McCance: Pathophysiology, 6th Edition

Chapter 01: Cellular Biology

Key Points – Print

SUMMARY REVIEW

Cellular Functions

1. Cells become specialized through the process of differentiation, or maturation.
2. The eight specialized cellular functions are movement, conductivity, metabolic absorption, secretion, excretion, respiration, reproduction, and communication.

Structure and Function of Cellular Components

1. The eukaryotic cell consists of three general components: the plasma membrane, the cytoplasm, and the intracellular organelles.
2. The nucleus is the largest membrane-bound organelle and is usually found in the cell's center. The chief functions of the nucleus are cell division and control of genetic information.
3. Cytoplasm, or the cytoplasmic matrix, is an aqueous solution (cytosol) that fills the space between the nucleus and the plasma membrane.
4. The organelles are suspended in the cytoplasm and are enclosed in biologic membranes.
5. The endoplasmic reticulum is a network of tubular channels (cisternae) that extend throughout the outer nuclear membrane. It specializes in the synthesis and transport of protein and lipid components of most of the organelles.
6. The Golgi complex is a network of smooth membranes and vesicles located near the nucleus. The Golgi complex is responsible for processing and packaging proteins into secretory vesicles that break away from the Golgi complex and migrate to a variety of intracellular and extracellular destinations, including the plasma membrane.
7. Lysosomes are saclike structures that originate from the Golgi complex and contain digestive enzymes. These enzymes are responsible for digesting most cellular substances down to their basic form, such as amino acids, fatty acids, and sugars.
8. Cellular injury leads to a release of the lysosomal enzymes, causing cellular self-digestion.
9. Peroxisomes are similar to lysosomes but contain several enzymes that either produce or use hydrogen peroxide.
10. Mitochondria contain the metabolic machinery necessary for cellular energy metabolism. The enzymes of the respiratory chain (electron transport chain), found in the inner membrane of the mitochondria, generate most of the cell's ATP.
11. Vaults are newly discovered ribonucleoproteins thought to function as cellular "trucks" carrying mRNA from the nucleus to the ribosomal sites of protein synthesis.

12. The cytoskeleton is the “bone and muscle” of the cell. The internal skeleton is composed of a network of protein filaments including microtubules and actin filaments (microfilaments).
13. The plasma membrane encloses the cell and, by controlling the movement of substances across it, exerts a powerful influence on metabolic pathways.
14. The plasma membrane is a bilayer of lipids (phospholipids, glycolipids) and cholesterol, which gives the membrane its structural integrity.
15. Membrane functions are determined largely by proteins. These functions include (a) recognition and binding units (receptors) for substances moving in and out of the cell; (b) pores or transport channels; (c) enzymes that drive active pumps; (d) cell surface markers, such as glycoproteins; (e) cell adhesion molecules; and (f) catalysts of chemical reactions.
16. The fluid mosaic model accounts for the fluidity of the lipid bilayer and the flexibility, self-sealing properties, and selective impermeability of the plasma membrane.
17. Cellular receptors are protein molecules on the plasma membrane, in the cytoplasm, or in the nucleus, capable of recognizing and binding smaller molecules, called *ligands*.
18. The dynamic nature of the fluid plasma membrane enables it to vary the number of receptors on its surface. The cell is therefore capable of “hiding” from injurious agents by altering receptor number and pattern.
19. The ligand-receptor complex initiates a series of protein interactions, causing adenylyl cyclase to catalyze the transformation of cellular ATP to messenger molecules that stimulate specific responses within the cell.

Cell-to-Cell Adhesions

1. Cell-to-cell adhesions are formed on plasma membranes, thereby allowing the formation of tissues and organs. Cells are held together by three different means: (a) the extracellular membrane, (b) cell adhesion molecules in the cell’s plasma membrane, and (c) specialized cell junctions.
2. The extracellular matrix includes three types of protein fibers: collagen, elastin, and fibronectin. The matrix helps regulate cell growth and differentiation.
3. The three main types of cell junctions are desmosomes, tight junctions, and gap junctions.

Cellular Communication and Signal Transduction

1. Cells communicate in three ways: (a) they form protein channels (gap junctions); (b) they display receptors that affect intracellular processes or other cells in direct physical contact; and (c) they secrete signals for long-distance communication.
2. Primary modes of chemical signaling include hormonal, neurohormonal, paracrine, autocrine, and neurotransmitter.
3. Signal transduction involves signals or instructions from extracellular chemical messengers that are conveyed to the cell’s interior for execution.

4. Signaling cascades, or relay chains, have several important functions, including physically transferring the signal around the cell, amplifying the signal, distributing the signal, and modulating the signal.
5. Two important second messenger pathways are cAMP and Ca^{++}.
6. G protein is an intermediary between the receptor and adenylyl cyclase.
7. Phospholipase C, an enzyme protein effector, is bound to the inner side of the membrane.

Cellular Metabolism

1. The chemical tasks of maintaining essential cellular functions are referred to as *cellular metabolism.* Anabolism is the energy-using process of metabolism, whereas catabolism is the energy-releasing process.
2. ATP functions as an energy-transferring molecule. Energy is stored by molecules of carbohydrate, lipid, and protein, which, when catabolized, transfer energy to ATP.
3. Oxidative phosphorylation occurs in the mitochondria and is the mechanism by which the energy produced from carbohydrates, fats, and proteins is transferred to ATP.

Membrane Transport: Cellular Intake and Output

1. Water and small, electrically uncharged molecules move through pores in the plasma membrane's lipid bilayer in the process called *passive transport.*
2. Passive transport does not require the expenditure of energy; rather, it is driven by the physical effects of osmosis, hydrostatic pressure, and diffusion.
3. Larger molecules and molecular complexes (e.g., ligand-receptor complexes) are moved into the cell by active transport, which requires expenditure of energy (by means of ATP) by the cell.
4. The largest molecules (macromolecules) and fluids are transported by the processes of endocytosis (ingestion) and exocytosis (expulsion).
5. Two types of solutes exist in body fluids: electrolytes and nonelectrolytes. Electrolytes are electrically charged and dissociate into constituent ions when placed in solution. Nonelectrolytes do not dissociate when placed in solution.
6. Diffusion is the passive movement of a solute from an area of higher solute concentration to an area of lower solute concentration.
7. Hydrostatic pressure is the mechanical force of water pushing against cellular membranes.
8. Osmosis is the movement of water across a semipermeable membrane from a region of lower solute concentration to a region of higher solute concentration.
9. The amount of hydrostatic pressure required to oppose the osmotic movement of water is called the *osmotic pressure* of the solution.
10. The overall osmotic effect of colloids, such as plasma proteins, is called the *oncotic pressure* or *colloid osmotic pressure.*

11. Mediated transport can be passive or active. Mediated transport includes the movement of two molecules simultaneously in one direction (symport) or in opposite directions (antiport) or the movement of a single molecule in one direction (uniport).
12. Passive mediated transport is also called *facilitated diffusion.* It does not require the expenditure of metabolic energy.
13. Active mediated transport requires metabolic energy (ATP) to move molecules against the concentration gradient.
14. Active transport also occurs by endocytosis, or vesicle formation, in which the substance to be transported is engulfed by a segment of the plasma membrane, forming a vesicle that moves into the cell.
15. Pinocytosis is a type of endocytosis in which fluids and solute molecules are ingested through formation of small vesicles.
16. Phagocytosis is a type of endocytosis in which large particles, such as bacteria, are ingested through formation of large vesicles, called *vacuoles*.
17. In receptor-mediated endocytosis, the plasma membrane receptors are clustered, along with bristle-like structures, in specialized areas called *coated pits.*
18. Endocytosis occurs when coated pits invaginate, internalizing ligand-receptor complexes in coated vesicles.
19. Inside the cell, material ingested by endocytosis is processed and digested by lysosomal enzymes.
20. Caveolae are tiny flask-shaped pits on the outer surface of the plasma membrane. Cellular uptake through the opening and closing of caveolae is called *potocytosis.*
21. All body cells are electrically polarized, with the inside of the cell more negatively charged than the outside. The difference in voltage across the plasma membrane is the resting membrane potential.
22. When an excitable (nerve or muscle) cell receives an electrochemical stimulus, cations enter the cell, causing a rapid change in the resting membrane potential known as the *action potential.* The action potential "moves" along the cell's plasma membrane and is transmitted to an adjacent cell. This is how electrochemical signals convey information from cell to cell.

Cellular Reproduction: The Cell Cycle

1. Cellular reproduction in body tissues involves mitosis (nuclear division) and cytokinesis (cytoplasmic division).
2. Only mature cells are capable of division. Maturation occurs during a stage of cellular life called *interphase* (growth phase).
3. The cell cycle is the reproductive process that begins after interphase in all tissues with cellular turnover. The four phases of the cell cycle are (a) the S phase, during which DNA synthesis takes place in the cell nucleus; (b) the G_2 phase, the period between the completion of DNA synthesis and the next phase (M); (c) the M phase, which involves both nuclear

(mitotic) and cytoplasmic (cytokinetic) division; and (d) the G_1 phase (growth phase, or interphase), after which the cycle begins again.

4. The M phase (mitosis) involves four stages: prophase, metaphase, anaphase, and telophase.
5. The mechanisms that control cell division depend on “social control genes” and protein growth factors.
6. Cyclin-CDK complexes trigger cell cycle events.

Tissues

1. Cells of one or more types are organized into tissues, and different types of tissues compose organs. Organs are organized to function as tracts or systems.
2. Specialized cells are thought to form tissue by mitosis of one or more founder cells or by migration of founder cells and their subsequent assembly at the site of tissue formation.
3. The four basic types of tissues are epithelial, muscle, neural, and connective tissues.
4. Epithelial tissue covers most internal and external surfaces of the body. The functions of epithelial tissue include protection, absorption, secretion, and excretion.
5. Connective tissue binds various tissues and organs together, supporting them in their locations and serving as storage sites for excess nutrients.
6. Muscle tissue is composed of long, thin, highly contractile cells or fibers called *myocytes*. Muscle tissue that is attached to bones enables voluntary movement. Muscle tissues in internal organs enable involuntary movement, such as the heartbeat.
7. Neural tissue is composed of highly specialized cells called *neurons* that receive and transmit electric impulses very rapidly across junctions called *synapses.*