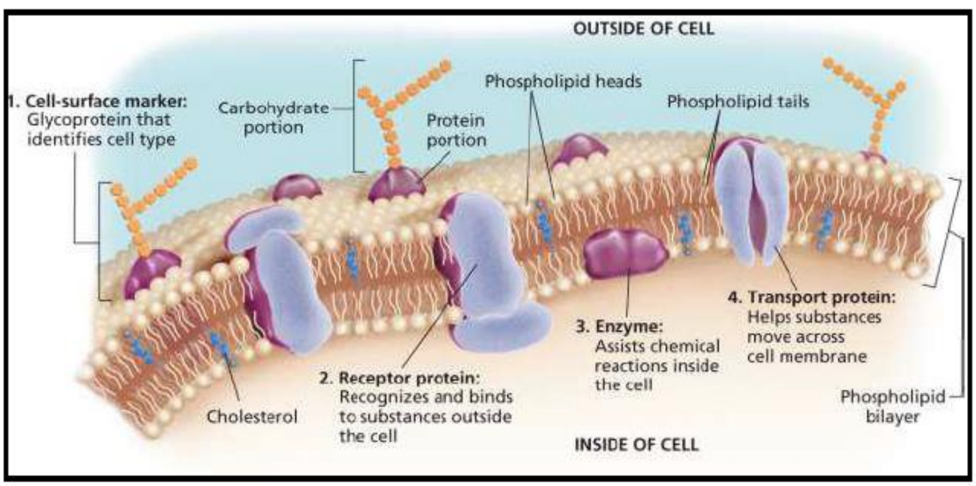
The carbohydrate moieties attached to the outer surface of the cell have several important functions:

(1) Many of them have a negative electrical charge, which gives most cells an overall negative surface charge that repels other negative objects.

(2) The glycocalyx of some cells attaches to the glycocalyx of other cells, thus attaching cells to one another.

(3) Many of the carbohydrates act as *receptor substances* for binding hormones, such as insulin; when bound, this combination activates attached internal proteins that, in turn, activate a cascade of intracellular enzymes.

(4) Some carbohydrate moieties enter into immune reactions.



At physiological temperatures, cell membranes are fluid; at cooler temperatures, they become gel-like. Scientists who model membrane structure and dynamics describe the membrane as a fluid mosaic in which transmembrane proteins can move laterally in the lipid bilayer. Therefore, the collection of lipids and proteins that make up a cellular membrane relies on natural biophysical properties to form and function. In living cells, however, many proteins are not free to move. They are often anchored in place within the membrane by tethers to proteins outside the cell, cytoskeletal elements inside the cell, or both.

What Do Membranes Do?

Cell membranes serve as barriers and gatekeepers. They are semi-permeable, which means that some molecules can diffuse across the lipid bilayer but others cannot. Small hydrophobic molecules and gases like oxygen and carbon dioxide cross membranes rapidly. Small polar molecules, such as water and ethanol, can also pass through membranes, but they do so more slowly. On the other hand, cell membranes restrict diffusion of highly charged molecules, such as ions, and large molecules, such as sugars and amino acids. The passage of these molecules relies on specific transport proteins embedded in the membrane.

Membrane transport proteins are specific and selective for the molecules they move, and they often use energy to catalyze passage. Also, these proteins transport some nutrients against the concentration gradient, which requires additional energy. The ability to maintain concentration gradients and sometimes move materials against them is vital to cell health and maintenance. Thanks to membrane barriers and transport proteins, the cell can accumulate nutrients in higher concentrations than exist in the environment and, conversely, dispose of waste products.

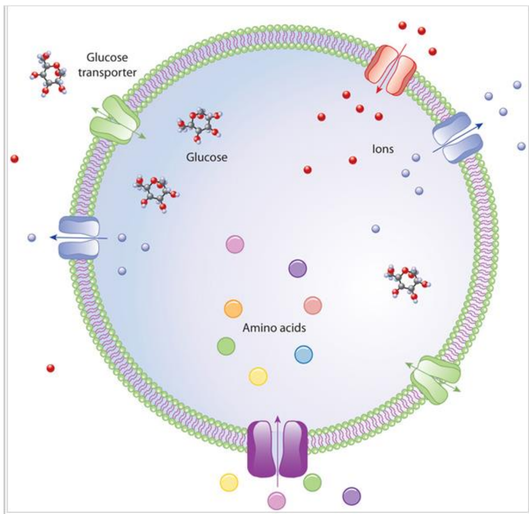


Figure 3: Selective transport
Specialized proteins in the cell membrane regulate the concentration of specific molecules inside the cell.

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Other transmembrane proteins have communication-related jobs. These proteins bind signals, such as hormones or immune mediators, to their extracellular portions. Binding causes a conformational change in the protein that transmits a signal to intracellular messenger molecules. Like transport proteins, receptor proteins are specific and selective for the molecules they bind.

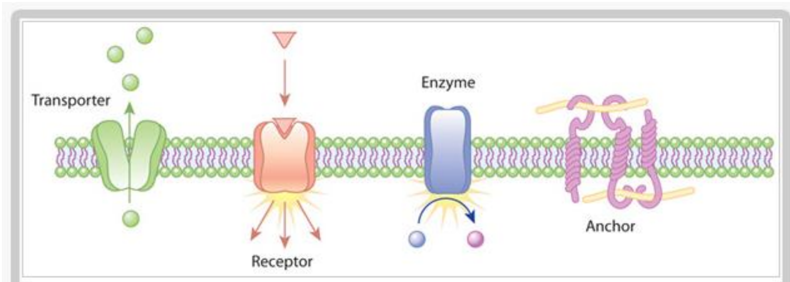


Figure 4: Examples of the action of transmembrane proteins

Transporters carry a molecule (such as glucose) from one side of the plasma membrane to the other. Receptors can bind an extracellular molecule (triangle), and this activates an intracellular process. Enzymes in the membrane can do the same thing they do in the cytoplasm of a cell: transform a molecule into another form. Anchor proteins can physically link intracellular structures with extracellular structures.

How Diverse Are Cell Membranes?

In contrast to prokaryotes, eukaryotic cells have not only a plasma membrane that encases the entire cell, but also intracellular membranes that surround various organelles. In such cells, the plasma membrane is part of an extensive **endomembrane system** that includes the endoplasmic reticulum (ER), the nuclear membrane, the Golgi apparatus, and lysosomes. Membrane components are exchanged throughout the endomembrane system in an organized fashion. For instance, the membranes of the ER and the Golgi apparatus have different compositions, and the proteins that are found in these membranes contain sorting signals, which are like molecular zip codes that specify their final destination.

Mitochondria and chloroplasts are also surrounded by membranes, but they have unusual membrane structures — specifically, each of these organelles has two surrounding membranes instead of just one. The outer membrane of mitochondria and chloroplasts has pores that allow small molecules to pass easily. The inner membrane is loaded with the proteins that make up the electron transport chain and help generate energy for the cell. The double membrane enclosures of mitochondria and chloroplasts are similar to certain modern.

Cytoplasm

Cytoplasm refers to the fluid that fills the cell, which includes the cytosol along with filaments, proteins, ions and macromolecular structures as well as the organelles suspended in the cytosol.

In eukaryotic cells, cytoplasm refers to the contents of the cell with the exception of the nucleus. Eukaryotes have elaborate mechanisms for maintaining a distinct nuclear compartment separate from the cytoplasm. Active transport is involved in the creation of these subcellular structures and for maintaining homeostasis with the cytoplasm. For prokaryotic cells, since they do not have a defined nuclear membrane, the cytoplasm also contains the cell’s primary genetic material. These cells are usually smaller in comparison to eukaryotes, and have a simpler internal organization of the cytoplasm.

Structure of Cytoplasm

The cytoplasm is unusual because it is unlike any other fluid found in the physical world. Liquids that are studied to understand diffusion usually contain a few solutes in an aqueous environment. However, the cytoplasm is a complex and crowded system containing a wide range of particles – from ions and small molecules, to proteins as well as giant multi protein complexes and organelles. These constituents are moved across the cell depending on the requirements of the cell along an elaborate cytoskeleton with the help of specialized motor proteins. The movement of such large particles also changes the physical properties of the cytosol.

The physical nature of the cytoplasm is variable. Sometimes, there is quick diffusion across the cell, making the cytoplasm resemble a colloidal solution. At other times, it appears to take on the properties of a gel-like or glass-like substance. It is said to have the properties of viscous as well as elastic materials – capable of deforming slowly under external force in addition to regaining its original shape with minimal loss of energy. Parts of the cytoplasm close to the plasma membrane are also 'stiffer' while the regions near the interior resemble free flowing liquids. These changes in the cytoplasm appear to be dependent on the metabolic processes within the cell and play an important role in carrying out specific functions and protecting the cell from stressors.

The cytoplasm can be divided into three components:

1. The cytoskeleton with its associated motor proteins
2. Organelles and other large multi-protein complexes
3. Cytoplasmic inclusions and dissolved solutes

Functions of Cytoplasm

The cytoplasm is the site for most of the enzymatic reactions and metabolic activity of the cell. Cellular respiration begins in the cytoplasm with anaerobic respiration or glycolysis. This reaction provides the intermediates that are used by the mitochondria to generate ATP. In addition, the translation of mRNA into proteins on ribosomes also occurs mostly in the cytoplasm. Some of it happens on free ribosomes suspended in the cytosol while the rest happens on ribosomes anchored on the endoplasmic reticulum.

The cytoplasm also contains the monomers that go on to generate the cytoskeleton. The cytoskeleton, in addition to being important for the normal activities of the cell is crucial for cells that have a specialized shape. For instance, neurons with their long axons need the presence of intermediate filaments, microtubules, and actin filaments in order to provide a rigid framework for the action potential to be transmitted to the next cell. Additionally, some epithelial cells contain small cilia or flagella to move the cell or remove foreign particles through coordinated activity of cytoplasmic extrusions formed through the cytoskeleton.

Cytoskeleton and Motor Proteins

The cytoskeleton acts to organize and maintain the cell's shape; anchors organelles in place; helps during endocytosis, the uptake of external materials by a cell, and cytokinesis, the separation of daughter cells after cell division; and moves parts of the cell in processes of growth and mobility.

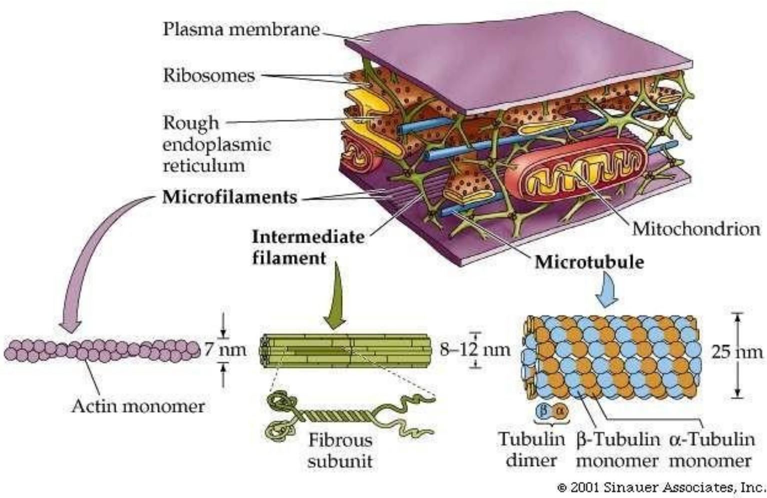
The basic shape of the cell is provided by its cytoskeleton formed primarily by three types of polymers – **actin filaments, microtubules and intermediate filaments**.

Actin filaments or microfilaments are 7 nm in width and are made of double stranded polymers of F-actin. These filaments are associated with a number of other proteins that help in filament assembly and are also involved in anchoring them close to the plasma membrane. This cytoplasmic location helps the microfilaments become involved in rapid responses to signal molecules from the extracellular environment and produce cellular responses through signal transduction or chemotaxis. In addition, myosin, an ATP-based motor protein transmits cargo and vesicles along the microfilament and is also involved in muscle contraction.

Microtubules are polymers of α and β tubulin, which form a hollow tube of 13 protofilaments. Each protofilament is a polymer of alternating α and β tubulin molecules. The inner diameter of a microtubule is 12 nm and its outer diameter is 24 nm. Microtubules radiate towards the periphery of the cell from microtubule organizing centers located close to the nucleus, and provide structure and shape to the cell.

The cytoplasm undergoes rapid reorganization during cell division with microtubules forming the spindle, which binds to chromosomes and form to two daughter cells. Microtubules are involved in cytoplasmic transport, chromosome segregation and in forming structures such as cilia and flagella for cellular movement.

Intermediate filaments are larger than microfilaments but smaller than microtubules and are formed by a group of proteins that share structural features. Though they are not involved in cell motility, they are important for cells to come together as tissues and to remain anchored to the extracellular matrix.



Cytoplasmic Streaming

-The cytoskeleton helps to make cytoplasmic streaming possible. Also known as **cyclosis**, this process involves the movement of the cytoplasm to circulate nutrients, organelles, and other substances within a cell.

- Cyclosis also aids in endocytosis and exocytosis, or the transport of substance into and out of a cell.

-As cytoskeletal microfilaments contract, they help to direct the flow of cytoplasmic particles. When microfilaments attached to organelles contract, the organelles are pulled along and the cytoplasm flows in the same direction.

-Cytoplasmic streaming occurs in both prokaryotic and eukaryotic cells. In protists, like amoebae, this process produces extensions of the cytoplasm known as **pseudopodia**. These structures are used for capturing food and for locomotion.

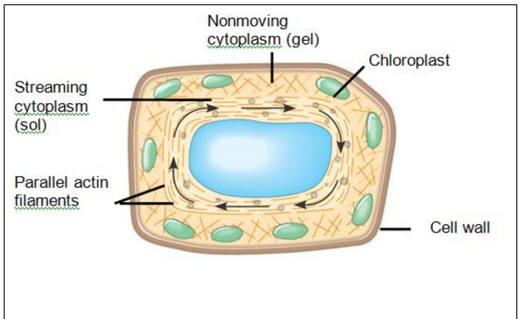


Fig.(1-16): Cytoplasmic streaming in plant cells

Cytoplasmic streaming is also important for positioning chloroplasts close to the plasma membrane to optimize photosynthesis and for distributing nutrients through the entire cell.

Nucleus

- The nucleus is a double membrane-bound structure responsible for controlling all cellular activities as well as a center for genetic materials, and it's transferring.
- It is one of the large cell organelles occupying 10% of total space in the cell.
- It is often termed the "brain of the cell" as it provides commands for the proper functioning of other cell organelles.
- A nucleus is clearly defined in the case of a eukaryotic cell; however, it is absent in prokaryotic organisms with the genetic material distributed in the cytoplasm.
- Structurally, the nucleus consists of a nuclear envelope, chromatin, and nucleolus.
- The nuclear envelope is similar to the cell membrane in structure and composition. It has pores that allow the movement of proteins and RNA in and outside the nucleus. It enables the interaction with other cell organelles while keeping nucleoplasm and chromatin within the envelope.

- The chromatin in the nucleus contains RNA or DNA along with nuclear proteins, as genetic material that is responsible for carrying the genetic information from one generation to another.
- The nucleolus is like a nucleus within the nucleus. It is a membrane-less organelle that is responsible for the synthesis of rRNA and assembly of ribosomes required for protein synthesis.

Nuclear envelope

* The nuclear envelope, otherwise known as nuclear membrane, consists of two cellular membranes, an inner and an outer membrane, arranged parallel to one another and separated by 10 to 50 nanometres (nm).

* The nuclear envelope completely encloses the nucleus and separates the cell's genetic material from the surrounding cytoplasm, serving as a barrier to prevent macromolecules from diffusing freely between the nucleoplasm and the cytoplasm.

* The outer nuclear membrane is continuous with the membrane of the rough endoplasmic reticulum(RER), the space between the membranes is called the perinuclear space and is continuous with the RER lumen

Nuclear pores

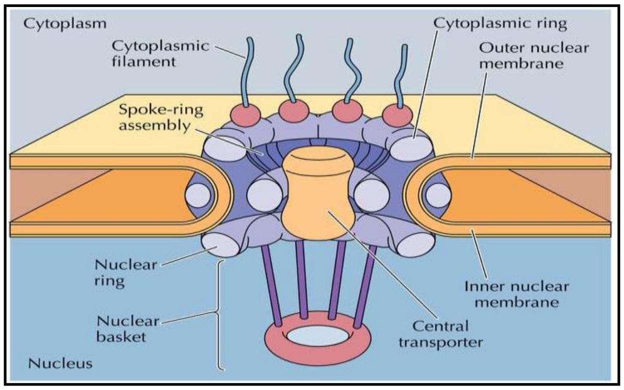
Nuclear pores, which provide aqueous channels through the envelope, are composed of multiple proteins, collectively referred to as nucleoporins.
This size selectively allows the passage of small water-soluble molecules while preventing larger molecules, such as nucleic acids and larger proteins, from inappropriately entering or exiting the nucleus. These large molecules must be actively transported into the nucleus instead.

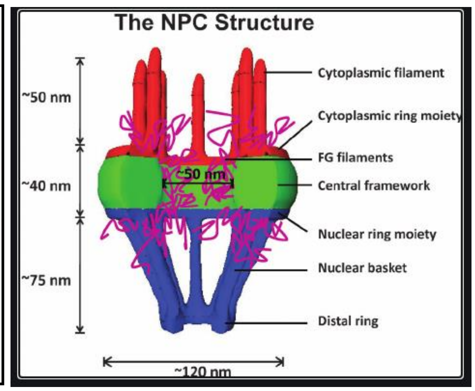
- The nucleus of a typical mammalian cell will have about 3000 to 4000 pores throughout its envelope.
- The pores are 100 nm in total diameter; however, the gap through which molecules freely diffuse is only about 9 nm wide, due to the presence of regulatory systems within the center of the pore.

The Nuclear Pore Complex (NPC)

- Each pore contains an **eight** fold-symmetric ring-shaped structure at a position where the inner and outer membranes fuse.
- Attached to the ring is a structure called the **nuclear basket** that extends into the nucleoplasm, and a series of filamentous extensions that reach into the cytoplasm. Both structures serve to mediate binding to nuclear transport proteins.
- Most proteins, ribosomal subunits, and some DNAs are transported through the pore complexes in a process mediated by a family of transport factors known as **karyopherins.** Those karyopherins that mediate movement into the nucleus are also called importins, whereas those that mediate movement out of the nucleus are called exportins.

- Proteins larger than ~50kDa are too large to passively diffuse from the cytoplasm to the nucleus and must be actively transported across the NPC. These proteins must contain a nuclear localization sequence/signal (NLS) in order to be recognized by the alpha subunit of importin. When the cargo protein binds to alpha importin, alpha importin binds to beta importin, and beta importin is recognized by the FG repeat domains on the cytoplasmic filaments of the NPC.





- Most karyopherins interact directly with their cargo, although some use adaptor proteins. Steroid hormones such as cortisol and aldosterone, as well as other small lipid-soluble molecules involved in intercellular signaling, can diffuse through the cell membrane and into the cytoplasm, where they bind nuclear receptor proteins that are trafficked into the nucleus.
- Large numbers of proteins synthesized in cytoplasm and transported into the nucleus, RNAs manufactured in nucleus transported to cytoplasm

Mitochondria

- Mitochondria are double membrane-bound cell organelles responsible for the supply and storage of energy for the cell.
- The oxidation of various substrates in the cell to release energy in the form of ATP (Adenosine Triphosphate) is the primary purpose of mitochondria.
- A mitochondrion contains two membranes with the outer layer being smooth while the inner layer is marked with folding and finger-like structures called cristae.
- The inner mitochondrial membrane contains various enzymes, coenzymes, and components of multiple cycles along with pores for the transport of substrates, ATP, and phosphate molecules.
- Within the membranes is a matrix that contains various enzymes of metabolic processes like Kreb’s cycle.
- In addition to these enzymes, mitochondria are also home to single or double-stranded DNA called mtDNA that is capable of producing 10% of the proteins present in the mitochondria.
- Mitochondria also help in balancing the amount of Ca+ ions within the cell and assists the process of apoptosis.
- Mitochondria in the liver have the ability to detoxify ammonia.

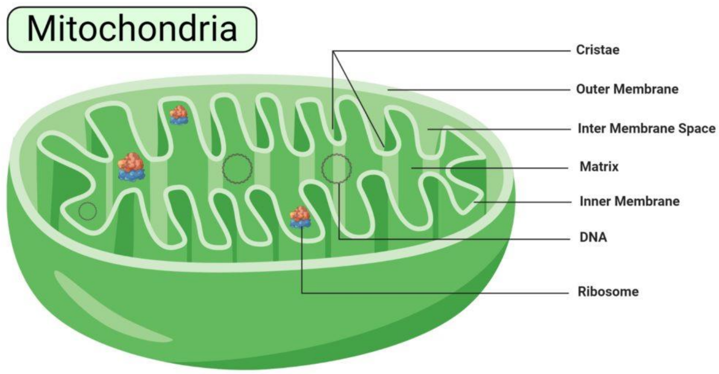


Figure: Mitochondria, Image Copyright © Sagar Aryal, www.microbenotes.com

Endoplasmic Reticulum (ER)

The endoplasmic reticulum (ER) is a large organelle made of membranous sheets and tubules that begin near the nucleus and extend across the cell.

Also, their walls are constructed of lipid bilayer membranes that contain large amounts of proteins, similar to the cell membrane.

The total surface area of this structure in some cells—the liver cells, for instance—can be as much as 30 to 40 times the cell membrane area.

The space inside the tubules and vesicles is filled with *endoplasmic matrix,* a watery medium that is different from the fluid in the cytosol outside the endoplasmic reticulum. Substances formed in some parts of the cell enter the space of the endoplasmic reticulum and are then conducted to other parts of the cell. Also, the vast surface area of this reticulum and the multiple enzyme systems attached to its membranes provide machinery for a major share of the metabolic functions of the cell.

The endoplasmic reticulum creates, packages, and secretes many of the products created by a cell.

The entire structure can account for a large proportion of the endomembrane system of the cell. **For instance, in cells such as liver hepatocytes that are specialized for protein secretion and detoxification, the ER can account for more than 50% of the total lipid bilayer of the cell.** Similarly, the ER membrane system is particularly prominent in pancreatic beta cells that secrete insulin, or within activated B-lymphocytes that produce antibodies.

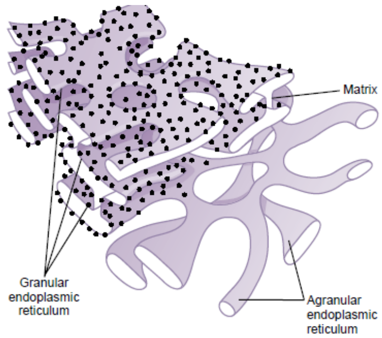


Figure 2–4

Structure of the endoplasmic reticulum. (Modified from DeRobertis EDP, Saez FA, DeRobertis EMF: Cell Biology, 6th ed. Philadelphia: WB Saunders, 1975.)

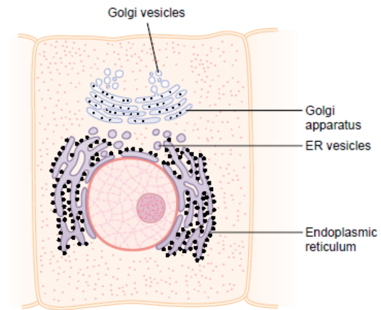
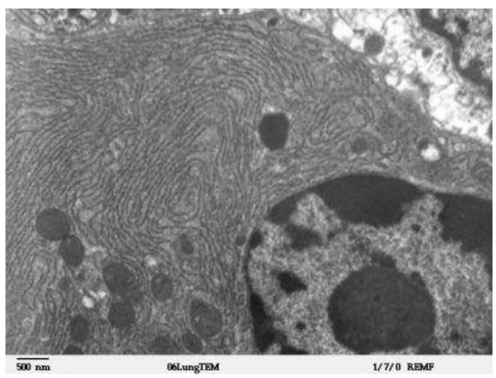


Figure 2–5

A typical Golgi apparatus and its relationship to the endoplasmic reticulum (ER) and the nucleus.

As seen in the image, the membranes of the endoplasmic reticulum are contiguous with the outer nuclear membrane, even though their compositions can be different. The ER contains special membrane-embedded proteins that stabilize its structure and curvature. **This organelle acts as an important regulator of cell function because it interacts closely with a number of other organelles.** Products of the endoplasmic reticulum often travel to the Golgi body for packaging and additional processing before being secreted.



This is a microscopic image of a section from mammalian lung tissue. The bottom right corner of the image shows the nucleus and the rest of the picture illustrates the extensive nature of the ER. Small dark circles are mitochondria that exist in physical proximity with the membranes of the ER.

Ribosomes and the Granular Endoplasmic Reticulum.

Attached to the outer surfaces of many parts of the endoplasmic reticulum are large numbers of minute granular particles called *ribosomes.* Where these are present, the reticulum is called the *granular endoplasmic reticulum.* The ribosomes are composed of a mixture of RNA and proteins, and they function to synthesize new protein molecules in the cell.

Agranular Endoplasmic Reticulum. Part of the endoplasmic reticulum has no attached ribosomes. This part is called the *agranular,* or *smooth, endoplasmic reticulum.*

The agranular reticulum functions for the synthesis of lipid substances and for other processes of the cells promoted by intrareticular enzymes.

Endoplasmic Reticulum Function

The ER plays a number of roles within the cell, from protein synthesis and lipid metabolism to detoxification of the cell. This creates the plasma membrane of the cell, as well as additional endoplasmic reticulum and organelles. They also appear to be important in maintaining the Ca^{2+} balance within the cell and in the interaction of the ER with mitochondria. This interaction also influences the aerobic status of the cell.
ER sheets appear to be crucial in the response of the organelle to stress, especially since cells alter their tubules-to-sheets ratio when the number of unfolded proteins increases. Occasionally, apoptosis is induced by the ER in response to an excess of unfolded protein within the cell. When ribosomes detach from ER sheets, these structures can disperse and form tubular cisternae.

Ribosomes

- Ribosomes are ribonucleoprotein containing equal parts RNA and proteins along with an array of other essential components required for protein synthesis.
- In prokaryotes, they exist freely while in eukaryotes, they are found either free or attached to the endoplasmic reticulum.
- The ribonucleoprotein consists of two subunits.
- Prokaryotic cells, the ribosomes are of the 70S with the larger subunit of 50S and the smaller one of 30S.
- Eukaryotic cells have 80S ribosomes with 60S larger subunit and 40S smaller subunit.
- Ribosomes are short-lived as after the protein synthesis, the subunits split up and can be either reused or remain broken up.

Functions

- Ribosomes are the site of biological protein synthesis in all living organisms.
- They arrange the amino acids in the order indicated by tRNA and assist in protein synthesis.

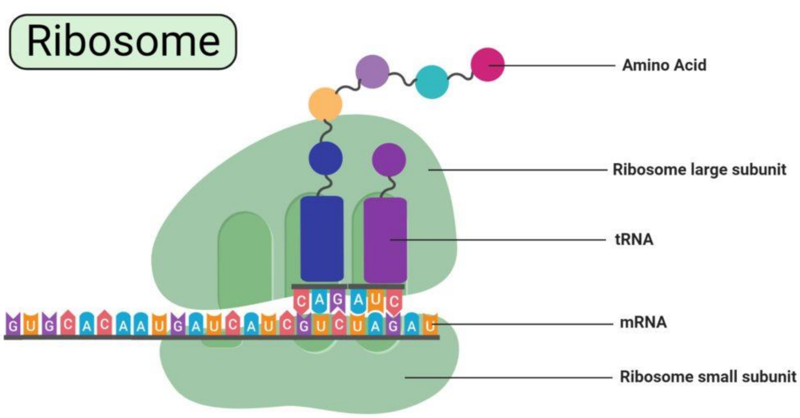


Figure: Ribosome, Image Copyright © Sagar Aryal, www.microbenotes.com

Golgi Apparatus/ Golgi Complex/ Golgi Body

The Golgi Apparatus is the cell organelle mostly present in eukaryotic cells which is responsible for the packaging of macromolecules into vesicles so that they can be sent out to their site of action.

- The structure of the Golgi Complex is pleomorphic; however, it typically exists in three forms, i.e. cisternae, vesicles, and tubules.
- The cisternae, which is the smallest unit of Golgi Complex, has a flattened sac-like structure which is arranged in bundles in a parallel fashion.
- Tubules are present as tubular and branched structures that radiate from the cisternae and are fenestrated at the periphery.
- Vesicles are spherical bodies that are divided into three groups as transitional vesicles, secretory vesicles, and clathrin-coated vesicles.

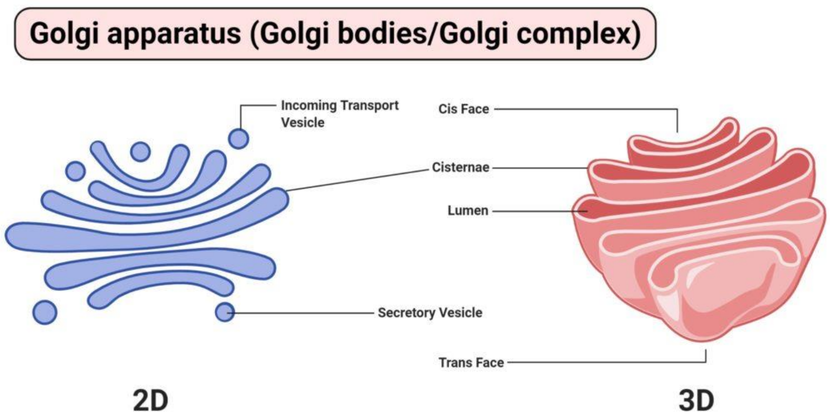


Figure: Golgi apparatus (Golgi bodies/Golgi complex), Image Copyright © Sagar Aryal, www.microbenotes.com

Functions

- Golgi Complex has an essential purpose of directing proteins and lipids to their destination and thus, act as the “traffic police” of the cell.
- They are involved in the exocytosis of various products and proteins like zymogen, mucus, lactoprotein, and parts of the thyroid hormone.
- Golgi Complex is involved in the synthesis of other cell organelles like a cell membrane, lysozymes, among others.
- They are also involved in the sulfation of various molecules.

Lysosome

- Lysosomes are membrane-bound organelles that occur in the cytoplasm of animal cells.
- These organelles contain an array of hydrolytic enzymes required for the degradation of various macromolecules.
- There are two types of lysosomes:

- Primary lysosome containing hydrolytic enzymes like lipases, amylases, proteases, and nucleases.

- Secondary lysozyme formed by the fusion of primary lysozymes containing engulfed molecules or organelles.

Functions

- These organelles are responsible for intracellular digestion where the larger macromolecules are degraded into smaller molecules with the help of enzymes present in them.
- Lysosomes also perform the critical function of the autolysis of unwanted organelles within the cytoplasm.
- Besides these, the lysosome is involved in various cellular processes, including secretion, plasma membrane repair, cell signaling, and energy metabolism.

Microvilli

- Microvilli are tiny finger-like structures that project on or out of the cells. These exist either on their own or in conjunction with villi.
- Microvilli are bundles of protuberances loosely arranged on the surface of the cell with little or no cellular organelles.
- These are surrounded by a plasma membrane enclosing cytoplasm and microfilaments.
- These are bundles of actin filaments bound by fimbrin, villin, and epsin.
- Microvilli increase the surface area of the cell, thus, enhancing the absorption and secretion functions.
- The membrane of microvilli is packed with enzymes that allow the break down of larger molecules into smaller allowing more effective absorption.
- Microvilli act as an anchoring agent in white blood cells and in sperms during fertilization.

Peroxisomes

- Peroxisomes are oxidative membrane-bound organelles found in the cytoplasm of all eukaryotes.
- The name is accredited due to their hydrogen peroxide generating and removing activities.
- Peroxisome consists of a single membrane and granular matrix scattered in the cytoplasm.
- They exist either in the form of interconnected tubules or as individual peroxisomes.
- The compartments within every peroxisome allow the creation of optimized conditions for different metabolic activities.
- They consist of several types of enzymes with major groups being urate oxidase, D-amino acid oxidase, and catalase.

Functions

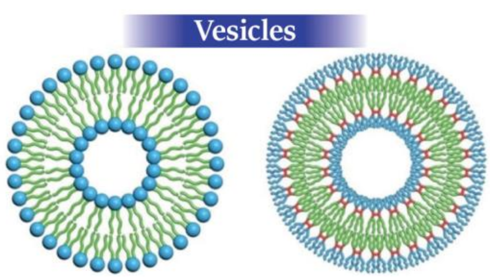
- Peroxisomes are involved in the production and elimination of hydrogen peroxide during biochemical processes.
- Oxidation of fatty acids takes place within peroxisomes.
- Additionally, peroxisomes are also involved in the synthesis of lipid-like cholesterol and plasmalogens.

Vacuole

- Vacuoles are membrane-bound structures varying in size in cells of different organisms.
- The vacuole is surrounded by a membrane called tonoplast, which encloses fluid containing inorganic materials like water and organic materials like nutrients and even enzymes.
- These are formed by the fusion of various vesicles, so vacuoles are very similar to vesicles in structure.
- Vacuoles act as a storage for nutrients as well as waste materials to protect the cell for toxicity.
- They have an essential function of homeostasis as it allows the balance of pH of the cell by influx and outflow of H+ ions to the cytoplasm.
- Vacuoles contain enzymes that play an important role in different metabolic processes.

Vesicles

- Vesicles are structures present inside the cell which are either formed naturally during processes like exocytosis, endocytosis or transport of materials throughout the cell, or they might form artificially, which are called liposomes.
- There are different types of vesicles like vacuoles, secretory and transport vesicles based on their function
- A vesicle is a structure containing liquid or cytosol which is enclosed by a lipid bilayer.
- The outer layer enclosing the liquid is called a lamellar phase which is similar to the plasma membrane. One end of the lipid bilayer it hydrophobic whereas the other end is hydrophilic.



- Vesicles facilitate the storage and transport of materials in and outside the cell. It even allows the exchange of molecules between two cells.
- Because vesicles are enclosed inside a lipid bilayer, vesicles also function in metabolism and enzyme storage.
- They allow temporary storage of food and also control the buoyancy of the cell.

Table 1.3 Structure and Function of Cellular Components

Component	Structure	Function
Cell (plasma) membrane	Membrane composed of phospholipid and protein molecules	Gives form to cell and controls passage of materials in and out of cell
Cytoplasm	Fluid, jellylike substance between the cell membrane and the nucleus in which organelles are suspended	Serves as matrix substance in which chemical reactions occur
Endoplasmic reticulum	System of interconnected membrane-forming canals with (rough) or without (smooth) attached ribosomes	Smooth endoplasmic reticulum metabolizes nonpolar compounds and stores Ca++ in straited muscle cells; rough endoplasmic reticulum assists in protein synthesis
Ribosomes	Granular particles composed of protein and RNA	Synthesize proteins
Golgi apparatus	Cluster of flattened, membranous sacs	Synthesizes carbohydrates and packages protein and lipid molecules for secretion
Mitochondria	Double-walled membranous sacs with folded inner partitions	Release energy from food molecules and transform energy into usable ATP
Lysosomes	Single-walled membranous sacs	Digest foreign molecules and worn and damaged cells
Peroxisomes	Spherical membranous vesicles	Contain enzymes that produce hydrogen peroxide and use this for various oxidation reactions
Centrosome	Nonmembranous mass of two rodlike centrioles	Helps organize spindle fibers and distribute chromosomes during mitosis
Vacuoles	Membranous sacs	Store and excrete various cytoplasmic substances
Fibrils and microtubules	Thin, rodlike, or hollow tubes of varying lengths	Support cytoplasm and transport materials within the cytoplasm (e.g., cytoskeleton)
Cilia and flagella	Small cytoplasmic projections containing microtubules	Move particles along surface of cell and enable sperm to migrate
Nuclear membrane	Porous, double membrane surrounding nucleus composed of protein and lipid molecules	Supports nucleus and controls passage of materials between nucleus and cytoplasm
Nucleolus	Dense, nonmembranous mass composed of protein and RNA molecules	Forms ribosomes
Chromatin	Fibrous strands composed of DNA molecules and protein	Controls cellular activity for carrying on life processes, such as protein synthesis