*(Objective Checklist, continued)*

- Describe the structure of the plasma membrane, and explain how the various transport processes account for the directional movements of specific substances across the plasma membrane.
- Describe briefly the process of DNA replication and of mitosis. Explain the importance of mitotic cell division.
- In relation to protein synthesis, describe the roles of DNA and of the three major varieties of RNA.
- Name some cell types, and relate their overall shape and internal structure to their special functions.

**PART II: BODY TISSUES** **(pp. 85–98)**

- Name the four major tissue types and their chief subcategories. Explain how the four major tissue types differ structurally and functionally.
- Give the chief locations of the various tissue types in the body.
- Describe the process of tissue repair (wound healing).

**PART III: DEVELOPMENTAL ASPECTS OF CELLS AND TISSUES** **(pp. 98–99)**

- Define *neoplasm*, and distinguish between benign and malignant neoplasms.
- Explain the significance of the fact that some tissue types (muscle and nerve) are largely amitotic after the growth stages are over.

# PART I: CELLS

In the late 1600s, Robert Hooke was looking through a crude microscope at some plant tissue—cork. He saw some cubelike structures that reminded him of the long rows of monk's rooms (or cells) at the monastery, so he named these structures **cells.** The living cells that had formed the cork were long since dead. However, the name stuck and is still used to describe the smallest unit, or the building block, of all living things, plants and animals alike. Whatever its form, however it behaves, the cell contains all the parts necessary to survive in a changing world. The human body has trillions of these microscopic building blocks.

## Overview of the Cellular Basis of Life

Perhaps the most striking thing about a cell is its organization. If we chemically analyze cells, we find that they are made up primarily of four elements—carbon, oxygen, hydrogen, and nitrogen—plus much smaller amounts of several other elements. Although the four major elements build most of the cell's structure (which is largely protein), the trace elements are very important for certain cell functions. For example, calcium is needed for blood clotting (among other things), and iron is necessary to make hemoglobin, which carries oxygen in the blood. Iodine is required to make the thyroid hormone that controls metabolism. In their ionic form, many of the metals (such as calcium, sodium, and potassium) can carry an electrical charge; when they do they are called *electrolytes* (e-lek′tro-līts). Sodium and potassium ions are essential if nerve impulses are to be transmitted and muscles are to contract. (A more detailed account of body chemistry appears in Chapter 2.)

Strange as it may seem, especially when we feel our firm muscles, living cells are about 60 percent water, which is one of the reasons water is essential

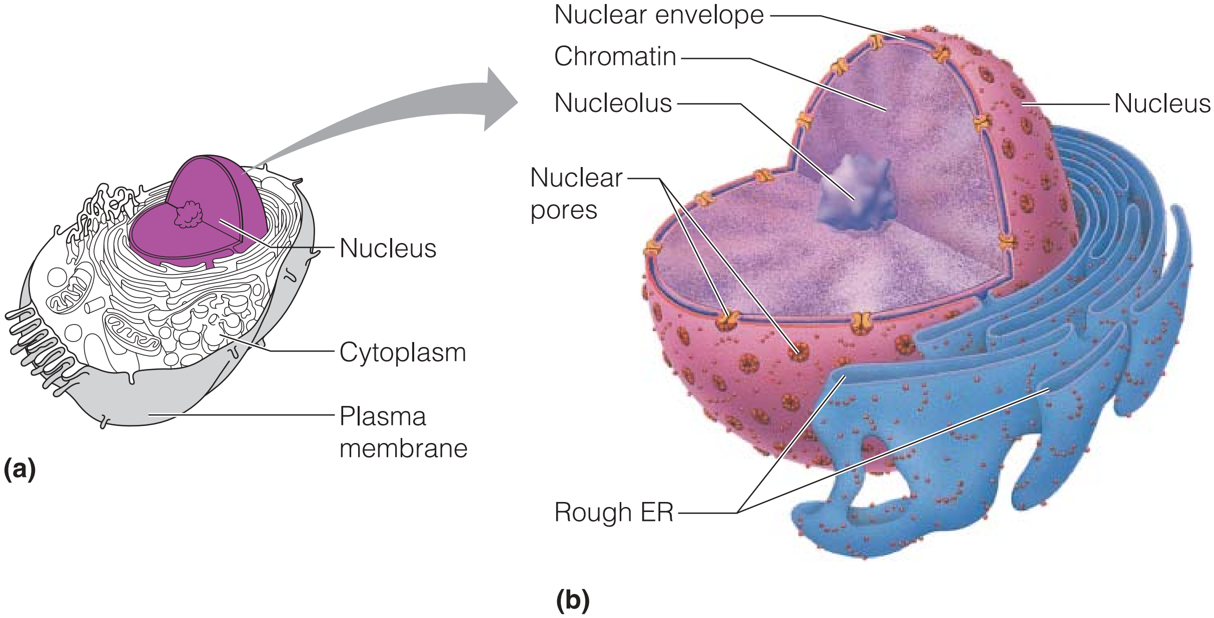



**FIGURE 3.1 Anatomy of the generalized animal cell nucleus.**
**(a)** Orientation diagram: The three main regions of the generalized cell.
**(b)** Structure of the nucleus.

for life. In addition to containing large amounts of water, all the body cells are constantly bathed in a dilute saltwater solution (something like seawater) called *interstitial fluid,* which is derived from the blood. All exchanges between cells and blood are made through this fluid.

Cells vary tremendously in length—ranging from 2 micrometers (1/12,000th of an inch) in the smallest cells to over a meter (3 feet) or more in the nerve cells that cause you to wiggle your toes. Furthermore, a cell's structure often reflects its function; this will become clear later in this chapter. Cells can have amazingly different shapes. Some are disk-shaped (red blood cells), some have threadlike extensions (nerve cells), others are like toothpicks pointed at each end (smooth muscle cells), and still others are cubelike (some types of epithelial cells).

Cells also vary dramatically in the functions, or roles, they play in the body. For example, white blood cells wander freely through the body tissues and protect the body by destroying bacteria and other foreign substances. Some cells make hormones or chemicals that regulate other body cells. Still others take part in gas exchanges in the lungs or cleanse the blood (kidney tubule cells).

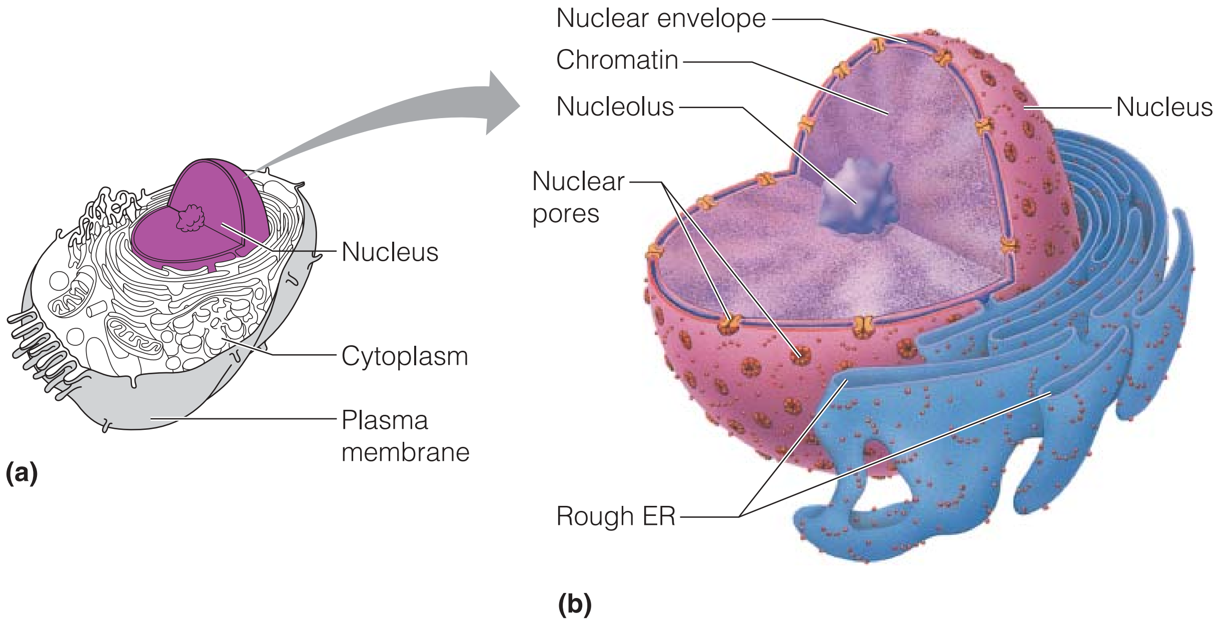
## Anatomy of a Generalized Cell

Although no one cell type is exactly like all others, cells *do* have the same basic parts, and there are certain functions common to *all* cells. Here we will talk about the **generalized cell,** which demonstrates these many typical features.

In general, all cells have three main regions or parts—a *nucleus* (nu′kle-us), *cytoplasm* (si′to-plazm″), and a *plasma membrane* (Figure 3.1). The nucleus is usually located near the center of the cell. It is surrounded by the semifluid cytoplasm, which in turn is enclosed by the plasma membrane, which forms the outer cell boundary. (Figure 3.4 on p. 67 shows the more detailed structure of the generalized cell as revealed by the electron microscope.)

### The Nucleus

Anything that works, works best when it is controlled. For cells, "headquarters," or the control center, is the gene-containing **nucleus** (*nucle* = kernal). The genetic material, or *deoxyribonucleic acid (DNA),* is much like a blueprint that contains all the instructions needed for building the whole

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While most often oval or spherical, the shape of the nucleus usually conforms to the shape of the cell. For example, if the cell is elongated, the nucleus is usually extended as well. The nucleus has three recognizable regions or structures: the nuclear envelope, nucleoli, and chromatin.

### Nuclear Envelope

The nucleus is bound by a double membrane barrier called the **nuclear envelope,** or **nuclear membrane** (see Figure 3.1). Between the two membranes is a fluid-filled "moat," or space. At various points, the two layers of the nuclear envelope fuse, and **nuclear pores** penetrate through the fused regions. Like other cellular membranes, the nuclear envelope is selectively permeable, but passage of substances through it is much freer than elsewhere because of its relatively large pores. The nuclear membrane encloses a jellylike fluid called *nucleoplasm* (nu′kle-o-plazm″) in which other nuclear elements are suspended.

### Nucleoli

The nucleus contains one or more small, dark-staining, essentially round bodies called **nucleoli** (nu-kle′o-li; "little nuclei"). Nucleoli are sites where ribosomes are assembled. The *ribosomes,* most of which eventually migrate into the cytoplasm, serve as the actual sites of protein synthesis, as described shortly.

### Chromatin

When a cell is not dividing, its DNA is combined with protein and forms a loose network of bumpy threads called **chromatin** (kro′mah-tin) that is scattered throughout the nucleus. When a cell is dividing to form two daughter cells, the chromatin threads coil and condense to form dense, rodlike bodies called **chromosomes**—much the way a stretched spring becomes shorter and thicker when allowed to relax. The functions of DNA and the mechanism of cell division are discussed in the Cell Physiology section beginning on p. 72.

## The Plasma Membrane

The flexible **plasma membrane** is a fragile, transparent barrier that contains the cell contents and separates them from the surrounding environment. (The term *cell membrane* is often used instead, but since nearly all cellular organelles are composed of membranes, we will specifically refer to the cell's surface or outer limiting membrane as the plasma membrane.) Although the plasma membrane is important in defining the limits of the cell, it is much more than a passive envelope, or "baggie." As you will see, its unique structure allows it to play a dynamic role in many cellular activities.

The structure of the plasma membrane consists of two lipid (fat) layers arranged "tail to tail" in which protein molecules float (Figure 3.2). Although most of the lipid portion is *phospholipids* (some with attached sugar groups), a substantial amount of *cholesterol* is also found in plasma membranes. (The characteristics of these specialized lipids are described in Chapter 2.) The olive oil–like lipid bilayer forms the basic "fabric" of the membrane. The polar "heads" of the lollipop-shaped phospholipid molecules are *hydrophilic* ("water loving") and are attracted to water, the main component of both the intercellular and extracellular fluids, and so they lie on both the inner and outer surfaces of the membrane. Their nonpolar "tails" are *hydrophobic* ("water hating") and avoid water, lining up in the center of the membrane. It is the hydrophobic makeup of the membrane interior that makes the plasma membrane relatively impermeable to most water-soluble molecules. The cholesterol has a stabilizing effect and helps keep the membrane fluid.

The proteins scattered in the lipid bilayer are responsible for most of the specialized functions of the membrane. Some proteins are enzymes. Many of the proteins mounted on the cell exterior are receptors for hormones or other chemical messengers or are binding sites for anchoring the cell to fibers or to other extracellular structures. Most proteins that span the membrane are involved in transport functions. For example, some cluster together to form protein channels (tiny *pores*) through which water and small water-soluble molecules or ions can move; others act as *carriers* that bind to a substance and move it through the membrane. Branching sugar groups are attached to most of the proteins abutting the extracellular space. Such

**Q** *Why do the phospholipids organize into a bilayer, tail to tail, in an aqueous environment?*

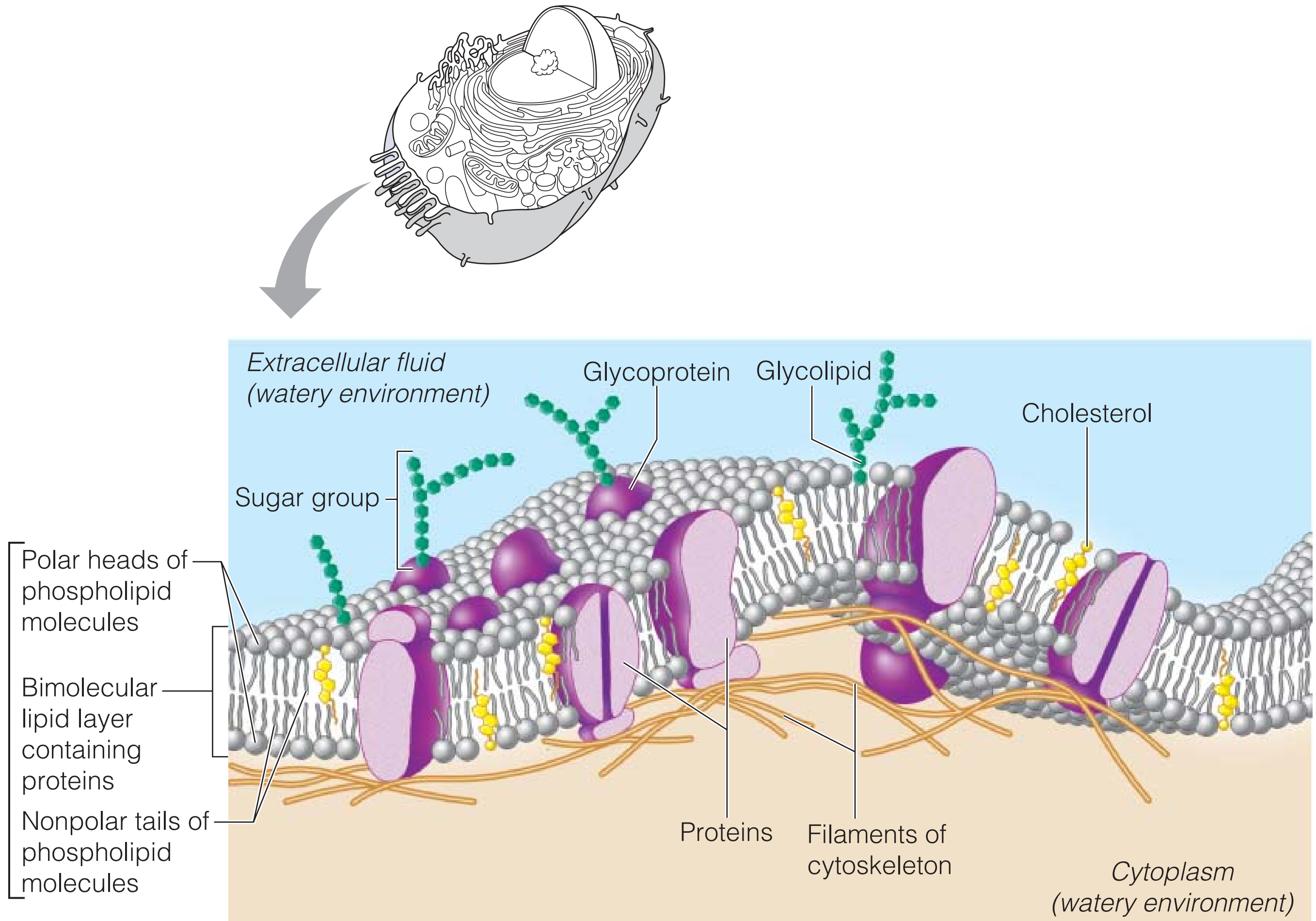


**FIGURE 3.2 Structure of the plasma membrane.**

"sugar-proteins" are called *glycoproteins,* and because of their presence, the cell surface is a fuzzy, sticky, sugar-rich area. (You can think of your cells as being sugar-coated.) Among other things, these glycoproteins determine your blood type, act as receptors that certain bacteria, viruses, or toxins can bind to, and play a role in cell-to-cell interactions. Definite changes in glycoproteins occur in cells that are being transformed into cancer cells. (Cancer is discussed in "A Closer Look" on pp. 100–101.)

**A** *The phospholipids have hydrophilic and hydrophobic regions. The hydrophobic (tail) regions shun water and form the inner portion of the membrane in an aqueous environment.*

## Specializations of the Plasma Membrane

Specializations of the plasma membrane—such as *microvilli* and *membrane junctions*—are commonly displayed by the (epithelial) cells that form the linings of hollow body organs, such as the small intestine (Figure 3.3). **Microvilli** (mi″kro-vil′i; "little shaggy hairs") are tiny fingerlike projections that greatly increase the cell's surface area for absorption so that the process occurs more quickly.

The **membrane junctions** vary structurally depending on their roles.

- **Tight junctions** are impermeable junctions that bind cells together into leakproof sheets that prevent substances from passing through

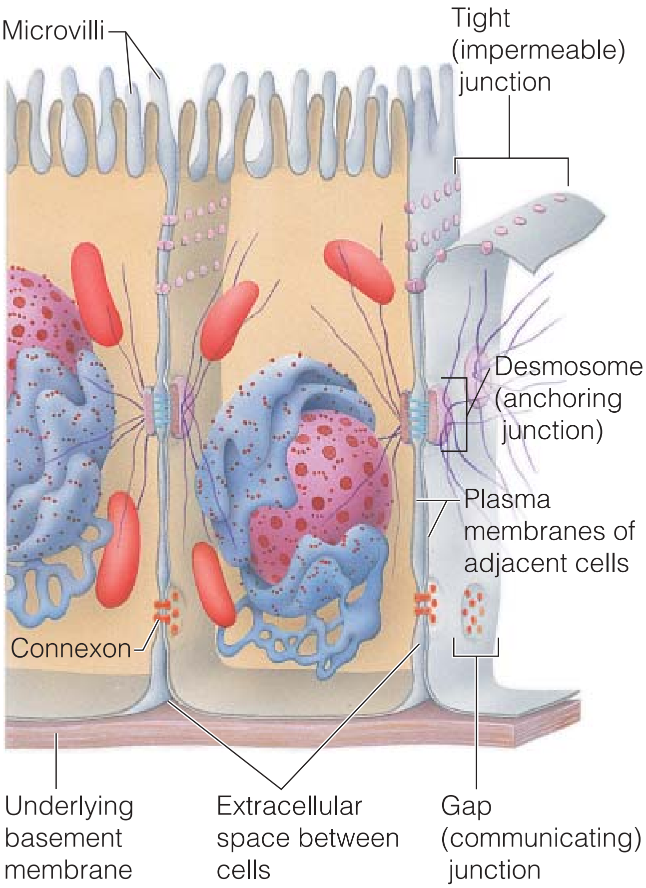


**FIGURE 3.3 Cell junctions.** An epithelial cell is shown joined to adjacent cells by the three common types of cell junctions: tight junctions, desmosomes, and gap junctions. Also illustrated are microvilli (seen projecting from the free cell surface).

the extracellular space between cells. In tight junctions, adjacent plasma membranes fuse together tightly like a zipper. In the small intestine, for example, these junctions prevent digestive enzymes from seeping into the bloodstream.

- **Desmosomes** (des′mo-somz) are anchoring junctions that prevent cells subjected to mechanical stress (such as skin cells) from being pulled apart. Structurally, these junctions are plaques, buttonlike thickenings of adjacent plasma membranes, which are connected by fine protein filaments. Thicker protein filaments extend from the plaques inside the cells to the plaques on the cells' opposite sides, thus forming an internal system of strong guy wires.
- **Gap junctions,** commonly seen in the heart and between embryonic cells, function mainly to allow communication. Chemical molecules, such as nutrients or ions, can pass directly from one cell to another through them. In gap junctions, the neighboring cells are connected by **connexons,** which are hollow cylinders composed of proteins that span the entire width of the abutting membranes.

## The Cytoplasm

The **cytoplasm** is the cellular material outside the nucleus and inside the plasma membrane. It is the site of most cellular activities, so it can be thought of as the "factory area" of the cell. Although early scientists believed that the cytoplasm was a structureless gel, the electron microscope has revealed that it has three major elements: the *cytosol, organelles,* and *inclusions.* The **cytosol** is semitransparent fluid that suspends the other elements. Dissolved in the cytosol, which is largely water, are nutrients and a variety of other solutes (dissolved substances).

The **organelles** (or″gah-nelz′), described in detail shortly, are the metabolic machinery of the cell. Each type of organelle is specialized to carry out a specific function for the cell as a whole. Some synthesize proteins, others package those proteins, and so on.

**Inclusions** are not functioning units, but instead are chemical substances that may or may not be present, depending on the specific cell type. Most inclusions are stored nutrients or cell products. They include the lipid droplets common in fat cells, glycogen granules abundant in liver and muscle cells, pigments such as melanin seen in skin and hair cells, mucus and other secretory products, and various kinds of crystals.

### Cytoplasmic Organelles

The cytoplasmic organelles, literally "little organs," are specialized cellular compartments (Figure 3.4), each performing its own job to maintain the life of the cell. Many organelles are bounded by a membrane similar to the plasma membrane. The membrane boundaries of such organelles allow them to maintain an internal environment quite different from that of the surrounding cytosol. This compartmentalization is crucial to their ability to perform