Cells: The Living Units
Outline

3.1 Cells are the smallest unit of life (pp. 61–63; Figs. 3.1–3.2)

A. The four concepts of the cell theory state: (p. 61; Figs. 3.1–3.2)
   1. A cell is the basic structural and functional unit of life.
   2. The activity of an organism depends on both the individual and combined activities of its cells.
   3. The biochemical activities of a cell are dictated by their shape and form, and subcellular structures.
   4. Cells may arise only from other cells.

B. A human cell has three main parts: the plasma membrane, cytoplasm, and the nucleus. (pp. 61–62; Figs. 3.1–3.2)

C. Extracellular materials are found outside the cell, and include body fluids, secretions by cells, and extracellular matrix, proteins, and polysaccharides that help hold cells together. (p. 63)

PART 1: PLASMA MEMBRANE

3.2 The fluid mosaic model depicts the plasma membrane as a double layer of phospholipids with embedded proteins (pp. 63–68; Figs. 3.3–3.5)

A. Membrane lipids form a bilayer, composed of two layers of phospholipids with small amounts of glycolipids, and cholesterol. (p. 65; Fig. 3.3)
   1. The tails of phospholipids are hydrophobic and line up facing each other in the interior of the bilayer, while the hydrophilic phospholipid heads to face the inner and outer surfaces of the membrane.

B. There are two distinct populations of membrane proteins: integral proteins that span the entire width of the membrane and are involved with transport as channels or carriers, and peripheral proteins attached to integral proteins or to phospholipids, that may function as enzymes or in mechanical functions of the cell. (pp. 65–66; Figs. 3.3–3.4)

C. The glycocalyx is the fuzzy, sticky, carbohydrate-rich area at a cell's surface that acts as a biological marker allowing cells to identify each other (p. 66).

D. Cell Junctions (pp. 66–68; Fig. 3.5)
   1. Most body cells are bound together using glycoproteins, specialized interlocking regions, or specialized cell junctions.
   2. Tight junctions are integral proteins between adjacent cells, forming an impermeable junction that prevents molecules from passing through the extracellular space between cells.
   3. Desmosomes are mechanical couplings that are scattered along the sides of adjoining cells that prevent their separation and reduce the chance of tearing when a tissue is stressed.
   4. Gap junctions are hollow cylinders of protein between cells that allow selected small molecules to pass between adjacent cells and are often used to conduct action potentials directly from cell to cell.

3.3 Passive membrane transport is diffusion of molecules down their concentration gradient (pp. 68–73; Figs. 3.6–3.9; Table 3.1)

A. Diffusion is the movement of molecules down their concentration gradient due to kinetic energy of the molecules and is influenced by the size of the molecule and the temperature. (pp. 68–73; Figs. 3.7–3.9; Table 3.1)
   1. The cell membrane is selectively permeable, but a molecule will diffuse through the membrane if it is lipid soluble, small enough to pass through channels, or assisted by a carrier.
   2. Simple diffusion is diffusion through the plasma membrane, without using a channel or carrier, and is restricted to the movement of very small molecules, or lipids.
   3. In facilitated diffusion, sugars, amino acids, or ions are moved through the plasma membrane by binding to protein carriers in the membrane or by moving through channels.
   4. Osmosis is the diffusion of water through a selectively permeable membrane.
      a. Water will move into areas where the osmolarity, the total concentration of particles in solution, is greater, regardless of the types of particles in each compartment.
      b. Tonicity refers to the ability of a solution to change the shape or tone of cells by changing the volume of water they contain.
      c. Compared to cells, solutions may be isotonic (same solute concentration), resulting in no net movement of water between the solutions, hypertonic (higher solute concentration), resulting in movement of water out of the cell, or hypotonic (lower concentration), resulting in movement of water into the cell.

3.4 Active membrane transport directly or indirectly uses ATP (pp. 73–79; Figs. 3.10–3.13; Focus Figure 3.1; Table 3.2)

A. Both primary active transport and secondary active transport use solute pumps to move substances against a concentration gradient: in primary active transport, energy used to transport molecules is directly from ATP, but, in secondary active transport, energy used to transport molecules is from energy stored in ionic gradients created by primary active transport. (pp. 73–75; Figs. 3.10; Focus Figure 3.1; Table 3.2).

B. Vesicular transport uses membranous sacs, called vesicles, to transport large particles, macromolecules, and fluids across the plasma membrane, or within the cell. (pp. 76–78; Figs. 3.11–3.13; Table 3.2)
   1. Endocytosis moves molecules into the cell by creating an infolding that forms a vesicle, which is then detached from the membrane and either combined with a lysosome, or transported across the cell and out by exocytosis.
      a. Phagocytosis is an endocytotic process in which large, solid materials are brought into the cell, and is often used by phagocytes, cells that dispose of debris and pathogens.
      b. Pinocytosis is an endocytotic process aimed at taking a small volume of extracellular fluid with dissolved solutes into the cell, and is often used by cells to sample the extracellular environment.

c. Receptor-mediated endocytosis is the main mechanism for the specific exocytosis and transcytosis of most macromolecules, and allows cells to concentrate molecules found in small amounts in extracellular fluid.

2. Exocytosis is a type of vesicular transport that moves molecules out of the to the extracellular environment, and is often used for secretion, or removal of wastes from the cell.

3.5 Selective diffusion establishes the membrane potential (pp. 79–81; Fig. 3.14)

A. A membrane potential is a voltage across the cell membrane that occurs due to a separation of oppositely charged particles (ions): voltage ranges from −5 to −100 millivolts, the negative value indicating the inside of the membrane is more negatively charged than the outside. (p. 79–80; Fig. 3.15)

1. The resting membrane potential is determined mainly by the concentration gradient of potassium (K^+) that freely diffuses out of the cell down a diffusion gradient, but also diffuses into the cell along an electrical gradient.

2. Active transport pumps ensure that passive ion movement does not lead to an electrochemical equilibrium across the membrane, thus maintaining the resting membrane potential.

3.6 Cell adhesion molecules and membrane receptors allow the cell to interact with its environment (pp. 81–82; Focus Figure 3.2)

A. Roles of Cell Adhesion Molecules (CAMs) (p. 81)

1. Cell adhesion molecules (CAMs) are glycoproteins that attach cells to extracellular molecules, pull migrating cells through their environment, act as signals to immune cells, and maintain tight junctions.

B. Roles of Plasma Membrane Receptors (pp. 81–82; Fig. 3.16; Focus Figure 3.2)

1. Contact signaling involves touch between membrane receptors of neighboring cells to facilitate recognition between cells.

2. Chemical signaling involves the binding of a chemical signal (a ligand) to a membrane receptor, resulting in the initiation of cellular responses.

a. G protein-linked receptors act indirectly to activate a second messenger system that typically is involved in phosphorylation of a molecule by ATP.

PART 2: THE CYTOPLASM

3.7 Cytoplasmic organelles each perform a specialized task (pp. 83–89; Figs. 3.15–3.22; Table 3.3)

A. The cytoplasm is the cellular material between the cell membrane and the nucleus, and has three major elements: the cytosol, cytoplasmic organelles, and cytoplasmic inclusions. (p. 83)

B. Mitochondria are membranous organelles that produce most of the ATP for a cell, by breaking down food molecules and transferring the energy to the bonds of ATP. (p. 83; Fig. 3.15; Table 3.3)

C. Ribosomes are small, dark-staining granules consisting of protein and ribosomal RNA that are the site of protein synthesis and may be free in the cytosol, or bound to rough ER. (p. 84; Fig. 3.16; Table 3.3)

D. The endoplasmic reticulum (ER) is an extensive system of tubes and membranes enclosing fluid-filled cavities, called cisterns, which extend throughout the cytosol. (pp. 84– 85; Fig. 3.16; Table 3.3)

1. The rough endoplasmic reticulum has ribosomes that manufacture all proteins that are secreted from cells.
2. Smooth ER is a continuation of rough ER, consisting of a looping network of tubules. Its enzymes catalyze reactions involved in lipid and glycogen metabolism, as well as performing detoxification processes.

E. The Golgi apparatus is a series of stacked, flattened, membranous sacs associated with groups of membranous vesicles. (pp. 85–86; Fig. 3.17; Table 3.3)

1. The main function of the Golgi apparatus is to modify, concentrate, and package the proteins and lipids made at the rough ER by creating vesicles containing proteins and lipids for export, or by packaging digestive enzymes into lysosomes.
2. The Golgi apparatus creates vesicles containing lipids and transmembrane proteins for incorporation into the cell membrane.
3. The Golgi apparatus packages digestive enzymes into lysosomes.

F. Peroxisomes are membranous sacs containing enzymes, such as oxidases and catalases, used to detoxify substances such as alcohol, formaldehyde, and free radicals. (p. 86; Fig. 3.18; Table 3.3)

G. Lysosomes are spherical membranous organelles that contain activated digestive enzymes used to handle particles taken in by endocytosis, degrade worn-out organelles or nonuseful tissues, and perform glycogen breakdown and release. (p. 86–87; Figs. 3.18–3.19; Table 3.3)

H. The endomembrane system functions together to produce, store, and export biological molecules, as well as degrade potentially harmful substances. (pp. 87–88; Fig. 3.20; Table 3.3)

I. The cytoskeleton is a series of rods running through the cytosol, supporting cellular structures and aiding in cell movement, and consists of three types of proteins: microtubules, microfilaments, and intermediate filaments. (pp. 88–89; Fig. 3.21; Table 3.3)

J. Centrosome and Centrioles (p. 89; Fig. 3.22; Table 3.3)

1. The centrosome is a region near the nucleus that functions to organize microtubules and organize the mitotic spindle during cell division.
2. Centrioles are small, barrel-shaped organelles associated with the centrosome and form the bases of cilia and flagella.

3.8 Cilia and microvilli are two main types of cellular extensions (pp. 89–91; Figs. 3.23–3.25)

A. Cilia are whip-like, motile cellular extensions on the exposed surfaces of some cells, while flagella are long cellular projections that move the cell through the environment. (pp. 89–91; Figs. 3.23–3.24; Table 3.3)

B. Microvilli are finger-like extensions of the plasma membrane that increase surface area. (p. 91; Fig. 3.25, Table 3.3)

PART 3: THE NUCLEUS

3.9 The nucleus includes the nuclear envelope, the nucleolus, and chromatin (pp. 91–96; Figs. 3.26–3.27)

A. The Nuclear Envelope (pp. 92–93; Fig. 3.26; Table 3.3)

1. The nuclear envelope is a double-membrane barrier surrounding the nucleus, enclosing the fluid and solutes of the nucleus: The outer membrane is continuous with the rough ER, while the inner membrane is lined

with a shape-maintaining network of protein filaments, the nuclear laminae.

a. At various points, nuclear pores penetrate areas where the membranes of the nuclear envelope fuse and regulate passage of large particles into and out of the nucleus.

B. Nucleoli are dark-staining spherical bodies within the nucleus that are the sites ofassembly of ribosomal subunits, and are large in actively growing cells. (p. 93; Table 3.3)

C. Chromatin is 30% DNA, the genetic material of the cell, 60% histone proteins, and 10% RNA chains: when a cell is preparing to divide, chromatin condenses into dense, rod-like chromosomes. (p. 93; Fig. 3.27; Table 3.3)

1. Nucleosomes are the fundamental unit of chromatin, consisting of clusters of eight histone proteins connected by a DNA molecule.
2. When a cell is preparing to divide, chromatin condenses into dense, rod-like chromosomes.

3.10 The cell cycle consists of interphase and a mitotic phase (pp. 96–98; Figs. 3.28–3.29)

A. Interphase and cell division are the two main periods of the cell cycle. (pp. 96–98; Figs. 3.28–3.29)

1. Interphase is the period from cell formation to cell division and has three subphases.
   a. During the G_1, or gap 1, subphase, the cell is synthesizing proteins and actively growing.
   b. During the S phase, DNA is replicated.
   c. During the G_2, or gap 2, subphase, enzymes and other proteins are synthesized and distributed throughout the cell.
   d. DNA replication takes place when the DNA helix uncoils, and the hydrogen bonds between its base pairs are broken. Then, each nucleotide strand of the DNA acts as a template for the construction of a complementary nucleotide strand.
2. Cell division is a process necessary for growth and tissue repair. There are three main events of cell division.
   a. Mitosis is the process of nuclear division in which cells contain all genes.
   b. Cytokinesis is the process of dividing the cytoplasm.Control of cell division depends on surface-volume relationships, chemical signaling, and contact inhibition.

3.11 Messenger RNA carries instructions from DNA for building proteins (pp. 98–108; Figs. 3.3–3.34)

A. DNA serves as the instructions for synthesis of proteins. (pp. 98–99)

1. Proteins are composed of polypeptide chains made up of amino acids.
2. Each gene is a segment of DNA that carries instructions for one polypetide chain.
3. There are four nucleotide bases, A, G, T, and C, that compose DNA, and each sequence of three nucleotide bases of DNA is called a triplet.
   a. Each triplet specifies a particular amino acid in the sequence of amino acids that makes up a protein.

B. The Role of RNA (p. 99; Fig. 3.30)

1. RNA exists in three forms that decode and carry out the instructions of DNA in protein synthesis: transfer RNA (tRNA), ribosomal RNA (rRNA), and messenger RNA (mRNA).
2. All three types of RNA are constructed on the DNA in the nucleus, then released from the DNA to migrate to the cytoplasm while the DNA recoils to its original form.

C. There are two main steps of protein synthesis: transcription and translation. (pp. 99–108; Figs. 3.31–3.34; Focus Figure 3.3)

1. Transcription is the process of transferring information from a gene's base sequence to a complementary mRNA molecule.
   a. To make the mRNA complement, the transcription factor mediates binding of RNA polymerase, an enzyme that directs the synthesis of mRNA.
   b. The mRNA that initially results from transcription, called primary transcript, contains introns that must be removed.
2. Translation is the process of converting the language of nucleic acids (nucleotides)
   to the language of proteins (amino acids).
   a. Each DNA triplet corresponds to a complementary RNA codon: There are 64 codons, each specifying a particular amino acid.
   b. Transfer RNA picks up a specific amino acid from the cytoplasm and, by binding to mRNA, transfers it to the ribosome, to be attached to the growing protein strand.

D. Other Roles of DNA (p. 108)

1. DNA codes for a variety of RNAs: MicroRNAs can suppress some mRNAs, and riboswitches can turn their own protein synthesis on or off in response to environmental changes.

3.12 Apoptosis disposes of unneeded cells; autophagy and proteasomes dispose of unneeded organelles and proteins (p. 109)

A. Autophagy involves the use of proteins, called ubiquitins, to degrade malfunctioning or obsolete organelles, to prevent excessive accumulation of these structures. (p. 109)

B. Apoptosis is the programmed cell death of stressed, unneeded, injured, or aged cells. (p. 109)

1. In response to cellular damage or some extracellular signal, chemicals are released to activate intracellular enzymes that digest cellular structures, killing the cell.

Developmental Aspects of Cells (pp. 109–110)

A. Embryonic cells are exposed to different chemical signals that cause them to follow different pathways in development. (p. 109)

1. Chemical signals influence development by switching genes on and off.
2. Cell differentiation is the process of cells developing specific and distinctive features.

B. Cell Destruction and Modified Rates of Cell Division (pp. 109–110)

1. Most organ systems are well-formed and functional before birth, but the body continues to form new cells throughout childhood and adolescence.

C. Cell Aging (p. 110)

1. The wear and tear theory considers the cumulative effect of slight chemical damage and the production of free radicals.

2. Cell aging may also be a result of autoimmune responses and progressive weakening of the immune response.
3. The genetic theory of cell aging suggests that cessation of mitosis and cell aging are genetically programmed.