The Cell:
A Microcosm of Life

- Cells may be defined as the basic living, structural, and functional units of the human body.
- They vary greatly in size, chemical composition, and function, but each one is a remarkable miniaturization of human life.
- Cells move, grow, ingest food and excrete wastes, react to their environment, and even reproduce
- Specialization among cells is a necessity for the living, breathing human, butcells in general have certain basic similarities.All human cells have a plasma membrane and a nucleus (or have had a nucleus), and most contain an endoplasmic reticulum, Golgi apparatus, and mitochondria.

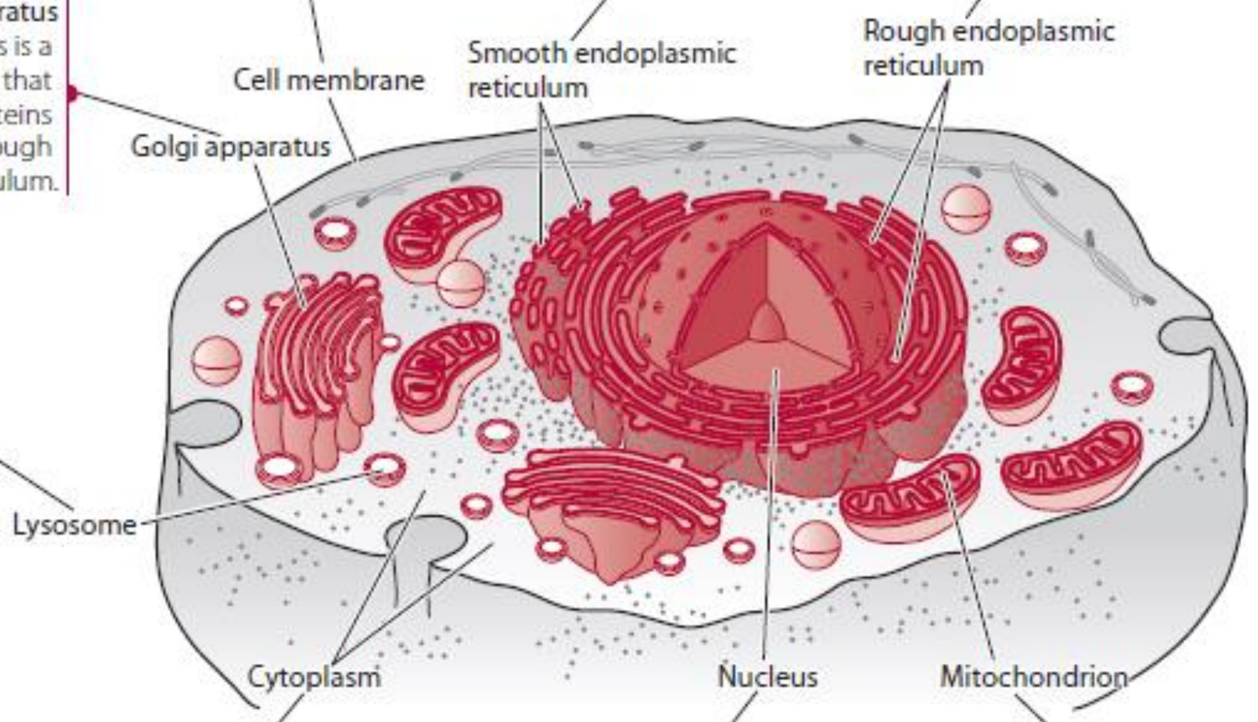
Cell membrane or plasma membrane
Cells are surrounded by a phospholipid bilayer that contains embedded proteins, carbohydrates, and lipids. Membrane proteins act as receptors sensitive to external stimuli and channels that regulate the movement of substances into and out of the cell.

Smooth endoplasmic reticulum
Region of the endoplasmic reticulum involved in lipid synthesis. Smooth endoplasmic reticula do not have ribosomes and are not involved in protein synthesis.

Rough endoplasmic reticulum
A series of membrane sacks that contain ribosomes that build and process proteins.

Golgi apparatus
The Golgi apparatus is a series of membrane sacks that process and package proteins after they leave the rough endoplasmic reticulum.

Lysosome
Contains digestive enzymes that break up proteins, lipids, and nucleic acids. They also remove and recycle waste products.



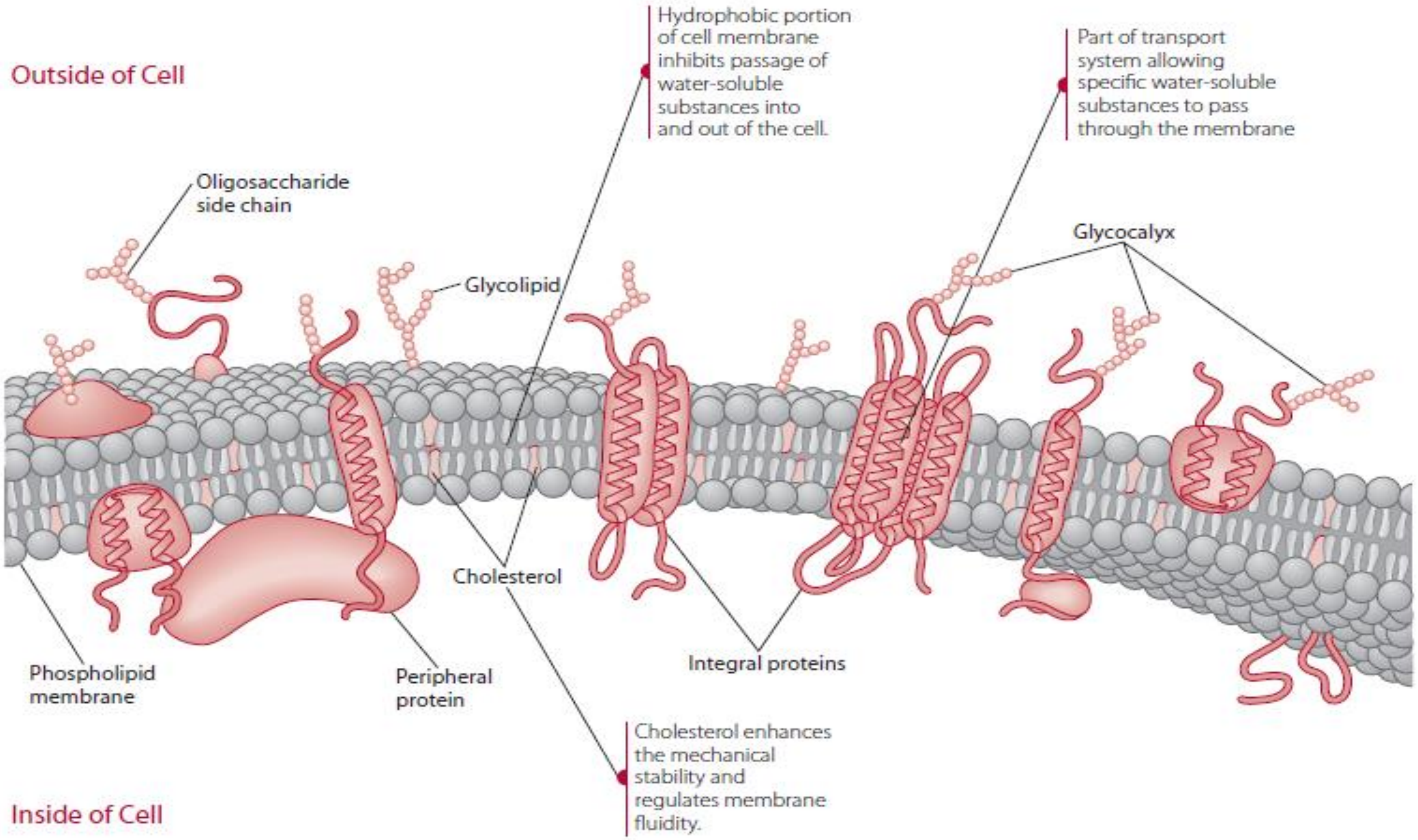
Cytoplasm
The cytoplasm is the gel-like substance inside cells. Cytoplasm contains cell organelles, protein, electrolytes, and other molecules.

Nucleus
The nucleus contains the DNA in the cell. Molecules of DNA provide coded instructions used for protein synthesis.

Mitochondrion
Organelles that produce most of the energy (ATP) used by cells.

Figure 1.1 Typical animal cell

The cell membrane

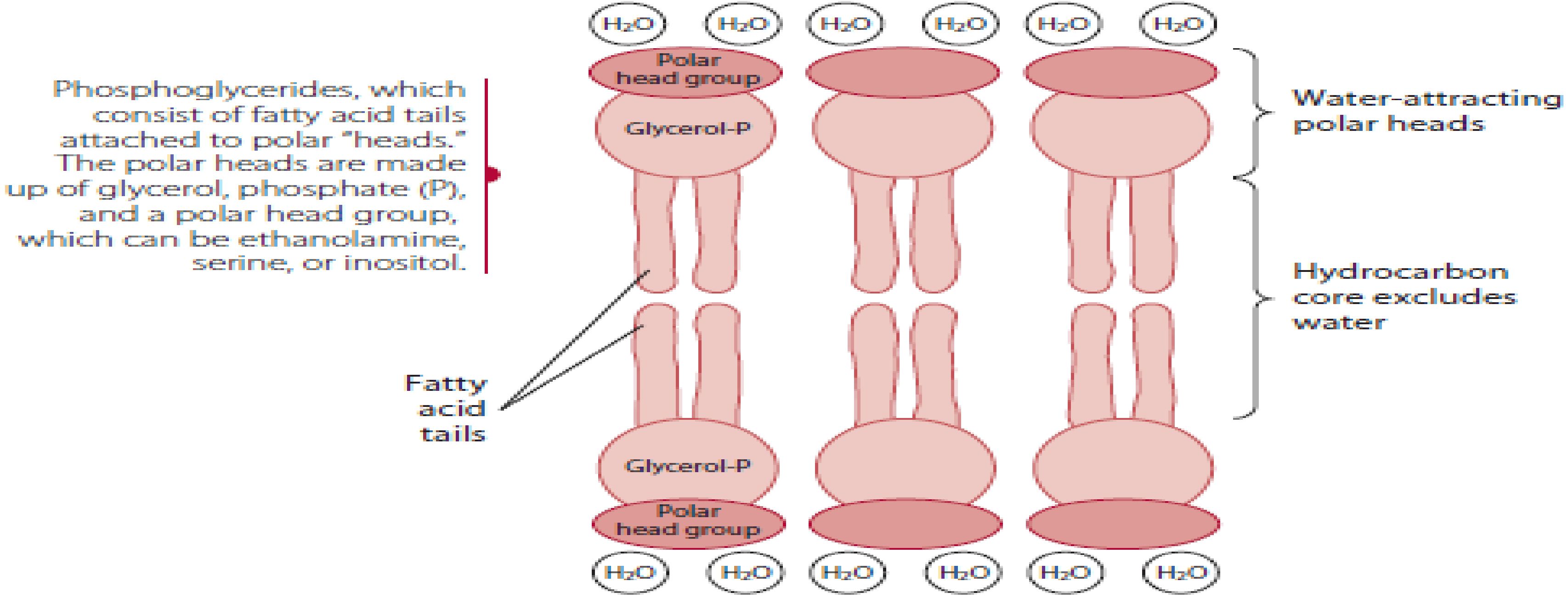


charateristics

- Membranes are sheet-like structures composed primarily of phospholipids and proteins held together by noncovalent interactions.
- Membrane phospholipids have both a hydrophobic and a hydrophilic moiety. This structural property of phospholipids allows them to spontaneously form bimolecular sheets in water, called lipid bilayers
- Phosphoglycerides and phosphingolipids (phosphate- containing sphingolipids) comprise most of the membrane phospholipids

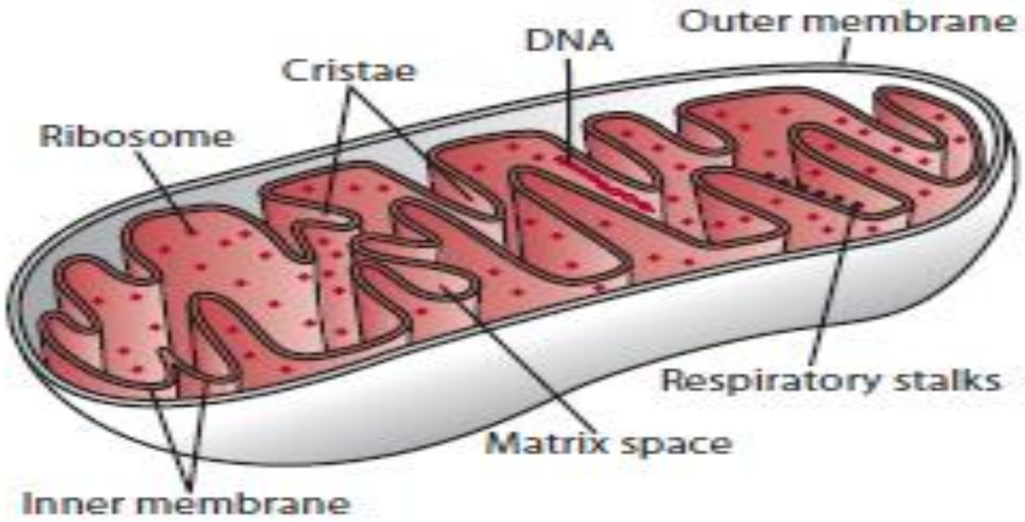
- Of the phosphoglycerides, phosphatidylcholine and phosphatidylethanolamine are particularly abundant in humans and higher animals. Another important membrane lipid is cholesterol, which is found in the hydrophobic portion of the bilayer in amounts that vary considerably from membrane to membrane. Membranes with higher levels of cholesterol are less fluid.
- Membrane proteins give biological membranes their functions: They serve as pumps, gates, receptors, energy transducers, and enzymes. Many of these proteins have either lipid or carbohydrate attachments.

- Membranes are asymmetrical. The inside and outside faces of the membrane are different
- Membranes are not static but are fluid structures. The lipid and protein molecules within them move laterally with ease and rapidity



Mitochondrion

- The **mitochondria** are the primary sites of oxygen use in the cell and are responsible for most of the metabolic energy (adenosine triphosphate, or ATP) produced in cells.
- The size and shape of the mitochondria in different tissues vary according to the function of the tissue. In muscle tissue,for example, the mitochondria are held tightly among the fibers of the contractile system. In the liver, however, the mitochondria have fewer restraints, appear spherical, and move freely through the cytoplasmic matrix.
- The mitochondrion consists of a matrix or interior space surrounded by a double membrane


Outer membrane
DNA
Cristae
Ribosome
Respiratory stalks
Matrix space
Inner membrane

- The mitochondrial outer membrane is relatively porous, whereas the inner membrane is selectively permeable, serving as a barrier between the cytoplasmic matrix and the mitochondrial matrix
- The inner membrane has many invaginations, called the cristae, which increase its surface area, and all the components of the electron transport chain are embedded within it.
- The electron transport (respiratory) chain is central to the process of **oxidative phosphorylation,** the mechanism by which most cellular ATP is produced.

- The function of the **electron transport chain** is to couple the energy released by nutrient oxidation to the formation of ATP. The chain components are precisely positioned within the inner mitochondrial membrane, an important feature of the mitochondria, because it brings the oxidizable products released in the matrix into close proximity with molecular oxygen.
- Among the metabolic enzyme systems functioning in the mitochondrial matrix are those that catalyze the reactions of the tricarboxylic cycle

Nucleus

- The nucleus is the largest of the organelles within the cell. Because of its DNA content, the nucleus initiates and regulates most cellular activities.
- Surrounding the nucleus is the **nuclear envelope.** The nuclear envelope is composed of two bilayer membranes (an inner and an outer membrane) that are dynamic structures
- The dynamic nature of these membranes makes communication possible between the nucleus and the cytoplasmic matrix and allows a continuous channel between the nucleus and the endoplasmic reticulum.

- The matrix held within the nuclear envelope contains molecules of DNA that encode the cell's genetic information plus all the enzymes needed for its duplication.
- The nuclear matrix also contains the minerals necessary for the activity of the nucleus. Condensed regions of the chromatin within the nuclear envelope, called **nucleoli,** contain not only DNA and its associated alkaline proteins (histones) but also considerable amounts of RNA (ribonucleic acid).

- Encoded within the nuclear DNA of the cell are thousands of genes that direct the synthesis of proteins. Each gene codes for a single specific protein. The cell **genome** is the entire set of genetic information, that is, all of the DNA within the cell. Barring mutations that may arise in the DNA, daughter cells, produced from a parent cell by mitosis, possess the identical genomic makeup of the parent.
- The process of DNA replication enables the DNA to be precisely copied at the time of mitosis.

Cellular Proteins

- Proteins synthesized on the cell's free polyribosomes remain within the cell to perform their specific structural, digestive, regulatory, or other functions. Among the more interesting areas of biomolecular research has been determining how newly synthesized protein finds its way from the ribosomes to its intended destination.
- At the time of synthesis, signal sequences direct proteins to their appropriate target compartment. These targeting sequences, located at the N-terminus of the protein, are generally cleaved (though not always) when the protein reaches its destination. Interaction between the signal sequences and specific receptors located on the various membranes permits the protein to enter its designated membrane or become incorporated into the designated organelle.

- A long list of metabolic diseases is attributed to a deficiency of, or the inactivity of, certain enzymes (protein catalysts). Tay-Sachs disease, phenylketonuria, maple syrup urine disease, and the lipid and glycogen storage diseases are a few well-known examples.

- As a result of research on certain mitochondrial proteins, it is believed that in at least some cases the enzymes are not necessarily inactive or deficient but rather fail to reach their correct destination.

- Several cellular proteins are of particular interest to the health science student:
- **receptors,** proteins that modify the cell's response to its environment
- **transport proteins,** proteins that regulate the flow of nutrients into and out of the cell
- **enzymes,** the catalysts for the hundreds of biochemical reactions taking place in the cell

Receptors and Intracellular Signaling

- Receptors are highly specific proteins located in the plasma membrane and facing the exterior of the cell. Bound to the outer surface of these specific proteins are oligosaccharide chains, which are believed to act as recognition markers
- Membrane receptors act as attachment sites for specific external stimuli such as hormones, growth factors, antibodies, lipoproteins, and certain nutrients
- These molecular stimuli, which bind specifically to receptors, are called **ligands**

- Although most receptor proteins are probably integral membrane proteins, some may be peripheral. In addition, receptor proteins can vary widely in their composition and mechanism of action.
- Although the composition and mechanism of action of many receptors have not yet been determined, at least three distinct types of receptors are known to exist:
- **those that bind the ligand stimulus** and convert it into an internal signal that alters behavior of the affected cell
- **those that function as ion channels**
- **those that internalize their stimulus intact**

Receptors That Produce Internal Chemical Signals

- The internal chemical signal most often produced by a stimulus-receptor interaction is 3′, 5′-cyclic adenosine monophosphate (cyclic adenosine monophosphate [AMP], or cAMP).
- It is formed from adenosine triphosphate (ATP) by the enzyme adenyl cyclase. Cyclic AMP is frequently referred to as the second messenger in the stimulation of target cells by hormones.
- As shown in the figure, the stimulated receptor reacts with guanosine

triphosphate (GTP)–binding protein (G-protein), which activates adenylcyclase, triggering production of Camp from ATP. G-protein is a trimer with three subunits (designated α, β, and γ).

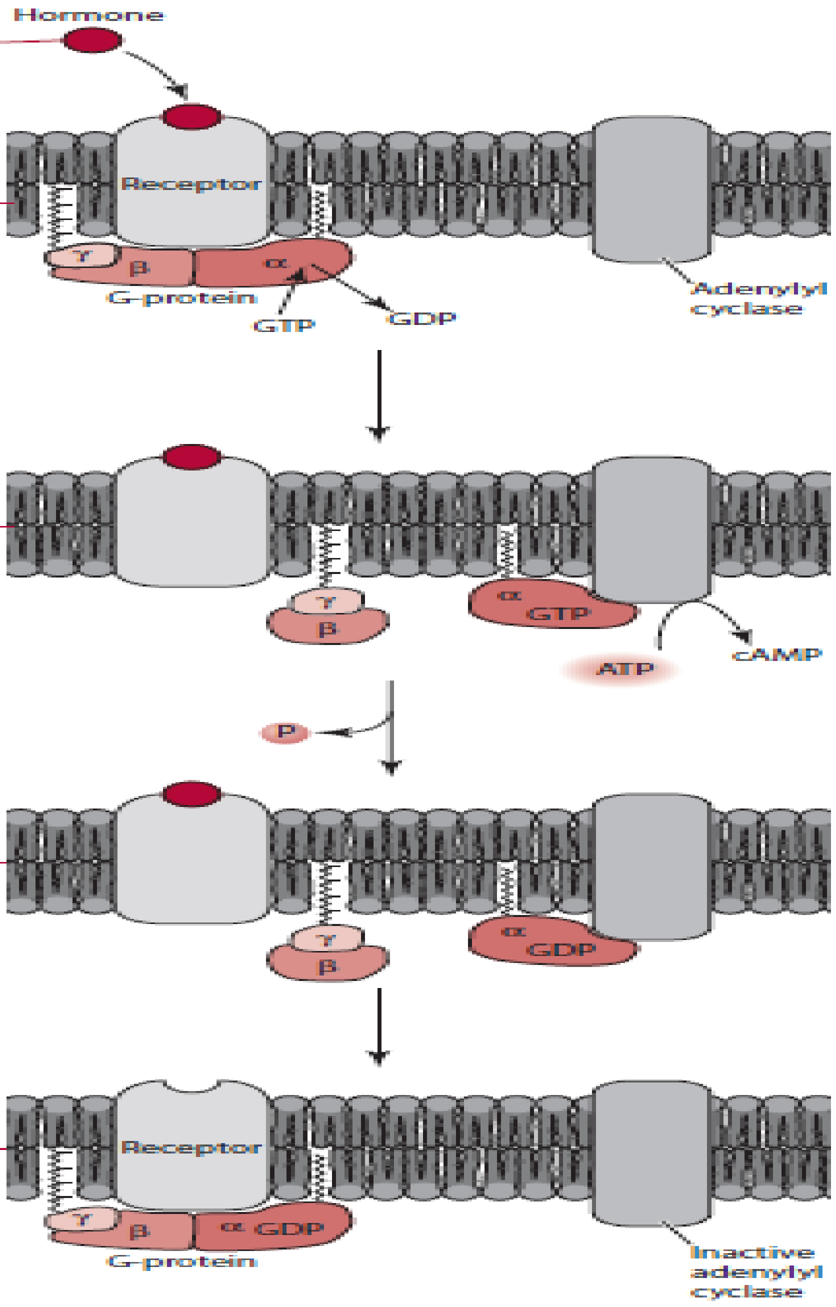
1. The hormone attaches to the receptor molecule.

2. The receptor has a G-protein (a protein with GTP or GDP attached to it) attached.

3. When a hormone attaches to the receptor, the GDP is converted to GTP and a portion of the G-protein attaches to adenyl cyclase, activating it. The activated adenyl cyclase reacts with ATP to form cAmp.

4. The G-protein functions as a GTPase. When GTP is converted to GDP, the fragment of G-protein moves back to the receptor.

5. Adenyl cyclase is inactivated and the receptor loses the hormone.

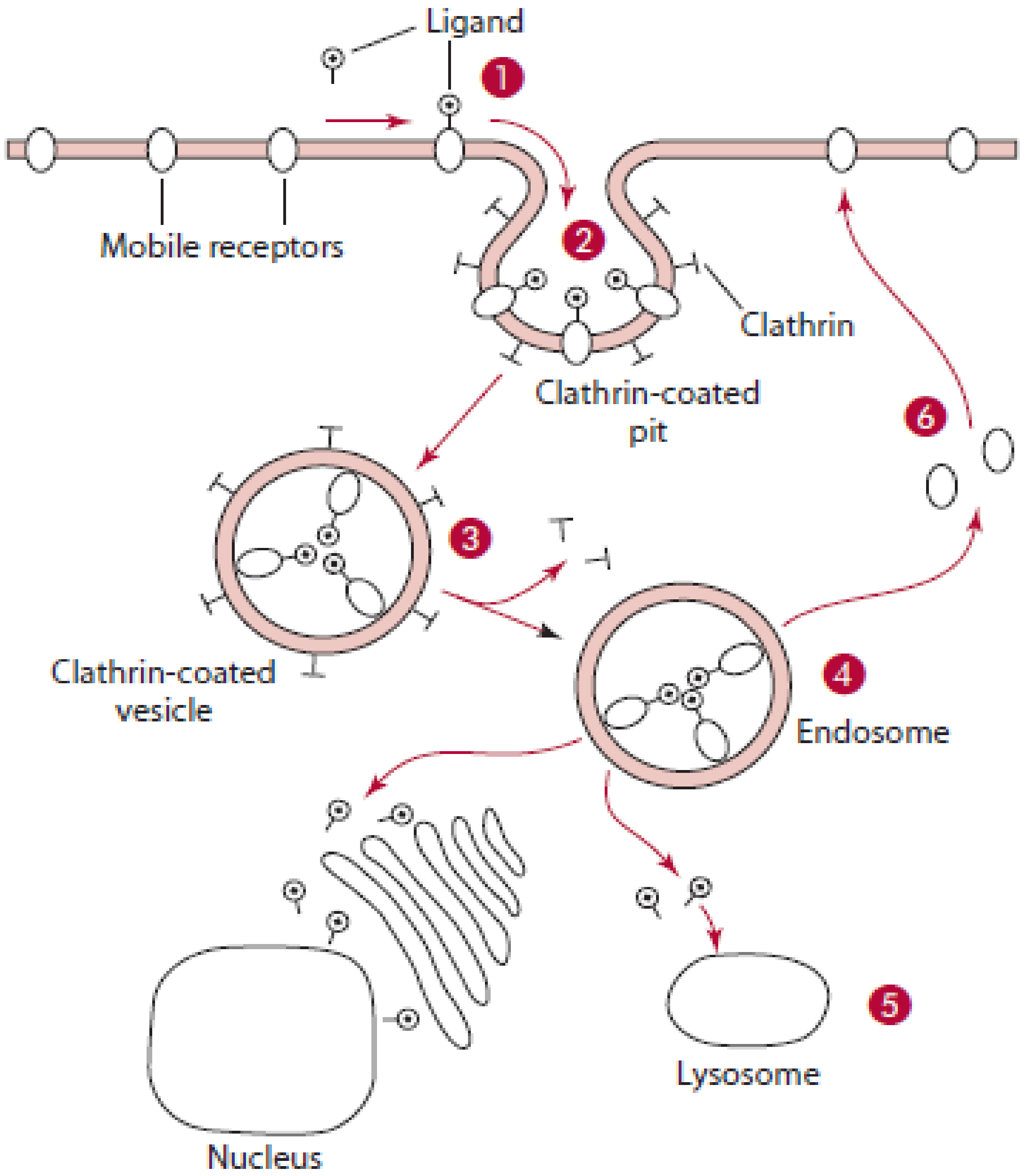


Receptors That Act as Ion Channels

- Receptors can also act as ion channels in stimulating a cell. In some cases, the binding of the ligand to its receptor causes a voltage change, which then becomes the signal for an appropriate cellular response.
- Such is the case when the neurotransmitter acetylcholine is the stimulus. The receptor for acetylcholine appears to function as an ion channel in response to voltage change. Stimulation by acetylcholine signals the channels to open, allowing sodium (Na) ions to pass through an otherwise impermeable membrane

Receptors That Internalize Stimuli

- Receptors that perform in such a manner exist for a variety of biologically active molecules, including the hormones insulin and triiodothyronine.
- Low-density lipoproteins (LDLs) are taken up by certain cells in much the same fashion ,except that their receptors, rather than being mobile, are already clustered in coated pits
- These pits, vesicles formed from the plasma membrane, are coated with several proteins, among which clathrin is primary
- The internalization of a stimulus into a fibroblast by way of its receptor is illustrated in Figure



1.Ligand binds with its receptor on the cell membrane.
2.Ligand and receptor move into a clathrin-coated pit.
3.Pit closes o and forms a clathrin-coated vesicle.
4.The vesicle forms an endosome.
5.Ligand can be used by the cell or undergo lysosomal degradation.
6.Receptor is recycled to the surface of the cell membrane.

Receptors' Role in Homeostasis

- The cells of every organ in the body have specialized receptors that respond to changes in external conditions.
- The reaction of a fibroblast to changes in blood glucose levels is a good example of cellular adjustment to the existing environment that is made possible through receptor proteins.
- When blood glucose levels are low, muscular activity leads to release of the hormone epinephrine by the adrenal medulla.
- Epinephrine becomes attached to its receptor protein on the fibroblast, thereby activating the receptor and causing it to stimulate G-protein and adenyl cyclase, which catalyzes the formation of cAMP from ATP.

- Then cAMP initiates a series of enzyme phosphorylation modifications, as described earlier in this section, which result in the phosphorolysis of glycogen to glucose-1-phosphate for use by the fibroblast.
- In contrast, when blood glucose levels are elevated, the hormone insulin, secreted by the β-cells of the pancreas, reacts with its receptors on the fibroblast and is transported into the cell by receptor-mediated endocytosis.
- Insulin allows diffusion of glucose into the cell by increasing the number of glucose receptors in the cell membrane, which in turn promote diffusion of glucose by its transport protein.

Transport Proteins

- Transport proteins regulate the flow of substances (including nutrients) into and out of the cell. Transport proteins may function by acting as carriers (or pumps), or they may provide protein-lined passages (pores) through which water-soluble materials of small molecular weight may diffuse.
- The active transport protein that has been studied most is the sodium (Na^+) pump. The Na^+ pump is essential not only to maintain ionic and electrical balance but also for intestinal and renal absorption of certain key nutrients (e.g., glucose and certain amino acids).

- These nutrients move into the epithelial cell of the small intestine against a concentration gradient, necessitating both a carrier and a source of energy, both of which are provided by the Na^+ pump.
- The process of facilitated (non–energy dependent) transport is also an important mechanism for regulating the flow of nutrients into the cell
- It is used broadly across a wide range of cell types. Proteins involved in this function are often called transporters; probably the most thoroughly studied of these are the glucose transporters

Catalytic Proteins (Enzymes)

- Enzymes are proteins that are distributed throughout all cellular compartments. Enzymes are catalysts that take part in a reaction but are not part of the final product of that reaction, and are essentially regenerated
- Enzymes have an “active site” where they bind with a substrate. Often, biologically metabolic pathways involve a number of enzymatic reactions that are associated with each other
- Enzymes that are components of the cellular membranes are usually found on the inner surface of the membranes; the exceptions are enzymes that function externally. Examples are the digestive enzymes: isomaltase, the disaccharidases (lactase, sucrase, and maltase), and certain peptidases located on the brush border of the epithelial cells lining the small intestine

- Membrane-associated enzymes are found distributed throughout the cell organelles, with the greatest concentration found in the mitochondria. As mentioned earlier, the enzymes of the electron transport chain, where energy transformation occurs, are located within the inner membrane of the mitochondria.