

## Chapter 3

### Cells: The Building Blocks

Our discussion of the cell must begin with two principles stated in *The Cell Theory*:

**The cell is the basic unit of life.**

**New cells can only arise from preexisting cells.**

In this chapter, we will explore the structure and function of eukaryotic cells, specifically human cells (remember, eukaryotic mean “cells with a nucleus”). In many instances, cells will develop over time to change their structure and function. This will be addressed in subsequent chapters.

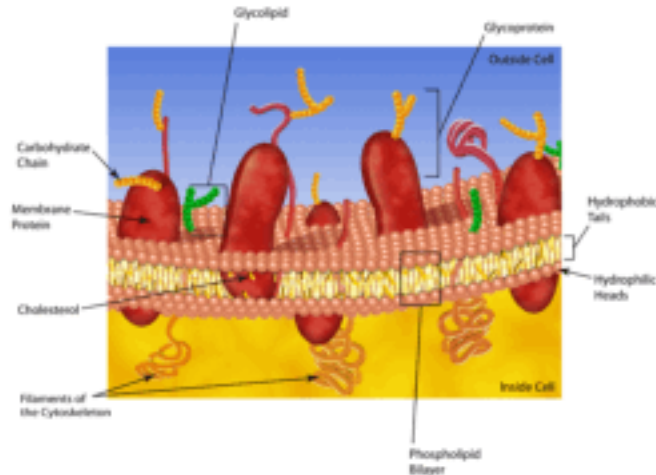
It is important to understand that a wide variety of cell types and sizes exist. For example, sperm cells are basically DNA with a tail, muscle cells are filled with mitochondria (to supply necessary energy for movement), and neurons have enormously long axons. The typical human cell is 10-30 micrometers in diameter, whereas an egg cell’s diameter is 100 micrometers. Although cells may have different shapes, sizes and functions, they all have the same basic structure. We will now turn our attention to the structure and function of organelles and the cell membrane. Get ready to explore this fascinating world, a miniature city of sorts, the dynamic unit of life - the cell!

### Cells: The Building Blocks

Every cell is delineated by a plasma membrane (cell membrane). The membrane forms a barrier between the cell and its surroundings. It also controls the transport of specific molecules and ions into and out of the cell.

Structurally, the plasma membrane is primarily composed of two different types of molecules, *lipids* (mainly phospholipids) and *proteins*. Recall that phospholipids contain two regions; a polar head (comprised of a phosphate-containing group) and a nonpolar tail (made up of two fatty acids). The head region is *hydrophilic* (“water-loving”) and the tail is *hydrophobic* (“water fearing”). This poses a “problem” for the molecule in the aqueous environment of the cell. Phospholipids solve this problem by forming a *lipid bilayer*. The hydrophobic tails associate to exclude water, while the hydrophilic heads are left exposed to the watery external and internal environments of the cell.

The plasma membrane is composed of different types of phospholipids with many different proteins embedded in, and often spanning the membrane. These *transmembrane proteins* are responsible for transport and other functions of the membrane.



## Membrane Transport Processes

We say that the plasma membrane is semipermeable, because some things can cross it easily while others cannot.

As we begin a discussion of transport, two important concepts must first be explored: *diffusion* and *osmosis*. These have to do with the movement of molecules and ions in a liquid, and the movement of water in response to these molecules. Often, small molecules, ions, and water can pass through the plasma membrane via these two processes.

### I. Diffusion

Molecules and ions dissolved in a liquid are called *solutes* and are constantly moving in a random fashion. If the solute is more highly concentrated in one area of the liquid, a *concentration gradient* is formed. Due to random movement, the solutes will move, or *diffuse*, down the concentration gradient: in other words, the molecules or ions will move from an area of high concentration to an area of lower concentration. This will occur until the solute is evenly distributed throughout the liquid and equilibrium is achieved.

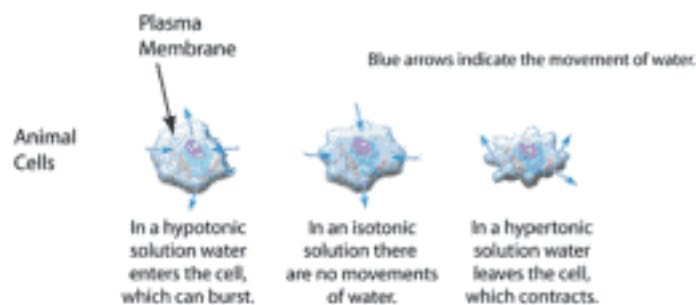
Only molecules that are very small and nonpolar can diffuse across the membrane, literally as if it wasn't there. Oxygen and carbon dioxide are two good examples of molecules that are constantly

moving into and out of our body's cells by simple diffusion.

## II. Osmosis

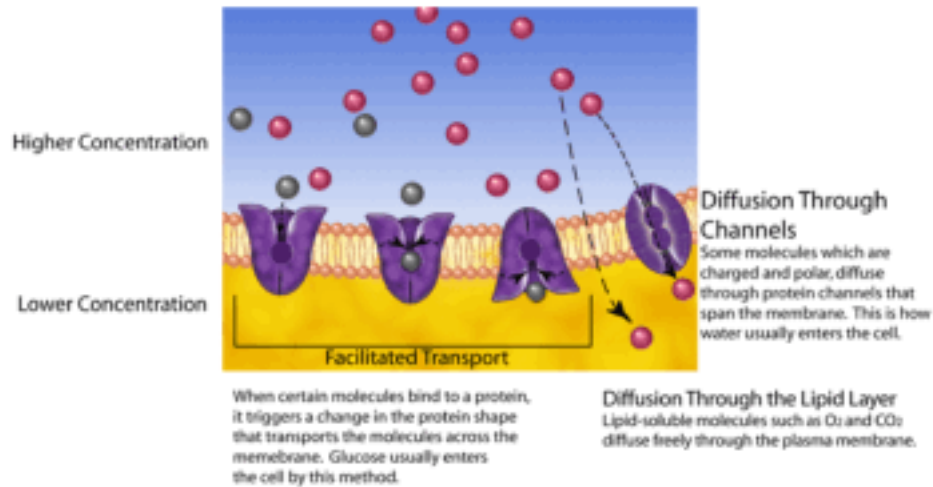
*Osmosis* is closely related to diffusion. It is defined as the diffusion of water across a biological, semipermeable membrane. It may be easiest to understand this process if you keep in mind that water is not only a solvent, but also a molecule itself that can have a concentration gradient. As the concentration of a solute increases, the concentration of water decreases. In the cell, the concentration gradient of water is influenced by the total number of molecules of all solutes present on both sides of the membrane. The movement of water in response to this gradient is not referred to as diffusion, but as osmosis.

The direction of water movement is influenced by *tonicity*, the relative concentration of solutes in two liquids. When solutes are in equal concentrations, the liquids are said to be *isotonic*, and there will be no net movement of water molecules. If the concentrations of solutes are not equal, water will move from the *hypotonic* solution (less solutes) to the *hypertonic* solution (more solutes). If the cell cannot adjust to the difference in solute concentrations between the cytoplasm and the external environment, the cell will burst (if placed in a hypotonic solution) or shrivel (if placed in a hypertonic solution).



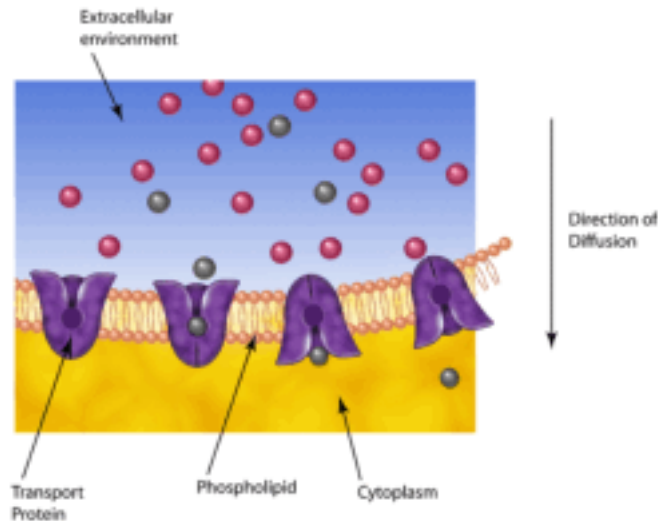
## III. Selective Transport

Transmembrane proteins permit certain molecules to pass through the lipid bilayer. This type of transport is highly specific. Each type of transport protein will only carry one type of molecule or ion. Therefore, the cell needs many different kinds of transport proteins. In general, all transport proteins function in a similar fashion. The molecule to be transported first binds to the protein. This causes the protein to change its shape. In essence, it “closes” behind the molecule and “opens” to the opposite side of the membrane (remember, molecules can be transported in either direction- from the inside out or from the outside in). Once the protein has allowed the molecule to pass through the lipid bilayer, the molecule is released. There are two types of selective transport:



### IIIa. Facilitated Diffusion (Passive Transport)

Sometimes, a molecule or ion is either too big or too charged to enter or leave the cell by simple diffusion. In these cases, it may need "help" to traverse the membrane. As long as the concentration gradient is favorable, this process requires no energy. An example of a molecule that often enters the cell by facilitated diffusion is glucose.



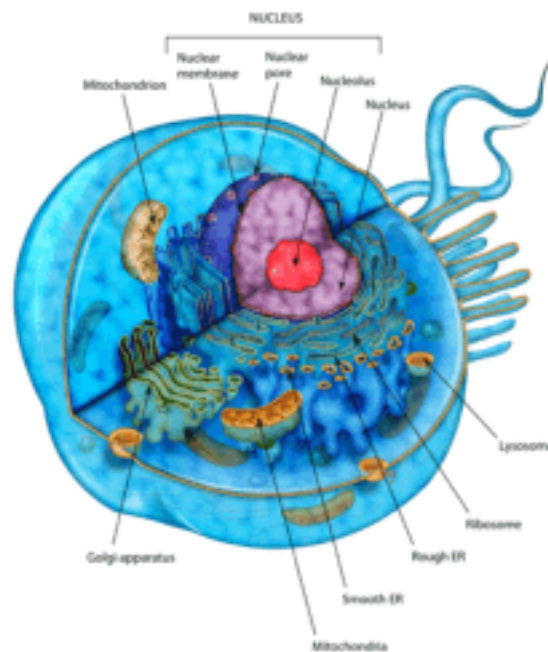
### IIIb. Active Transport

Molecules can also be pumped across the cell membrane **AGAINST** their concentration gradient, i. e.

from an area of low concentration to an area of higher concentration. Since this is not “normal” behavior for molecules, active transport requires energy, usually in the form of ATP. Once ATP binds, it alters the conformation of a transmembrane “pump” protein that then allows the transported molecule to bind. The molecule is transported across the membrane and is released. The protein returns to its original conformation, preventing the molecule from making the return trip across the membrane.

## Cellular Organelles

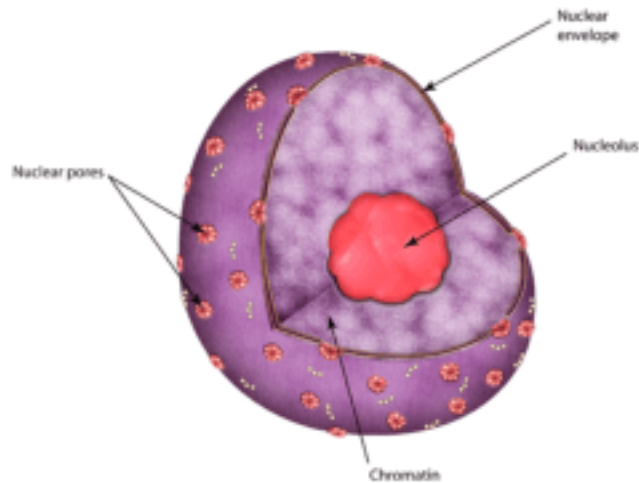
*Organelles* exist inside the cell, and bear the same relationship with the whole as do individual organs with an entire organism. They are usually membrane-bounded sacs that have specific metabolic functions. Basically, these structures form separate compartments so various enzymatic reactions can occur in a suitable environment. The barriers also prevent reactions from interfering with any other activities occurring in the cell.



Depending on the function of the cell, various organelles may be more or less prevalent. However, most human cells contain all the organelles discussed here.

## The Nucleus

The nucleus is a prominent, central structure that contains the *chromosomes* (structures that carry the genetic information). It is often referred to as the “control center”, or the “brain” of the cell. There are two noteworthy aspects of nuclear structure we can mention:



## I. The Nucleolus

The nucleolus is a dense mass inside the nucleus. Ribosomal RNAs are created and assembled into subunits here.

## II. The Nuclear Envelope

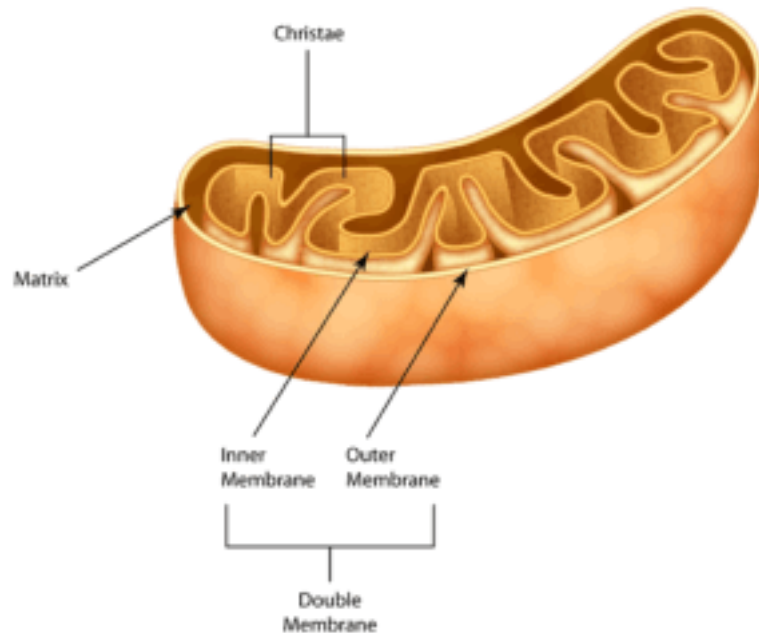
As stated above, organelles are bounded by membranes. The membrane surrounding the nucleus consists of two lipid bilayers, each similar to the plasma membrane. This double membrane creates a barrier to large water-soluble substances. *Pores* span both membranes and allow ions and small molecules to pass through. Large molecules are selectively transported across the membrane. The pores are responsible for transport both into and out of the nucleus. The nuclear membrane is continuous with the *endoplasmic reticulum* (ER), which will be discussed shortly.

## Ribosomes

These tiny organelles are the only ones NOT surrounded by a membrane. They are large assemblies of RNAs and proteins, and play a single, vital role in the cell: they are the site of all protein synthesis. Often hundreds of ribosomes are present in a given cell; sometimes they can be found attached to the *endoplasmic reticulum*.

## Mitochondria

*Mitochondria* are often referred to as the “powerhouse” of the cell. Like the nucleus, mitochondria are delimited by a double membrane. The outer membrane is smooth and faces the cytoplasm. However, unlike the nucleus, the inner membrane is highly convoluted and forms folds, called *cristae*, in the interior of the organelle. The mitochondria convert the energy stored in food molecules into the usable energy of ATP. This process is known as *aerobic cellular respiration*.

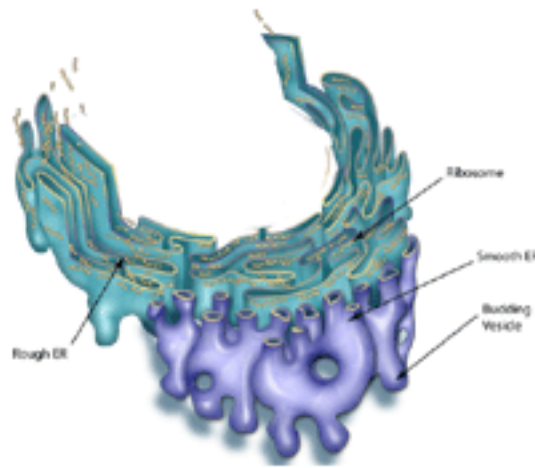


## The Cytomembrane System

A series of interconnected membranous structure permeates the cell, playing a variety of extremely important roles in cell function. The cytomembrane system consists of the following components:

### I. The Endoplasmic Reticulum (ER)

The ER is a series of interconnected “tunnels” that begins at the nuclear envelope and runs out into the cytoplasm. So called “*rough ER*” has ribosomes attached to its cytoplasmic face. Proteins destined for secretion are threaded into the interior of the ER, and will travel through it until they reach the end of a tube. At this point, they are said to “bud off” in a *vesicle* (a small membranous sac) that is heading for the *Golgi Apparatus*.



## II. The Golgi Apparatus

The Golgi apparatus, often simply called the Golgi or Golgi bodies, are often compared in their appearance to a “stack of pancakes”. They consist of a series of flattened sacs, and are involved in the processing and packaging of proteins and other molecules received from the ER. After packaging, vesicles again bud off, carrying proteins to their intended destinations in the cell, or fusing with the plasma membrane if a protein is to be secreted.

## III. Lysosomes

One type of vesicle that buds from the Golgi is the *lysosome*. Lysosomes are small sacs that contain hydrolytic (“breaking down”) enzymes and are involved in intracellular digestion. Sometimes referred to as the “recycling center” of the cell, various macromolecules can be digested here and their subunits returned to the cytoplasm.

## Cellular Metabolism

Cellular metabolism refers to the net sum of all chemical reactions taking place in a cell. All of these reactions must be facilitated, or catalyzed, by protein molecules called *enzymes*. Of particular interest to us is the metabolic pathway called aerobic cellular respiration, during which glucose is combined with oxygen in the mitochondria. The end products of this reaction are usable energy in the form of *ATP (adenosine triphosphate)*, water, and the waste product carbon dioxide. While we will not go into great detail here, this is a vital reaction that allows organisms to meet their constant energy requirements. This reaction, in a very real sense, is similar to *combustion* reactions with which you are already familiar. These include the burning of gasoline to power your car, or the burning of wood to release light and heat when you make a campfire.