Chapter 3 Outline

I. INTRODUCTION

A. A cell is the basic, living, structural, and functional unit of the body.

B. Cytology is the study of cell structure, and cell physiology is the study of cell function.

II. PARTS of a CELL

A. A generalized view of the cell is a composite of many different cells in the body. No single cell includes all of the features seen in the generalized cell.

B. The cell can be divided into three principal parts for ease of study.

1. Plasma (cell) membrane
2. Cytoplasm
    a. Cytosol
    b. Organelles (except for the nucleus)
3. Nucleus

III. THE PLASMA MEMBRANE

A. The plasma membrane is a flexible, sturdy barrier that surrounds and contains the cytoplasm of the cell.

1. The fluid mosaic model describes its structure.
2. The membrane consists of proteins in a sea of lipids.

B. The Lipid Bilayer

1. The lipid bilayer is the basic framework of the plasma membrane and is made up of three types of lipid molecules: phospholipids, cholesterol, and glycolipids.
2. The bilayer arrangement occurs because the lipids are amphipathic molecules. They have both polar (charged) and nonpolar (uncharged) parts with the polar “head” of the phospholipid pointing out and the nonpolar “tail” pointing toward the center of the membrane.

C. Arrangement of Membrane Proteins

1. The membrane proteins are divided into integral and peripheral proteins.
    a. Integral proteins extend into or across the entire lipid bilayer among the fatty acid tails of the phospholipid molecules.
    b. Peripheral proteins are found at the inner or outer surface of the membrane and can be stripped away from the membrane without disturbing membrane integrity.
2. Integral membrane proteins are amphipathic.
    a. Those that stretch across the entire bilayer and project on both sides of the membrane are termed transmembrane proteins.
    b. Many integral proteins are glycoproteins.
3. The combined glycoproteins and glycolipids form the glycocalyx which helps cells recognize one another, adhere to one another, and be protected from digestion by enzymes in the extracellular fluid.

D. Functions of Membrane Proteins

1. Membrane proteins vary in different cells and function as channels (pores), transporters, receptors, enzymes, cell-identity markers, and linkers.
2. The different proteins help to determine many of the functions of the plasma membrane.

E. Membrane Fluidity

1. Membranes are fluid structures, rather like cooking oil, because most of the membrane lipids and many of the membrane proteins easily move in the bilayer.
2. Membrane lipids and proteins are mobile in their own half of the bilayer.
3. Cholesterol serves to stabilize the membrane and reduce membrane fluidity.

F. Membrane Permeability

1. Plasma membranes are selectively permeable, meaning that some things can pass through and others cannot.
2. The lipid bilayer portion of the membrane is permeable to small, nonpolar, uncharged molecules but impermeable to ions and charged or polar molecules. It is also permeable to water.
3. Transmembrane proteins that act as channels or transporters increase the permeability of the membrane to molecules that cannot cross the lipid bilayer.
4. Macromolecules are unable to pass through the plasma membrane except by vesicular transport.

G. Gradients Across the Plasma Membrane

1. A concentration gradient is the difference in the concentration of a chemical between one side of the plasma membrane and the other.
    a. Oxygen and sodium ions are more concentrated outside the cell membrane with carbon dioxide and potassium ions more concentrated inside the cell membrane.
    b. The inner surface of the membrane is more negatively charged and the outer surface is more positively charged. This sets up an electrical gradient, also called the *membrane potential.*
2. Maintaining the concentration and electrical gradients are important to the life of the cell.
3. The combined concentration and electrical gradients are called the electrochemical gradient.

IV. TRANSPORT ACROSS THE PLASMA MEMBRANE

A. Processes to move substances across the cell membrane are essential to the life of the cell.

1. Some substances cross the lipid bilayer while others cross through ion channels.

2. Transport processes that move substances across the cell membrane are either active or passive.
    a. Three types of passive processes are diffusion through the lipid bilayer, diffusion through ion channels, and facilitated diffusion
    b. Active transport requires cellular energy.
3. Materials can also enter or leave the cell through vesicle transport.

B. Principles of Diffusion
1. *Diffusion* is the random mixing of particles that occurs in a solution as a result of the kinetic energy of the particles.
2. Diffusion rate across plasma membranes is influenced by several factors: steepness of the concentration gradient, temperature, size or mass of the diffusing substance, surface area, and diffusion distance.

C. *Osmosis* is the net movement of a solvent through a selectively permeable membrane, or in living systems, the movement of water (the solute) from an area of higher concentration to an area of lower concentration across the membrane.
1. Water molecules penetrate the membrane by diffusion through the lipid bilayer or through aquaporins, transmembrane proteins that function as water channels.
2. Water moves from an area of lower solute concentration to an area of higher solute concentration.
3. Osmosis occurs only when the membrane is permeable to water but not to certain solutes.
4. *Tonicity* of a solution relates to how the solution influences the shape of body cells.
    a. In an *isotonic* solution, red blood cells maintain their normal shape.
    b. In a *hypotonic* solution, red blood cells undergo hemolysis.
    c. In a *hypertonic* solution, red blood cells undergo crenation.

D. Diffusion Through the Lipid Bilayer

1. Nonpolar, hydrophobic molecules such as respiratory gases, some lipids, small alcohols, and ammonia can diffuse across the lipid bilayer.
2. It is important for gas exchange, absorption of some nutrients, and excretion of some wastes.

E. Diffusion Through Membrane Channels
    1. Most membrane channels are ion channels, allowing passage of small, inorganic ions which are hydrophilic.
    2. Ion channels are selective and specific and may be gated or open all the time.

F. Facilitated Diffusion
    1. In *facilitated diffusion*, a solute binds to a specific transporter on one side of the membrane and is released on the other side after the transporter undergoes a conformational change.

G. Active Transport
    1. Active transport is an energy-requiring process that moves solutes such as ions, amino acids, and monosaccharides against a concentration gradient.
    2. Primary Active Transport
        a. In *primary active transport*, energy derived from ATP changes the shape of a transporter protein, which pumps a substance across a plasma membrane against its concentration gradient.
        b. The most prevalent primary active transport mechanism is the sodium ion/potassium ion pump.

    3. Secondary Active Transport

a. In *secondary active transport*, the energy stored in the form of a sodium or hydrogen ion concentration gradient is used to drive other substances against their own concentration gradients.

b. Plasma membranes contain several antiporters and symporters powered by the sodium ion gradient.

H. Transport in Vesicles

1. A vesicle is a small membranous sac formed by budding off from an existing membrane.

2. Two types of vesicular transport are endocytosis and exocytosis.

A. Endocytosis

In *endocytosis*, materials move into a cell in a vesicle formed from the plasma membrane.

1) *Receptor-mediated endocytosis* is the selective uptake of large molecules and particles by cells.

a) The steps of receptor-mediated endocytosis includes binding, vesicle formation, uncoating, fusion and endosome formation, recycling of receptors, degradation in lysosomes.

b) Viruses can take advantage of this mechanism to enter cells.

2) *Phagocytosis* is the ingestion of solid particles.

3) *Pinocytosis* is the ingestion of extracellular fluid.

B. Exocytosis

In exocytosis, membrane-enclosed structures called secretory vesicles that form inside the cell fuse with the plasma membrane and release their contents into the extracellular fluid.

In transcytosis, vesicles undergo endocytosis on one side of a cell, move across the cell, and then undergo exocytosis on the opposite side.

V. CYTOPLASM

A. *Cytosol*, the intracellular fluid, is the semifluid portion of cytoplasm that contains inclusions and dissolved solutes.

1. Cytosol is composed mostly of water, plus proteins, carbohydrates, lipids, and inorganic substances.
2. The chemicals in cytosol are either in solution or in a colloidal (suspended) form.
3. Functionally, cytosol is the medium in which many metabolic reactions occur.

B. Organelles

1. Organelles are specialized structures that have characteristic shapes and perform specific functions in cellular growth, maintenance, and reproduction.
2. The Cytoskeleton
    a. The *cytoskeleton* is a network of several kinds of protein filaments that extend throughout the cytoplasm and provides a structural framework for the cell.
    b. It consists of microfilaments, intermediate filaments, and microtubules.
        1) Most microfilaments are composed of actin and function in movement and mechanical support.
        2) Intermediate filaments are composed of several different proteins and function in support and to help anchor organelles such as the nucleus.
        3) Microtubules are composed of a protein called tubulin and help determine cell shape and function in the intracellular transport of organelles and the migration of chromosome during cell division.
3. *Centrosomes* are dense areas of cytoplasm containing the *centrioles*, which are paired cylinders arranged at right angles to one another, and serve as centers for organizing microtubules in interphase cells and the mitotic spindle during cell division.
4. Cilia and Flagella

a. *Cilia* are numerous, short, hairlike projections extending from the surface of a cell and functioning to move materials across the surface of the cell.
b. *Flagella* are similar to cilia but are much longer; usually moving an entire cell. The only example of a flagellum in the human body is the sperm cell tail.

5. Ribosomes
    a. *Ribosomes* are tiny spheres consisting of ribosomal RNA and several ribosomal proteins; they occur free (singly or in clusters) or together with endoplasmic reticulum.
    b. Functionally, ribosomes are the sites of protein synthesis.
6. Endoplasmic Reticulum
    a. The *endoplasmic reticulum* (ER) is a network of membranes that form flattened sacs or tubules called cisterns.
    b. *Rough ER* is continuous with the nuclear membrane and has its outer surface studded with ribosomes.
    c. *Smooth ER* extends from the rough ER to form a network of membrane tubules but does not contain ribosomes on its membrane surface.
    d. The ER transports substances, stores newly synthesized molecules, synthesizes and packages molecules, detoxifies chemicals, and releases calcium ions involved in muscle contraction.
7. Golgi Complex
    a. The *Golgi complex* consists of four to six stacked, flattened membranous sacs (cisterns) referred to as cis, medial, and trans.
    b. The principal function of the Golgi complex is to process, sort, and deliver proteins and lipids to the plasma membrane, lysosomes, and secretory vesicles.
8. Lysosomes

a. *Lysosomes* are membrane-enclosed vesicles that form in the Golgi complex and contain powerful digestive enzymes.

b. Lysosomes function in intracellular digestion, digestion of worn-out organelles (autophagy), digestion of cellular contents (autolysis) during embryological development, and extracellular digestion.

9. Perioxosomes

a. *Peroxisomes* are similar in structure to lysosomes, but are smaller.

b. They contain enzymes (e.g., catalase) that use molecular oxygen to oxidize various organic substances.

10. Proteosomes

a. Proteosomes are structures that destroy unneeded, damaged, or faulty proteins.

b. They contain proteases which cut proteins into small peptides.

c. Proteosomes are thought to be a factor in several diseases.

11. Mitochondria

a. The *mitochondrion* is bound by a double membrane. The outer membrane is smooth with the inner membrane arranged in folds called cristae.

b. Mitochondria are the site of ATP production in the cell by the catabolism of nutrient molecules.

c. Mitochondria self-replicate using their own DNA.

d. Mitochondrial DNA (genes) is usually inherited only from the mother.

VI. NUCLEUS

A. The *nucleus* is usually the most prominent feature of a cell.

B. Most body cells have a single nucleus; some (red blood cells) have none, whereas others (skeletal muscle fibers) have several.

C. The parts of the nucleus include the nuclear envelope (which is perforated by channels called nuclear pores), nucleoli, and genetic material (DNA),

D. Within the nucleus are the cell's hereditary units, called *genes*, which are arranged in single file along chromosomes.

1. Each chromosome is a long molecule of DNA that is coiled together with several proteins.
2. Human somatic cells have 46 chromosomes arranged in 23 pairs.

E. The various levels of DNA packing are represented by nucleosomes, chromatin fibers, loops, chromatids, and chromosomes.

VII. PROTEIN SYNTHESIS

A. Much of the cellular machinery is devoted to synthesizing large numbers of diverse proteins.

1. The proteins determine the physical and chemical characteristics of cells.
2. The instructions for protein synthesis are found in the DNA in the nucleus.

VIII. CELL DIVISION

A. Cell division is the process by which cells reproduce themselves. It consists of nuclear division (mitosis or meiosis) and cytoplasmic division (*cytokinesis*).

1. *Cell division* that results in an increase in body cells is called *somatic cell division* and involves a nuclear division called *mitosis*, plus cytokinesis.
2. Cell division that results in the production of sperm and eggs is called <u>reproductive cell division</u> and consists of a nuclear division called *meiosis* plus cytokinesis.

B. The Cell Cycle in Somatic Cells

1. The *cell cycle* is an orderly sequence of events by which a cell duplicates its contents and divides in two. It consists of interphase and the mitotic phase.
2. Interphase

a. During *interphase* the cell carries on every life process except division. Interphase consists of three phases: G_1, S and G_2.

1) In the G_1 phase, the cell is metabolically active, duplicating its organelles and cytosolic components except for DNA.

2) In the S phase, chromosomes are replicated.

3) In the G_2 phase, cell growth continues and the cell completes its preparation for cell division.

b. A cell in interphase shows a distinct nucleus and the absence of chromosomes.

3. Mitotic Phase

a. The mitotic phase consists of mitosis (or nuclear division) and cytokinesis (or cytoplasmic division).

b. Nuclear division: mitosis

1) *Mitosis* is the distribution of two sets of chromosomes, one set into each of two separate nuclei.

2) Stages of mitosis are prophase, metaphase, anaphase, and telophase.

a) During *prophase*, the chromatin condenses and shortens into chromosomes. The nuclear envelope "disappears", the nucleolus "disappears, and the spindle forms as the centrioles move to the poles of the cell.

b) During *metaphase*, the centromeres line up at the exact center of the mitotic spindle, a region called the metaphase plate or equatorial plane region. *Anaphase* is characterized by the splitting and separation of centromeres and the movement of the two sister chromatids of each pair toward opposite poles of the cell.

c) Telophase begins as soon as chromatid movement stops; the identical sets of chromosomes at opposite poles of the cell uncoil and revert to their threadlike chromatin form, centrioles move to center of cell, a new nuclear envelope forms, new

nucleoli appear, and the new mitotic spindle eventually breaks up.

c. Cytoplasmic Division: Cytokinesis

1) *Cytokinesis* is the division of a parent cell's cytoplasm and organelles. The process begins in late anaphase or early telophase with the formation of a cleavage furrow.

2) When cytokinesis is complete, interphase begins.

D. Control of Cell Destiny

1. The three possible destinies of a cell are to remain alive and functioning without dividing, to grow and divide, or to die.
2. Maturation promoting factor (MPF) induces cell division.
3. Cell death, a process called *apoptosis*, is triggered either from outside the cell or from inside the cell due to a "cell-suicide" gene.
4. *Necrosis* is a pathological cell death due to injury.

D. Tumor-suppressor genes can produce proteins that normally inhibit cell division resulting in the uncontrollable cell growth known as cancer.

IX. CELLULAR DIVERSITY

A. Not all cells look alike, nor do they perform identical functional roles in the body.

B. The shapes of cells vary considerably.