# Physiology

## Lec. 1

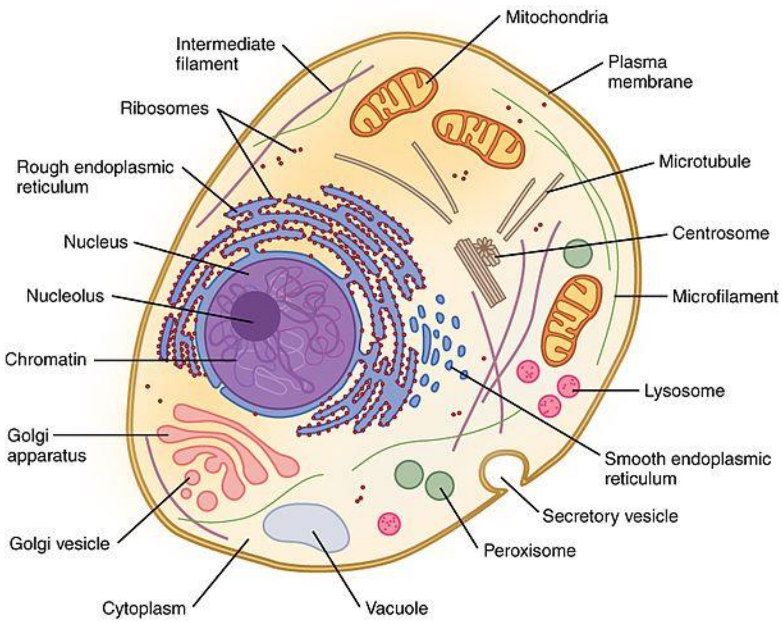
# Cell physiology

**Cell physiology** is the biological study about the activities that take place in a cell to keep it alive. This includes, among animal cells, plant cells and microorganisms. The term "physiology" refers to all the normal functions that take place in a living organism. All of these activities in the cell could be counted as following; nutrition, environmental response, cell growth, cell division, reproduction and differentiation.

Two classes of cells, **eukaryotic cells** and **prokaryotic cells ,**can be distinguished by their structure.

- The cells of the human body, as well as those of other multicellular animals and plants, are eukaryotic (true-nucleus) cells. These cells contain a nuclear membrane surrounding the cell nucleus and also contain numerous other membrane-bound structures.
- Prokaryotic cells, such as bacteria, lack these membranous structures.

Cells are surrounded by a limiting barrier, the **plasma membrane** (also called the cell membrane), which covers the cell surface. The cell interior is divided into a number of compartments surrounded by membranes. These membrane-bound compartments, along with some particles and filaments, are known as **cell organelles .**Each cell organelle performs specific functions that contribute to the cell's survival.




The interior of a cell is divided into two regions:

(1) the **nucleus ,** a spherical or oval structure usually near the center ofthe cell,

(2) the **cytoplasm ,** the region outside the nucleus.

The cytoplasm contains cell organelles and fluid surrounding the organelles, known as the **cytosol .**the term **intracellular fluid** refers to ***all*** the fluid inside a cell—in other words, cytosol plus the fluid inside all the organelles, including the nucleus. The chemical compositions of the fluids in cell organelles may differ from that of the cytosol .The cytosol is by far the largest intracellular fluid compartment.

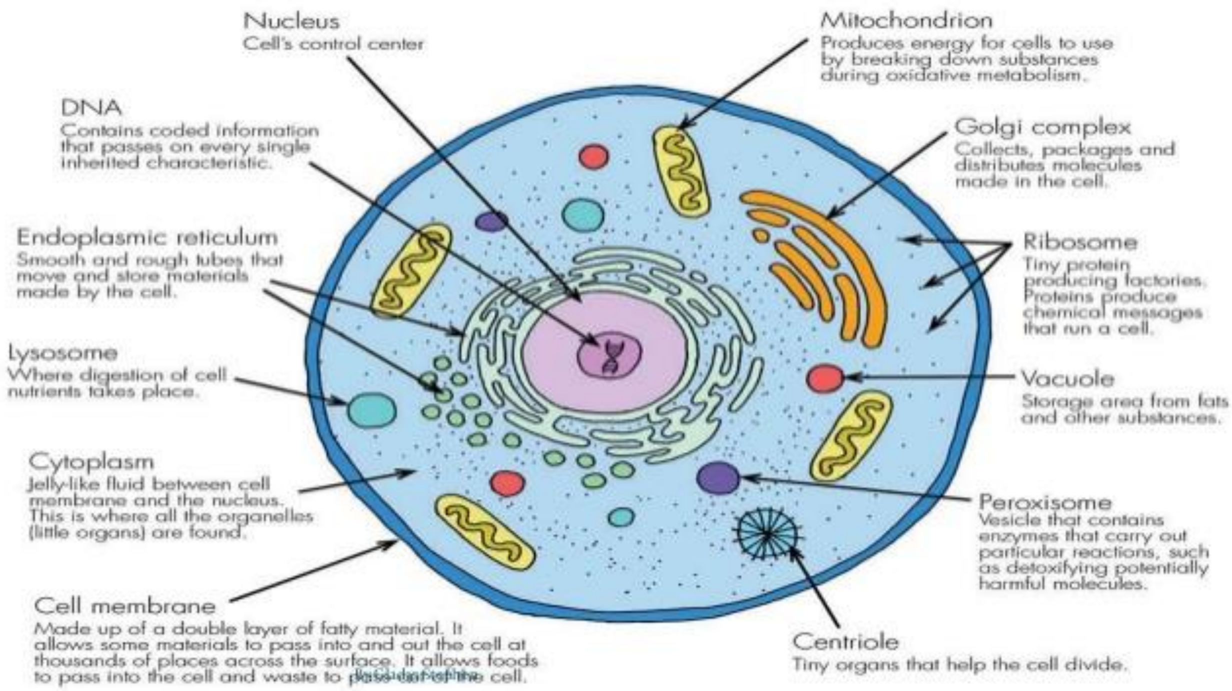
## Membranes

Membranes form a major structural element in cells. Althoughmembranes perform a variety of functions that are importantin physiology table(3-1)

| TABLE 3.1 | Functions of Plasma Membranes |
|---|---|
| Regulate the passage of substances into and out of cells and between cell organelles and cytosol. | |
| Detect chemical messengers arriving at the cell surface. | |
| Link adjacent cells together by membrane junctions. | |
| Anchor cells to the extracellular matrix. | |

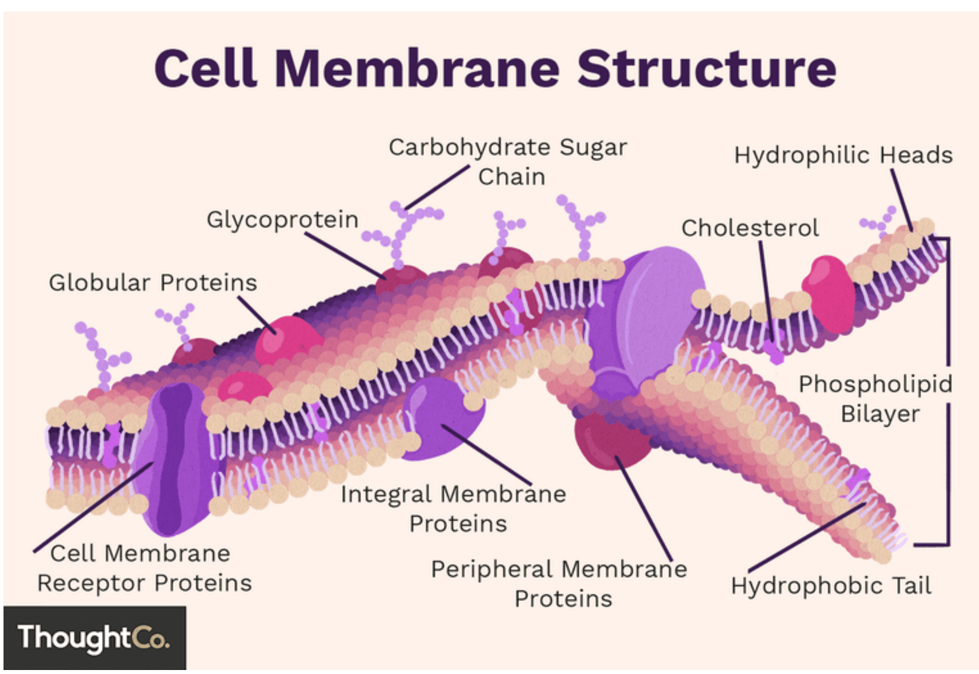
Their most universal role is to act as a **selective barrier** to the passage of molecules, allowing some molecules to cross while excluding others. The plasmamembrane **regulates the passage of substances into and out of the cell**, whereas the membranes surrounding cell organelle sallow the selective movement of substances between the organelles and the cytosol. One of the advantages of restricting the movements of molecules across membranes is confining the products of chemical reactions to specific cell organelles. The hindrance a membrane offers to the passage of substances can be altered to allow increased or decreased flow of molecules or ions across the membrane in response to various signals.

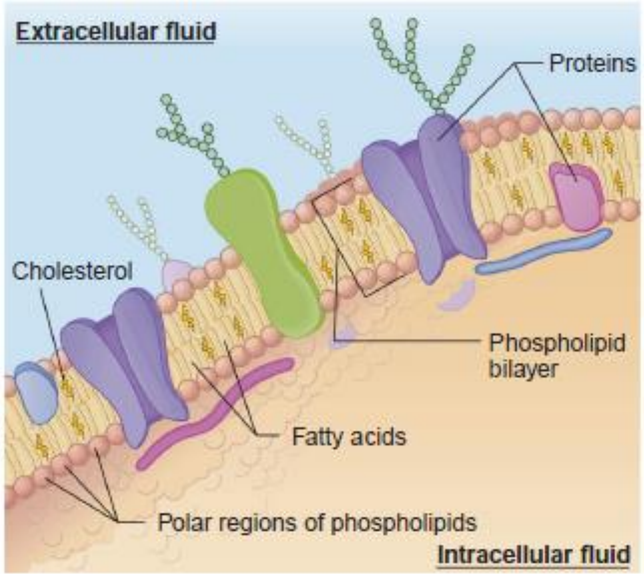
In addition to acting as a selective barrier, the plasma membrane plays an important role in **detecting chemical signals** from other cells and in **anchoring cells to adjacent cells and to the extracellular matrix of connective-tissue proteins**.



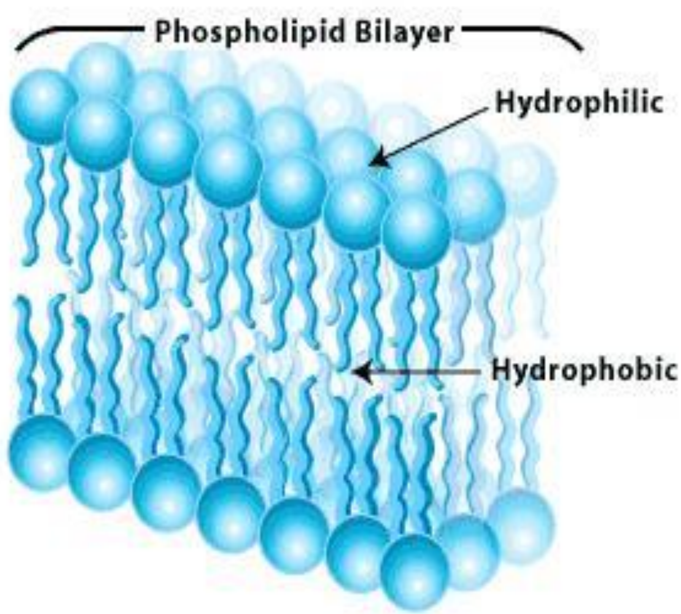

**Membrane Structure**

The structure of membranes determines their function. Forexample, all membranes consist of a double layer of lipid molecules containing embedded proteins .






(b)




The major membrane lipids are **phospholipids.** One end of a phospholipids has a charged or polar region, and the remainder ofthe molecule, which consists of two long fatty acid chains,is nonpolar; therefore, phospholipids are **amphipathic**.

The phospholipids in plasma membranes are organized into a bilayer with the nonpolar fatty acid chains in the middle. The polar regions of the phospholipids are oriented toward the surfaces of the membrane as a result of their attraction to the polar water molecules in the extracellular fluid and cytosol. The lipid bilayer acts as a barrier to the movement of polar molecules into and out of cells.

With some exceptions, chemical bonds do not link the phospholipids to each other or to the membrane proteins.

**each molecule is free to move independently of the others**. This results in considerable random lateral movement of both membrane lipids and proteins parallel to the surfaces of the bilayer. As a consequence, the lipid bilayer has the characteristics of a fluid, much like a thin layer of oil on a water surface, and this makes the membrane quite flexible.

This **flexibility**, along with the fact that cells are filled with fluid, allows cells to undergo moderate changes in shape without disrupting their structural integrity. Like a piece of cloth,a membrane can be bent and folded but cannot be significantly stretched without being torn. These structural features of membranes permit cells to undergo processes such as exocytosis طرد المادة من الخليه and endocytosis, and to withstands light changes in volume due to osmotic imbalances.

The plasma membrane also contains cholesterol, whereas intracellular membranes contain very little. Cholesterol isslightly amphipathic because of a single polar hydroxyl group attached to its relatively rigid, nonpolar ring structure.

Like the phospholipids, therefore, cholesterol is inserted into the lipid bilayer with its polar region at the bilayer surfaceand its nonpolar rings in the interior in association with the fattyacid chains. The polar hydroxyl group forms hydrogen bondswith the polar regions of phospholipids.

A more highly ordered, tightly packed arrangementof fatty acids tends to reduce membrane fluidity. Thus, cholesterol and phospholipids play a coordinated role in maintainingan intermediate membrane fluidity. At high temperatures, cholesterol reduces membrane fluidity, possibly by limiting lateral movement of phospholipids. At low temperatures, cholesterol minimizes the decrease in fluidity that would otherwise occur.

There are two classes of membrane proteins: integral and peripheral.

- **Integral membrane proteins**

closely associated with the membrane lipids and cannot be extracted from the membrane without disrupting the lipid bilayer. Like the phospholipids,the integral proteins are amphipathic, having polar amino acid side chains in one region of the molecule and nonpolarside chains clustered together in a separate region. Because they are amphipathic, integral proteins are arranged in the membrane with the same orientation as amphipathic lipids—the polar regions are at the surfaces in association with polarwater molecules, and the nonpolar regions are in the interior inassociation with nonpolar fatty acid chains .

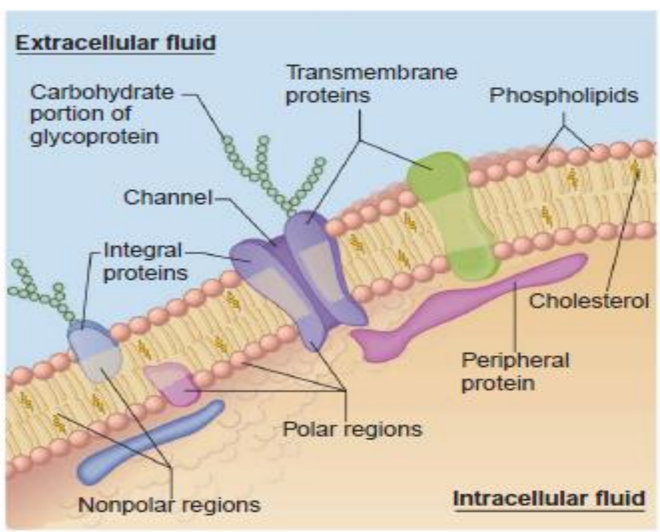



**Figure 3.6** AP|R Arrangement of integral and peripheral membrane proteins in association with a bimolecular layer of phospholipids.

Likethe membrane lipids, many of the integral proteins can move laterally in the plane of the membrane, but others are immobilized because they are linked to a network of peripheral proteins located primarily at the cytosolic surface of the membrane.

Most integral proteins span the entire membrane and are referred to as **transmembrane proteins.** The polypeptide chainsof many of these transmembrane proteins cross the lipid bilayerseveral times .

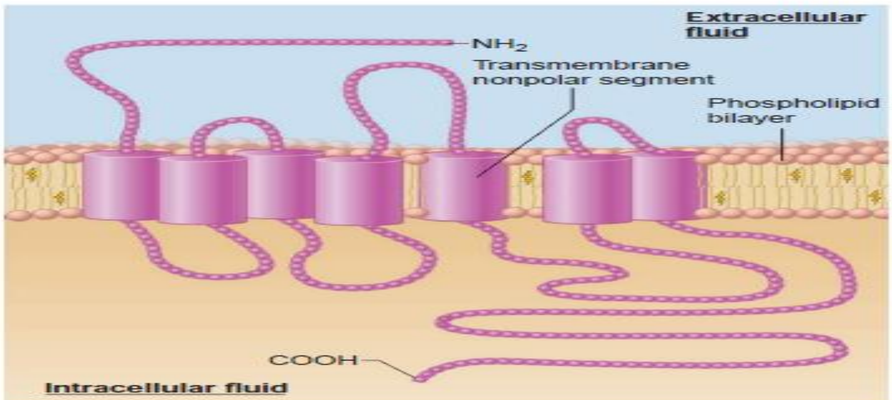



**Figure 3.7** A typical transmembrane protein with multiple hydrophobic segments traversing the lipid bilayer. Each transmembrane segment is composed of nonpolar amino acids spiraled in an alpha-helical conformation (shown as cylinders).

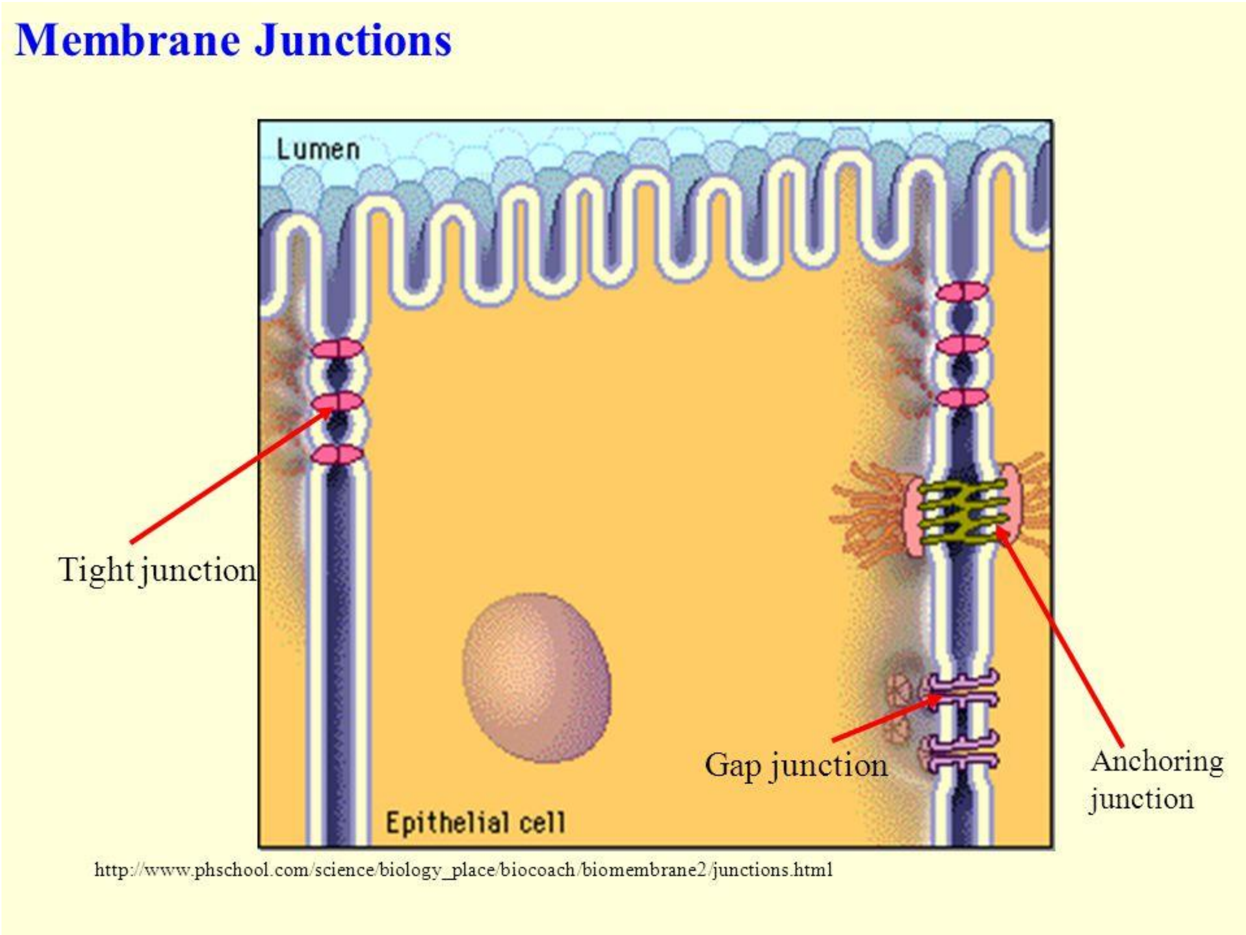
**Peripheral membrane proteins**

are not amphipathic and do not associate with the nonpolar regions of the lipids in theinterior of the membrane. They are located at the membranesurface where they are bound to the Polar Regions of the integralmembrane proteins and also in some casesto the charged polar regions of membrane phospholipids.

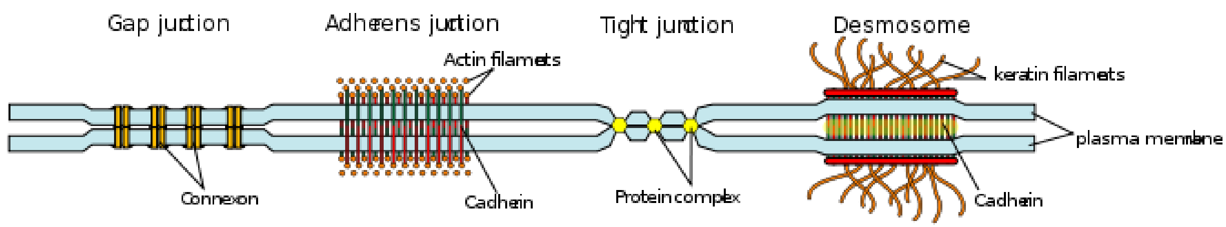
The extracellular surface of the plasma membrane contains small amounts of **carbohydrate covalently linked to someof the membrane lipids and proteins**. These carbohydratesconsist of short, branched chains of monosaccharides that extend from the cell surface into the extracellular fluid, wherethey form a layer known as the **glycocalyx .**These surface carbohydrates play important roles in ***enabling cells to identify and interact with each other***.

## Membrane Junctions

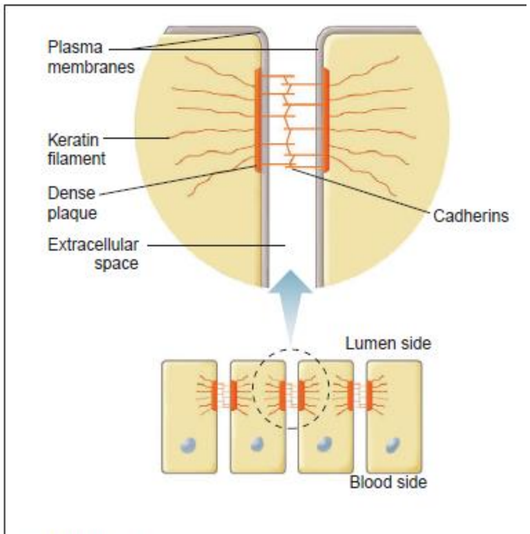
In addition to providing a barrier to the movements of molecules between the intracellular and extracellular fluids, plasmamembranes are involved in the interactions between cells to form tissues. Most cells are packaged into tissues and are not free to move around the body. Even in tissues, however, thereis usually a space between the plasma membranes of adjacentcells. This space, filled with extracellular (interstitial) fluid, provides a pathway for substances to pass between cells on their way to and from the blood.




The way that cells become organized into tissues and organs depends, in part, on the ability of certain transmembrane proteins in the plasma membrane, known as **integrins** ,to bind to specific proteins in the extracellular matrix and linkthem to membrane proteins on adjacent cells.




Many cells are physically joined at discrete locations alongtheir membranes by specialized types of junctions, including desmosomes, tight junctions, and gap junctions. These junctionsprovide an excellent example of the physiological principlethat structure and function are related, in this case at thecellular level. **Desmosomes** consist of a region between **two adjacent cells** where the apposed plasma membranesare separated by about 20 nm. Desmosomes are characterizedby accumulations of protein known as "**dense plaques**"along the cytoplasmic surface of the plasma membrane. These proteins serve as anchoring points for cadherins. **Cadherins** are proteins that extend from the cell into the extracellular space,where they link up and bind with cadherins from an adjacentcell. In this way, two adjacent cells can be firmly attached to eachother. The presence of numerous desmosomes between cellshelps to provide the structural integrity of tissues in the body.In addition, other proteins such as **keratin filaments** anchor the cytoplasmic surface of desmosomes to interior structures ofthe cell. It is believed that this helps secure the desmosome inplace and also provides structural support for the cell. Desmosomes hold adjacent cells firmly together in areas that are subject to considerable stretching, such as the skin. The specializedarea of the membrane in the region of a desmosome is usuallydisk-shaped; these membrane junctions could be likened to rivetsor spot welds.

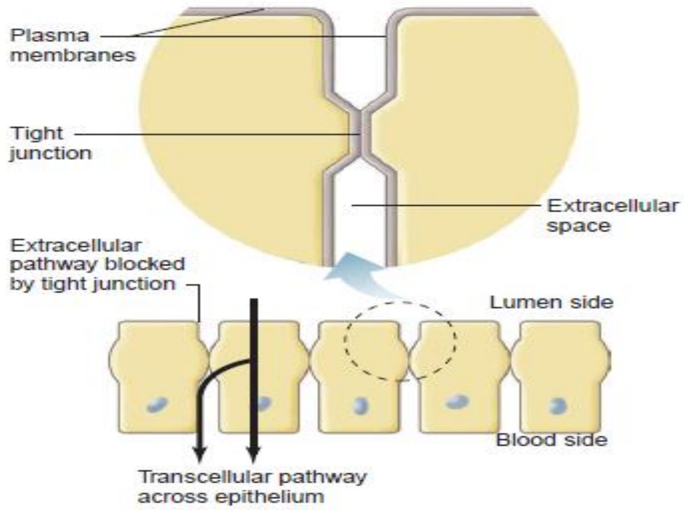


(a) Desmosome

**tight junction** forms when the extracellular surfaces of two adjacent plasma membranes join together so that **no extracellular space remains between them**. Unlike the desmosome, whichis limited to a disk-shaped area of the membrane, the tightjunction occurs in a band around the entire circumference ofthe cell. Most epithelial cells are joined by tight junctions neartheir apical surfaces. For example, epithelial cells line the innersurface of the small intestine, where they come in contact withthe digestion products in the cavity (or lumen) of the intestine.

For many substances, however, movement through the extracellularspace is blocked by the tight junctions; this forces organic nutrients to pass through the cells rather than between them. In thisway, the selective barrier properties of the plasma membrane can control the types and amounts of substances absorbed.

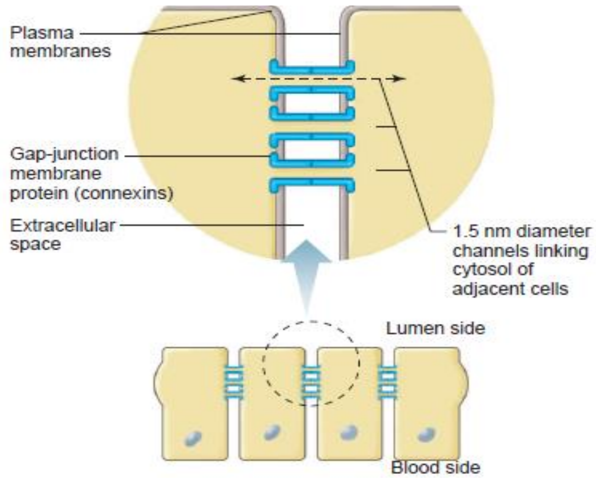
The ability of tight junctions to impede molecular movementbetween cells is not absolute. Ions and water can move throughthese junctions with varying degrees of ease in different epithelia.



(b) Tight junction

The **gap junction ,** consistsof protein channels linking the cytosols of adjacent cells. In the region of the gap junction, the two opposing plasma membranes come within 2 to 4 nm of eachother, which allows specific proteins (called connexins) from the two membranes to join, forming small, protein-linedchannels linking the two cells. The small diameter of thesechannels (about 1.5 nm) limits what can pass between thecytosols of the connected cells to small molecules and ions,such as Na 1 and K 1 , and excludes the exchange of large proteins.

A variety of cell types possess gap junctions, includingthe muscle cells of the heart, where they play a very importantrole in the transmission of electrical activity between the cells.



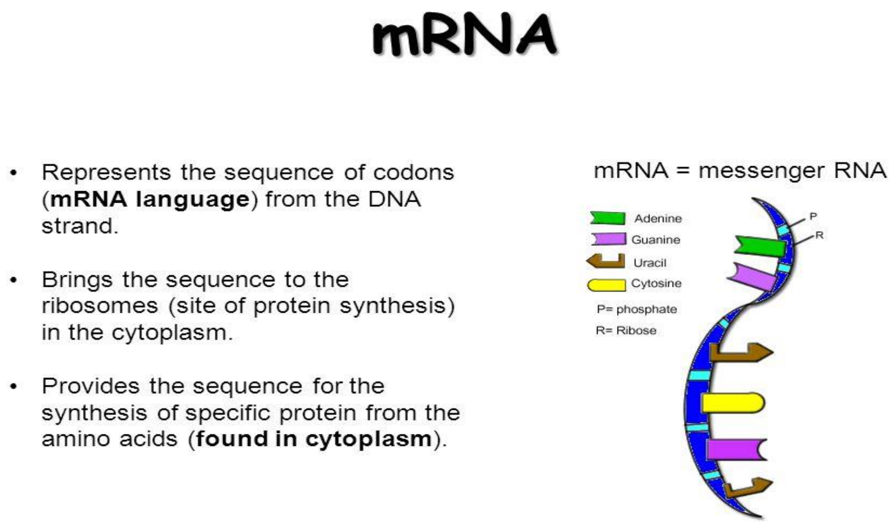

(d) Gap junction

## Cell Organelles

### Nucleus

Almost all cells contain a single nucleus, the largest of the membrane-bound cell organelles. A few specialized cells, such as skeletal muscle cells, contain multiple nuclei, whereas mature redblood cells have none. *The primary function of the nucleus is the storage and transmission of genetic information to the next generationof cells*. This information, coded in molecules of DNA,is also used to synthesize the proteins that determine the structureand function of the cell, as described later in this chapter.

RNA molecules that determine the structure of proteins synthesized in the cytoplasm move between the nucleus and cytoplasm through these nuclear pores. Proteins that modulate the expression of various genes in DNA .



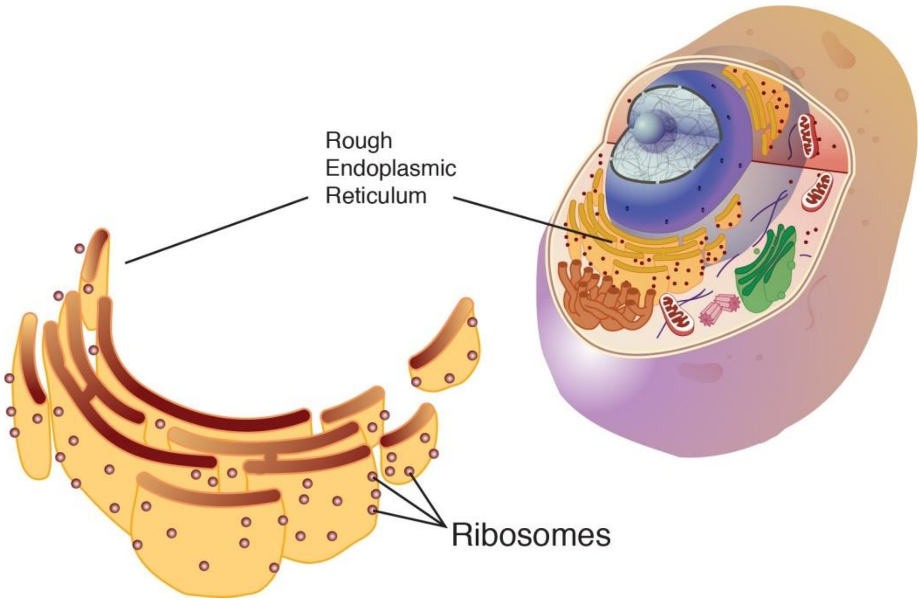

Within the nucleus, DNA, in association with proteins,forms a fine network of threads known as **chromatin.**

At the time of cell division, thechromatin threads become tightly condensed, forming rod-like bodies known as **chromosomes.**

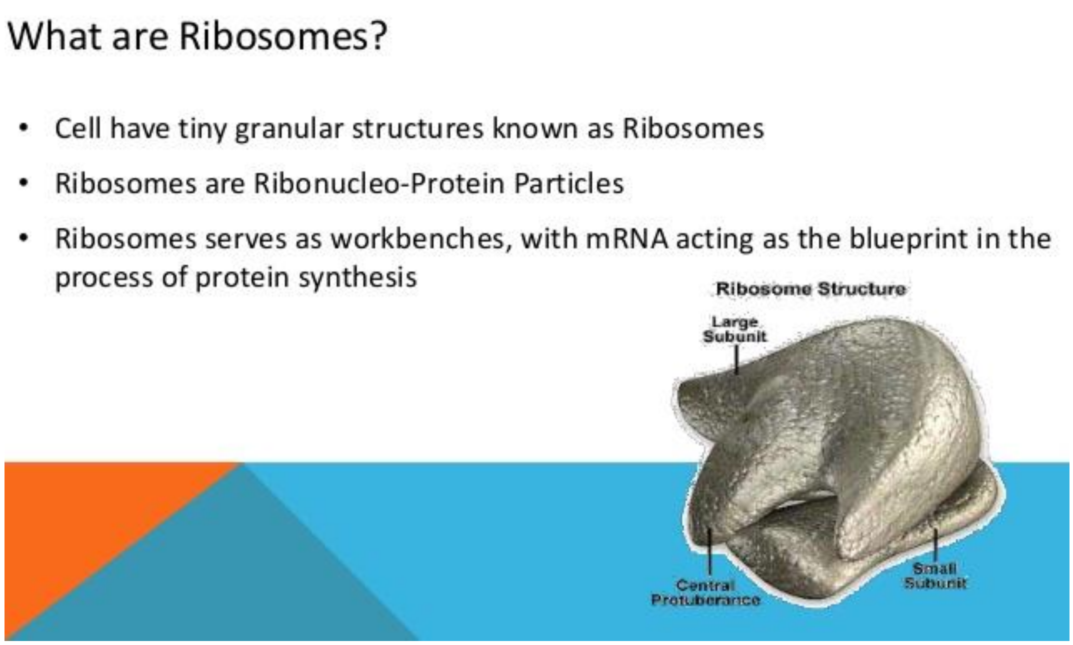
## Ribosomes

**Ribosomes** are the protein factories of a cell. On ribosomes, protein molecules are synthesized from amino acids, using genetic information carried by RNA messenger molecules from DNAin the nucleus. Ribosomes are large particles, about 20 nm indiameter, composed of about 70 to 80 proteins and several RNAmolecules.

Ribosomes consist of two subunits that either are floating free in the cytoplasm or combine during protein synthesis. In the latter case, the ribosomes bindto the organelle called rough endoplasmic reticulum. A typical cell may contain as many as 10 million ribosomes.

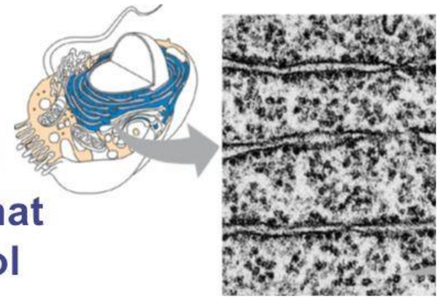



The proteins synthesized on the free ribosomes are released into the cytosol, where they perform their varied functions. The proteins synthesized by ribosomes attached to the rough endoplasmic reticulum pass into the lumen of the reticulum and are then transferred to another organelle, the Golgi apparatus. They are ultimately secreted from the cell or distributed to other organelles.

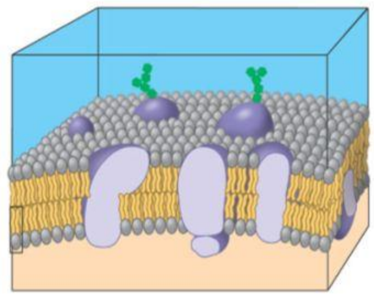


## Types of Ribosomes

- **Free ribosomes**
  - suspended in cytosol
  - synthesize proteins that function within cytosol



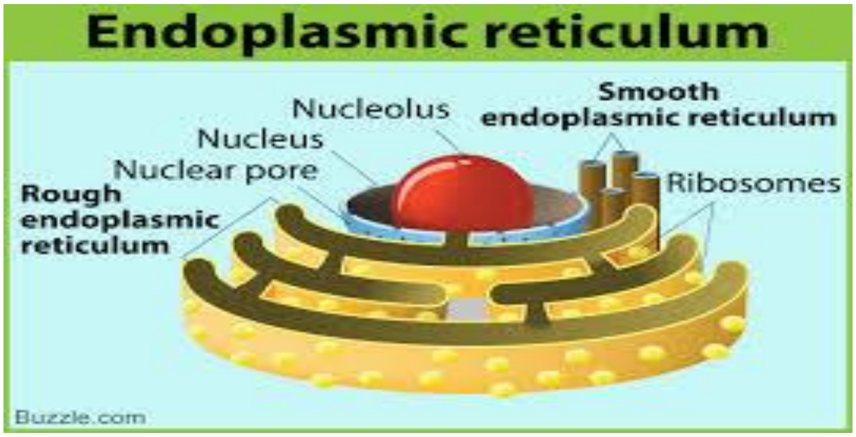
- **Bound ribosomes**
  - attached to outside of endoplasmic reticulum
  - synthesize proteins for export or for membranes



**Endoplasmic Reticulum**

The most extensive cytoplasmic organelle is the network(or “reticulum”) of membranes that form the **endoplasmicreticulum**. These membranes enclose a space that is continuous throughout the network.

Two forms of endoplasmic reticulum can be distinguished:rough, or granular, and smooth, or agranular.

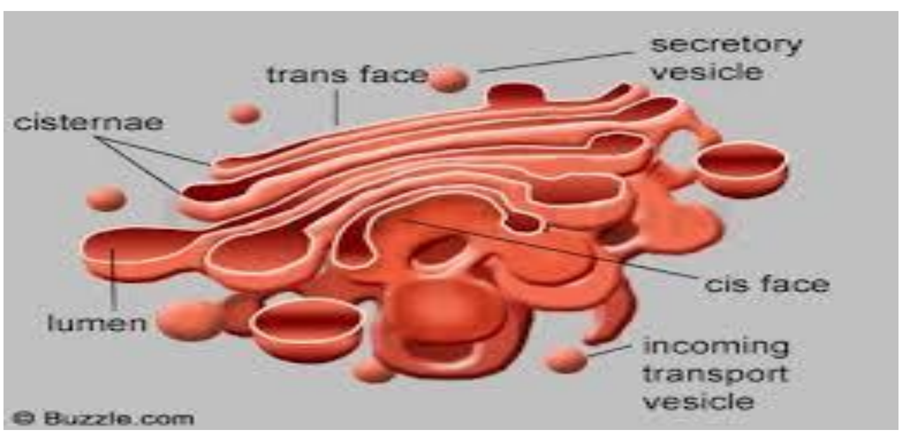



Therough endoplasmic reticulum has ribosomes bound to its cytosolic surface, and it has a flattened-sac appearance. Rough endoplasmic reticulum is involved in **packaging proteins** that,after processing in the Golgi apparatus, are secreted by the cell or distributed to other cell organelles. The smooth endoplasmic reticulum has no ribosomalparticles on its surface and has a branched, tubular structure.

Smooth endoplasmic reticulum is the site at which certain lipid molecules are synthesized,it plays a role in detoxification of certain hydrophobic molecules,and it also stores and releases calcium ions involved incontrolling various cell activities.

**Golgi apparatus**

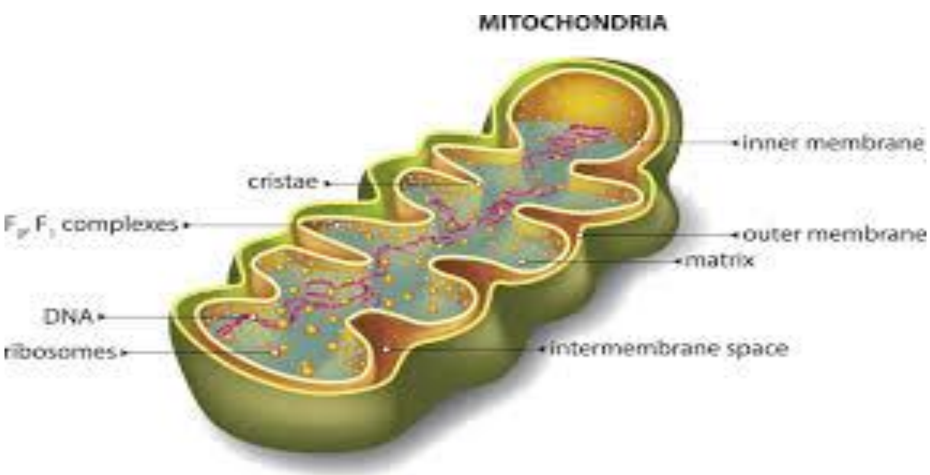
The Golgi apparatus is a series of closely apposed, flattened membranous sacs that are slightly curved, forming a cup shaped structure.




Proteins arriving at the Golgi apparatus from the rough endoplasmic reticulum undergo a series of modifications as they pass from one Golgi compartment to the next. For example,carbohydrates are linked to proteins to form glycoproteins,and the length of the protein is often shortened by removing a terminal portion of the polypeptide chain. Vesicles containingproteins to be secreted from the cell are known as **secretoryvesicles.** Such vesicles are found, for example, in certain endocrine gland cells, where protein hormones are released into theextracellular fluid to modify the activities of other cells.

**Mitochondria**

Mitochondria participate in the chemical processes that transfer energy from the chemical bonds of nutrient molecules to newly created adenosine triphosphate(ATP) molecules, which are then made available tocells. Most of the ATP that cells use is formed in the mitochondria by a process called cellular respiration, which consumes oxygen and produces carbon dioxide, heat, and water. Mitochondria are spherical or elongated, rodlike structuressurrounded by an inner and an outer membrane .




The outer membrane is smooth, whereas the inner membraneis folded into sheets or tubules known as **cristae,** which extend into the inner mitochondrial compartment, the **matrix.** Mitochondria are found throughout the cytoplasm.

Large numbersof them, as many as 1000, are present in cells that utilize large amounts of energy, whereas less active cells contain fewer. In all celltypes that have been examined, mitochondria appear to exist atleast in part in a reticulum ( **Figure 3.14** ). Moreover, the extent of the reticulum may change in different physiological settings;more mitochondria may fuse, or split apart, or even destroythemselves as the energetic demands of cells change.

In addition to providing most of the energy required to power physiological events such as muscle contraction, mitochondria also play a role in the synthesis of certain lipids, such as the hormones estrogen and testosterone.

**Lysosomes**

Lysosomes are spherical or oval organelles surrounded by asingle membrane. A typical cell may contain several hundred lysosomes. The fluid within a lysosome is acidic and contains a variety of digestive enzymes. Lysosomes act to break down bacteria and the debris from dead cells thathave been engulfed by a cell. They may also break down cellorganelles that have been damaged and no longer function normally.

They play an especially important role in the various cells that make up the defense systems of the body.

**Cytoskeleton**

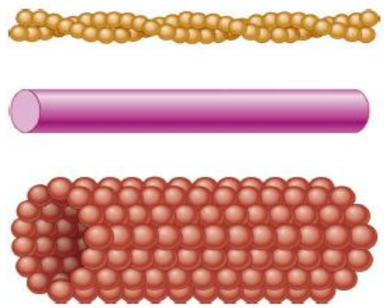
In addition to the membrane-enclosed organelles, the cytoplasm of most cells contains a variety of protein filaments. Thisfilamentous network is referred to as the cell's **cytoskeleton,**and, like the bony skeleton of the body, it is associated withprocesses that maintain and change cell shape and produce cell movements.

The three classes of cytoskeletal filaments are based ontheir diameter and the types of protein they contain. In order of size, starting with the thinnest, they are

(1) actin filaments(also called microfilaments).

(2) intermediate filaments.

(3) microtubules



| Cytoskeletal filaments | Diameter (nm) | Protein subunit |
|---|---|---|
| Actin filament | 7 | G-actin |
| Intermediate filament | 10 | Several proteins |
| Microtubule | 25 | Tubulin |

Figure 3.15 AP|R Cytoskeletal filaments associated with cell shape and motility.

Actin filaments and microtubules can be assembled تتجمعand disassembled rapidly, allowing a cell to alter these components of its cytoskeletal framework according to changing requirements. In contrast, intermediatefilaments, once assembled, are less readily disassembled.

**Intermediate filaments** are composed of twisted strands of several different proteins. These filaments also contribute to cell shape and help anchor the nucleus. They provide considerable strength tocells and consequently are most extensively developed in theregions of cells subject to mechanical stress (for example, inassociation with desmosomes).

**Microtubules** are hollow tubes about 25 nm in diameter,whose subunits are composed of the protein **tubulin .**

They are the most rigid of the cytoskeletal filaments and arepresent in the long processes of neurons, where they providethe framework that maintains the processes' cylindricalshape. Microtubules also radiate from a region of thecell known as the **centrosome ,**which surrounds two small,cylindrical bodies called **centrioles ,** composed of nine setsof fused microtubules.

**Cilia,**the hair-like motile extensions on the surfaces of some epithelial cells, have acentral core of microtubules organized in a pattern similarto that found in the centrioles.