BOX 2–1

CELL STRUCTURES AND FUNCTIONS

Protoplasm comprises the internal environment of body cells. It is composed of water, electrolytes (potassium, magnesium, phosphate, sulfate, and bicarbonate), proteins, lipids, and carbohydrates.

Water makes up 70% to 85% of most cells; cellular enzymes, electrolytes, and other chemicals are dissolved or suspended in the water.

Electrolytes provide chemicals for cellular reactions and are required for some processes (eg, transmission of electrochemical impulses in nerve and muscle cells).

Proteins comprise 10% to 20% of the cell mass. They consist of "physical" proteins that form the structure of cells and "chemical" proteins that function mainly as enzymes within the cell. These enzymatic proteins come into direct contact with other substances in the cell fluid and catalyze chemical reactions within the cell.

Lipids, mainly phospholipids and cholesterol, form the membranes that separate structures inside the cell and the cell itself from surrounding cells and body fluids.

Carbohydrates play a minor role in cell structure, but a major role in cell nutrition. Glucose is present in extracellular fluid and readily available to supply the cell's need for energy. In addition, a small amount of carbohydrate is stored within the cell as glycogen, a storage form of glucose that can be rapidly converted when needed.

The **nucleus** might be called the "manager" of cellular activities because it regulates the type and amount of proteins, enzymes, and other substances to be produced.

The **cytoplasm** surrounds the nucleus and contains the working units of the cell.

The **endoplasmic reticulum** (ER) contains ribosomes, which synthesize enzymes and other proteins. These include enzymes that synthesize glycogen, triglycerides, and steroids and those that detoxify drugs and other chemicals. The ER is important in the production of hormones by glandular cells and the production of plasma proteins and drug-metabolizing enzymes by liver cells.

The **Golgi complex** stores hormones and other substances produced by the ER. It also packages these substances into secretory granules, which then move out of the Golgi complex into the cytoplasm and, after an appropriate stimulus, are released from the cell through the process of exocytosis.

Mitochondria generate energy for cellular activities and require oxygen.

Lysosomes are membrane-enclosed vesicles that contain enzymes capable of digesting nutrients (proteins, carbohydrates, fats), damaged cellular structures, foreign substances (eg, bacteria), and the cell itself. When a cell becomes worn out or damaged, the membrane around the lysosome breaks and the enzymes (hydrolases) are released. However, lysosomal contents also are released into extracellular spaces, destroying surrounding cells. Normally, the enzymes are inactivated by enzyme inhibitors and excessive tissue destruction is prevented.

The **cell membrane,** a complex structure composed of phospholipids, proteins, cholesterol and carbohydrates, separates intracellular contents from the extracellular environment, provides receptors for hormones and other biologically active substances, participates in electrical events that occur in nerve and muscle cells, and helps regulate growth and proliferation.

The cell membrane, which covers the entire surface of the cell, consists of a thin, double layer of lipids interspersed with proteins (see Fig. 2–3). The lipid layer is composed of phospholipid (fatty acid and phosphate) molecules. The phosphate end of each phospholipid molecule, located on the external surface and in contact with the tissue fluids surrounding the cell, is soluble in water. The fatty acid end of the phospholipid molecule, located in the middle of the membrane, is soluble only in fat. Thus, this portion of the membrane allows easy penetration of fat-soluble substances such as oxygen and alcohol, but is impermeable to water-soluble substances such as ions and glucose.

Cell membrane proteins, most of which are combined with a carbohydrate as glycoproteins, include integral and peripheral proteins. Integral proteins penetrate through the entire membrane so that each end is available to interact with other substances. The protein portion protrudes on the intracellular side of the cell membrane; the glyco portion protrudes to the outside of the cell, dangling outward from the cell surface. Some of these proteins provide structural channels or pores through which water and water-soluble substances (eg, sodium, potassium, and calcium ions) can diffuse between extracellular and intracellular fluids. Others act as carriers to transport substances that otherwise could not penetrate the lipid layer of the membrane. Still others act as enzymes to catalyze chemical reactions within the cell. Peripheral proteins do not penetrate the cell membrane. They are usually attached to the intracellular side of the membrane and to integral proteins. These proteins function as enzymes and other substances that regulate intracellular function.

Cell membrane carbohydrates occur mainly in combination with proteins (glycoproteins) or lipids (glycolipids). Glycoproteins composed of carbohydrate around a small, inner core of protein (called proteoglycans) often are attached to and cover the entire outside surface of the cell. As a result, the carbohydrate molecules are free to interact with extracellular substances and perform several important functions. First, many have a negative electrical charge which gives most cells an overall negative surface charge that repels other negatively charged substances. Second, the "carbohydrate coat" of some cells attaches to the carbohydrate coat of other cells and thereby connects cells to each other. Third, many of the carbohydrates act as receptor molecules for binding hormones (eg, insulin). The receptor–hormone combination then activates the attached inner core of protein to perform its enzymatic or other functions in the cell.