TABLE OF CONTENTS

1 THE HUMAN BODY: AN ORIENTATION

CHAPTER SUMMARY

An Overview of Anatomy and Physiology (pp. 3–4)

1. Anatomy is the study of body structures and their relationships. Physiology is the science of how body parts function.

Topics of Anatomy (pp. 3–4)

2. Major subdivisions of anatomy include gross anatomy, microscopic anatomy, and developmental anatomy.

Topics of Physiology (p. 4)

3. Typically, physiology concerns the functioning of specific organs or organ systems. Examples include cardiac physiology, renal physiology, and muscle physiology.

4. Physiology is explained by chemical and physical principles.

Complementarity of Structure and Function (p. 4)

5. Anatomy and physiology are inseparable: What a body can do depends on the unique architecture of its parts. This is called the complementarity of structure and function.

Levels of Structural Organization (pp. 4–7)

1. The levels of structural organization of the body, from simplest to most complex, are: chemical, cellular, tissue, organ, organ system, and organismal.

2. The 11 organ systems of the body are the integumentary, skeletal, muscular, nervous, endocrine, cardiovascular, lymphatic, respiratory, digestive, urinary, and reproductive systems. The immune system is a functional system closely associated with the lymphatic system. (For functions of these systems see pp. 6–7)

Maintaining Life (pp. 8–10)

Necessary Life Functions (pp. 8–9)

1. All living organisms carry out certain vital functional activities necessary for life, including maintenance of boundaries, movement, responsiveness, digestion, metabolism, excretion, reproduction, and growth.

Survival Needs (pp. 9–10)

2. Survival needs include nutrients, water, oxygen, appropriate body temperature, and atmospheric pressure.

Homeostasis (pp. 10–13)

1. Homeostasis is a dynamic equilibrium of the internal environment. All body systems contribute to homeostasis, but the nervous and endocrine systems are most important. Homeostasis is necessary for health.

Homeostatic Control Mechanisms (pp. 10–13)

2. Control systems of the body contain at least three elements: receptor(s), control center, and effector(s).

3. Negative feedback mechanisms reduce the original stimulus, and are essential for maintaining homeostasis. Body temperature, heart rate, breathing rate and depth, and blood levels of glucose and certain ions are regulated by negative feedback mechanisms.

4. Positive feedback mechanisms intensify the initial stimulus, leading to an enhancement of the response. Positive feedback mechanisms rarely contribute to homeostasis, but blood clotting and labor contractions are regulated by such mechanisms.

Homeostatic Imbalance (p. 13)

5. With age, the efficiency of negative feedback mechanisms declines, and positive feedback mechanisms occur more frequently. These changes underlie certain disease conditions.

The Language of Anatomy (pp. 14–23)

Anatomical Position and Directional Terms (pp. 15–16)

1. In the anatomical position, the body is erect, facing forward, feet together, arms at sides with palms forward.

2. Directional terms allow body parts to be located precisely. Terms used to describe body directions and orientation include: superior/inferior; anterior/posterior; ventral/dorsal; medial/lateral; intermediate; proximal/distal; and superficial/deep.

Regional Terms (pp. 14–15)

3. Regional terms are used to designate specific areas of the body (see Figure 1.7).

Body Planes and Sections (pp. 15, 17)

4. The body or its organs may be cut along planes, or imaginary lines, to produce different types of sections. Frequently used planes are sagittal, frontal, and transverse.

Body Cavities and Membranes (pp. 15, 18–19, 22)

5. The body contains two major closed cavities. The dorsal cavity, subdivided into the cranial and spinal cavities, contains the brain and spinal cord. The ventral cavity is subdivided into the superior thoracic cavity, which houses the heart and lungs, and the inferior abdominopelvic cavity, which contains the liver, digestive organs, and reproductive structures.

6. The walls of the ventral cavity and the surfaces of the organs it contains are covered with thin membranes, the parietal and visceral serosae, respectively. The serosae produce a thin fluid that decreases friction during organ functioning.

7. There are several smaller body cavities. Most of these are in the head and open to the exterior.

Abdominopelvic Regions and Quadrants (pp. 22–23)

8. The abdominopelvic cavity may be divided by four planes into nine abdominal regions (epigastric, umbilical, hypogastric, right and left iliac, right and left lumbar, and right and left hypochondriac), or by two planes into four quadrants. (For boundaries and organs contained see Figures 1.11 and 1.12.)

2 CHEMISTRY COMES ALIVE

CHAPTER SUMMARY

References to Interactive Physiology **IP** *appear below specific key chapter topics to help your review.*

Part 1: Basic Chemistry

Definition of Concepts: Matter and Energy (pp. 23-24)

Matter (p. 23)

1. Matter is anything that takes up space and has mass. Energy is the capacity to do work or put matter into motion.

Energy (pp. 23–24)

2. Energy exists as potential energy (stored energy or energy of position) and kinetic energy (active or working energy).

3. Forms of energy involved in body functioning are chemical, electrical, radiant, and mechanical. Of these, chemical (bond) energy is most important.

4. Energy may be converted from one form to another, but some energy is always unusable (lost as heat) in such transformations.

Composition of Matter: Atoms and Elements (pp. 24–27)

1. Elements are unique substances that cannot be decomposed into simpler substances by ordinary chemical methods. Four elements (carbon, hydrogen, oxygen, and nitrogen) make up 96% of body weight.

Atomic Structure (pp. 24-26)

2. The building blocks of elements are atoms.

3. Atoms are composed of positively charged protons, negatively charged electrons, and uncharged neutrons. Protons and neutrons are located in the atomic nucleus, constituting essentially the atom's total mass; electrons are outside the nucleus in the electron shells. In any atom, the number of electrons equals the number of protons. (See Figures 2.1 and 2.2.)

Identifying Elements (pp. 24–26)

4. Atoms may be identified by their atomic number (p^+) and mass number ($p^+ + n^0$). The notation ${}^{4}_{2}He$ means that helium (He) has an atomic number of 2 and a mass number of 4.

5. Isotopes of an element differ in the number of neutrons they contain. The atomic weight of any element is approximately equal to the mass number of its most abundant isotope.

Radioisotopes (p. 27)

6. Many heavy isotopes are unstable (radioactive). These so-called radioisotopes decompose to more stable forms by emitting α or β particles or γ rays. Radioisotopes are useful in medical diagnosis and treatment and in biochemical research.

How Matter Is Combined: Molecules and Mixtures (pp. 27–28)

Molecules and Compounds (p. 27)

1. A molecule is the smallest unit resulting from the chemical bonding of two or more atoms. If the atoms are different, they form a molecule of a compound.

Mixtures (pp. 27–28)

2. Mixtures are physical combinations of solutes in a solvent. Mixture components retain their individual properties.

3. The types of mixtures, in order of increasing solute size, are solutions, colloids, and suspensions.

4. Solution concentrations are typically designated in terms of percent or molarity.

Distinguishing Mixtures from Compounds (p. 28)

5. Compounds are homogeneous; their elements are chemically bonded. Mixtures may be homogeneous or heterogeneous; their components are physically combined and separable.

Chemical Bonds (pp. 28-32)

The Role of Electrons in Chemical Bonding (pp. 28-29)

1. Electrons of an atom occupy areas of space called electron shells or energy levels. Electrons in the shell farthest from the nucleus (valence shell) are most energetic.

2. Chemical bonds are energy relationships between valence shell electrons of the reacting atoms. Atoms with a full valence shell or eight valence shell electrons are chemically unreactive (inert); those with an incomplete valence shell interact with other atoms to achieve stability.

Types of Chemical Bonds (pp. 29-32)

3. Ionic bonds are formed when valence shell electrons are completely transferred from one atom to another.

4. Covalent bonds are formed when atoms share electron pairs. If the electron pairs are shared equally, the molecule is nonpolar; if they are shared unequally, it is polar (a dipole).

5. Hydrogen bonds are weak bonds formed between hydrogen and nitrogen or hydrogen and oxygen. They bind together different molecules (e.g., water molecules) or different parts of the same molecule (as in protein molecules).

Chemical Reactions (pp. 32-35)

Chemical Equations (pp. 32-33)

1. Chemical reactions involve the formation, breaking, or rearrangement of chemical bonds.

Patterns of Chemical Reactions (pp. 33–34)

2. Chemical reactions include synthesis, decomposition, and exchange reactions. Oxidation-reduction reactions may be considered a special type of exchange (or catabolic) reaction.

Energy Flow in Chemical Reactions (p. 34)

3. Bonds are energy relationships and there is a net loss or gain of energy in every chemical reaction.

4. In exergonic reactions, energy is liberated; in endergonic reactions, energy is absorbed.

Reversibility of Chemical Reactions (pp. 34–35)

5. If reaction conditions remain unchanged, all chemical reactions eventually reach a state of chemical equilibrium in which the reaction proceeds in both directions at the same rate.

6. All chemical reactions are theoretically reversible, but many biological reactions go in only one direction because of energy requirements or the removal of reaction products.

Factors Influencing the Rate of Chemical Reactions (p. 35)

7. Chemical reactions occur only when particles collide and valence shell electrons interact.

2 Chemistry Comes Alive

8. The smaller the reacting particles, the greater their kinetic energy and the faster the reaction rate. Higher temperature or reactant concentration, as well as the presence of catalysts, increases chemical reaction rates.

Part 2: Biochemistry

Inorganic Compounds (pp. 35–38)

1. Most inorganic compounds do not contain carbon. Those found in the body include water, salts, and inorganic acids and bases.

Water (pp. 35-36)

2. Water is the single most abundant compound in the body. It absorbs and releases heat slowly, acts as a universal solvent, participates in chemical reactions, and cushions body organs.

Salts (p. 36)

3. Salts are ionic compounds that dissolve in water and act as electrolytes. Calcium and phosphorus salts contribute to the hardness of bones and teeth. Ions of salts are involved in many physiological processes.

Acids and Bases (pp. 36–38)

4. Acids are proton donors; in water, they ionize and dissociate, releasing hydrogen ions (which account for their properties) and anions.

IP Fluid, Electrolyte, and Acid/Base Balance CD-ROM: Introduction to Body Fluids, pages 1–8.

5. Bases are proton acceptors. The most important inorganic bases are the hydroxides; bicarbonate ion and ammonia are important bases in the body.

6. pH is a measure of hydrogen ion concentration of a solution (in moles per liter). A pH of 7 is neutral; a higher pH is alkaline, and a lower pH is acidic. Normal blood pH is 7.35–7.45. Buffers help to prevent excessive changes in the pH of body fluids.

IP Fluid, Electrolyte, and Acid/Base Balance CD-ROM: Acid Base Homeostasis, pages 1–12, 16, 17.

Organic Compounds (pp. 38-51)

1. Organic compounds contain carbon. Those found in the body include carbohydrates, lipids, proteins, and nucleic acids, all of which are synthesized by dehydration synthesis and digested by hydrolysis. All of these biological molecules contain C, H, and O. Proteins and nucleic acids also contain N.

Carbohydrates (pp. 38-40)

2. Carbohydrate building blocks are monosaccharides, the most important of which are hexoses (glucose, fructose, galactose) and pentoses (ribose, deoxyribose).

3. Disaccharides (sucrose, lactose, maltose) and polysaccharides (starch, glycogen) are composed of linked monosaccharide units.

4. Carbohydrates, particularly glucose, are the major energy fuel for forming ATP. Excess carbohydrates are stored as glycogen or converted to fat for storage.

Lipids (pp. 41-42)

5. Lipids dissolve in fats or organic solvents, but not in water.

6. Neutral fats are composed of fatty acid chains and glycerol. They are found chiefly in fatty tissue where they provide insulation and reserve body fuel.

7. Phospholipids are modified phosphorus-containing neutral fats that have polar and nonpolar portions. They are found in all plasma membranes.

8. The steroid cholesterol is found in cell membranes and is the basis of steroid hormones, bile salts, and vitamin D.

Proteins (pp. 43-48)

9. The unit of proteins is the amino acid; 20 common amino acids are found in the body.

10. Many amino acids joined by peptide bonds form a polypeptide. A protein (one or more polypeptides) is distinguished by the number and sequence of amino acids in its chain(s) and by the complexity of its three-dimensional structure.

11. Fibrous proteins, such as keratin and collagen, have secondary (α helix or β pleated sheet) and perhaps quaternary structure. Fibrous proteins are used as structural materials.

12. Globular proteins achieve tertiary or quaternary structure and are generally spherical, soluble molecules. Globular proteins (e.g., enzymes, some hormones, antibodies, hemoglobin) perform special functional roles for the cell (e.g., catalysis, molecule transport).

13. Proteins are denatured by extremes of temperature or pH. Denatured globular proteins are unable to perform their usual function.

14. Enzymes are biological catalysts; they increase the rate of chemical reactions by decreasing the amount of activation energy needed. They do this by combining with the reactants and holding them in the proper position to interact. Many enzymes require cofactors to function.

15. Molecular chaperones assist in folding proteins into their functional 3-D shape. They are synthesized in greater amounts when cells are stressed by environmental factors and begin to accumulate denatured proteins.

Nucleic Acids (DNA and RNA) (pp. 48-50)

16. Nucleic acids include deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). The structural unit of nucleic acids is the nucleotide, which consists of a nitrogenous base (adenine, guanine, cytosine, thymine, or uracil), a sugar (ribose or deoxyribose), and a phosphate group.

17. DNA is a double-stranded helix: it contains deoxyribose and the bases A, G, C, and T. DNA specifies protein structure and replicates itself exactly before cell division.

18. RNA is single-stranded; it contains ribose and the bases A, G, C, and U. RNA is involved in carrying out DNA's instructions for protein synthesis.

Adenosine Triphosphate (ATP) (pp. 50-51)

19. ATP is the universal energy compound of body cells. Some of the energy liberated by the breakdown of glucose and other food fuels is captured in the bonds of ATP molecules and transferred via coupled reactions to energy-consuming reactions.

3 CELLS: THE LIVING UNITS

CHAPTER SUMMARY

References to Interactive Physiology IP *appear below specific key chapter topics to help your review.*

Overview of the Cellular Basis of Life (pp. 55-57)

1. All living organisms are composed of cells—the basic structural and functional units of life. Cells vary widely in both shape and size.

2. The principle of complementarity states that the biochemical activity of cells reflects the operation of organelles.

3. The generalized cell is a concept that typifies all cells. The generalized cell has three major regions—the nucleus, cytoplasm, and plasma membrane.

The Plasma Membrane: Structure (pp. 55, 58)

1. The plasma membrane encloses cell contents, mediates exchanges with the extracellular environment, and plays a role in cellular communication.

The Fluid Mosaic Model (pp. 58-60)

2. The fluid mosaic model depicts the plasma membrane as a fluid bilayer of lipids (phospholipids, cholesterol, and glycolipids) within which proteins are inserted.

3. The lipids have both hydrophilic and hydrophobic regions that organize their aggregation and self-repair. The lipids form the structural part of the plasma membrane.

4. Most proteins are integral transmembrane proteins that extend entirely through the membrane. Some, appended to the integral proteins, are peripheral proteins.

5. Proteins are responsible for most specialized membrane functions: some are enzymes, some are receptors, and others mediate membrane transport functions. Externally facing glycoproteins contribute to the glycocalyx.

Specializations of the Plasma Membrane (pp. 60-61)

6. Microvilli are extensions of the plasma membrane that increase its surface area for absorption.

7. Membrane junctions join cells together and may aid or inhibit movement of molecules between or past cells. Tight junctions are impermeable junctions; desmosomes mechanically couple cells into a functional community; gap junctions allow joined cells to communicate.

The Plasma Membrane: Functions (p. 61)

Membrane Transport (pp. 61-71)

1. The plasma membrane acts as a selectively permeable barrier. Substances move across the plasma membrane by passive processes, which depend on the kinetic energy of molecules or on pressure gradients, and by active processes, which depend on the use of cellular energy (ATP).

2. Diffusion is the movement of molecules (driven by kinetic energy) down a concentration gradient. Fat-soluble solutes can diffuse directly through the membrane by dissolving in the lipid. Charged small molecules or ions move by diffusion through the membrane if they are small enough to pass through the protein channels. Some protein channels are selective.

3. Facilitated diffusion is the passive movement of certain solutes across the membrane by their combination with a membrane carrier protein. As with other diffusion processes, it is driven by kinetic energy, but the carriers are selective.

4. Osmosis is the diffusion of a solvent, such as water, through a selectively permeable membrane. Water diffuses through membrane pores (aquaporins) or directly through the lipid portion of the membrane from a solution of lesser osmolarity to a solution of greater osmolarity.

5. The presence of impermeable solutes leads to changes in cell tone that may cause the cell to swell or shrink. Net osmosis ceases when the solute concentration on both sides of the plasma membrane reaches equilibrium.

6. Solutions that cause a net loss of water from cells are hypertonic; those causing net water gain are hypotonic; those causing neither gain nor loss of water are isotonic.

7. Filtration occurs when a filtrate is forced across a membrane by hydrostatic pressure. It is nonselective and limited only by pore size. The pressure gradient is the driving force.

8. Active transport (solute pumping) depends on a carrier protein and ATP. Substances transported move against concentration or electrical gradients. In primary active transport, such as the Na^+-K^+ pump, ATP directly provides the energy. In secondary active transport, the energy of an ion gradient (produced by a primary active transport process) is used to transport a substance passively. Many secondary active transport systems (pumps) are coupled, that is, cotransported substances move in the same (symport) or opposite (antiport) directions across the membrane.

9. Vesicular transport also requires that ATP be provided. Exocytosis ejects substances (hormones, wastes, secretions) from the cell. Endocytosis brings substances into the cell. If the substance is particulate, the process is called phagocytosis; if the substance is dissolved molecules in general, the process is bulk-phase endocytosis. Receptor-mediated endocytosis is selective; engulfed particles attach to receptors on the membrane before endocytosis occurs.

Generating and Maintaining a Resting Membrane Potential (pp. 71-72)

10. All cells in the resting stage exhibit a voltage across their membrane, called the resting membrane potential. Because of the membrane potential, both concentration and electrical gradients determine the ease of an ion's diffusion.

11. The membrane potential is generated by concentration gradients of and differential permeability of the plasma membrane to sodium and potassium ions. Sodium is in high extracellular–low intracellular concentration, and the membrane is poorly permeable to it. Potassium is in high concentration in the cell and low concentration in the extracellular fluid. The membrane is more permeable to potassium than to sodium.

12. The greater outward diffusion of potassium (than inward diffusion of sodium) leads to a charge separation at the membrane (inside negative). This charge separation is maintained by the operation of the sodium-potassium pump.

IP Nervous System I CD–ROM: Ion Channels, pages 3, 18, 19; Membrane Potentials, pages 1–17.

3 *Cells: The Living Units*

Cell-Environment Interactions (pp. 72-73)

13. Cells interact directly and indirectly with other cells. Indirect interactions involve extracellular chemicals carried in body fluids or forming part of the extracellular matrix.

14. Molecules of the glycocalyx are intimately involved in cell-environment interactions. Most are cell adhesion molecules or membrane receptors.

15. Activated membrane receptors act as catalysts, regulate channels, or like G protein–linked receptors, act through second messengers such as cyclic AMP and Ca^{2+}. Ligand binding results in changes in protein structure or function within the targeted cell.

The Cytoplasm (p. 73)

1. The cytoplasm, the cellular region between the nuclear and plasma membranes, consists of the cytosol (fluid cytoplasmic environment), inclusions (nonliving nutrient stores [lipid droplets, glycosomes], pigment granules, crystals, etc.), and cytoplasmic organelles.

Cytoplasmic Organelles (pp. 73-83)

2. The cytoplasm is the major functional area of the cell. These functions are mediated by cytoplasmic organelles.

3. Mitochondria, organelles limited by a double membrane, are sites of ATP formation. Their internal enzymes carry out the oxidative reactions of cellular respiration.

4. Ribosomes, composed of two subunits containing ribosomal RNA and proteins, are the sites of protein synthesis. They may be free or attached to membranes.

5. The rough endoplasmic reticulum is a ribosome-studded membrane system. Its cisternae act as sites for protein modification. Its external face acts in phospholipid and cholesterol synthesis. Vesicles pinched off from the ER transport the proteins to other cell sites.

6. The smooth endoplasmic reticulum synthesizes lipid and steroid molecules. It also acts in fat metabolism and in drug detoxification. In muscle cells, it is a calcium ion depot.

7. The Golgi apparatus is a membranous system close to the nucleus that packages protein secretions for export, packages enzymes into lysosomes for cellular use, and modifies proteins destined to become part of cellular membranes.

8. Lysosomes are membranous sacs of acid hydrolases packaged by the Golgi apparatus. Sites of intracellular digestion, they degrade worn-out organelles, and tissues that are no longer useful, and release ionic calcium from bone.

9. Peroxisomes are membranous sacs containing oxidase enzymes that protect the cell from the destructive effects of free radicals and other toxic substances by converting them first to hydrogen peroxide and then water.

10. The cytoskeleton includes microfilaments, intermediate filaments, and microtubules. Microfilaments, formed of contractile proteins, are important in cell motility or movement of cell parts. Microtubules organize the cytoskeleton and are important in intracellular transport. Motility functions involve motor proteins. Intermediate filaments help cells resist mechanical stress and connect other elements.

11. Centrioles form the mitotic spindle and are the basis of cilia and flagella.

The Nucleus (pp. 83-85)

1. The nucleus is the control center of the cell. Most cells have a single nucleus. Without a nucleus, a cell cannot divide or synthesize more proteins; thus, it is destined to die.

2. The nucleus is surrounded by the nuclear envelope, a double membrane penetrated by fairly large pores.

3. Nucleoli are nuclear sites of ribosome subunit synthesis.

4. Chromatin is a complex network of slender threads containing histone proteins and DNA. The chromatin units are called nucleosomes. When a cell begins to divide, the chromatin coils and condenses, forming chromosomes.

Cell Growth and Reproduction (pp. 85-91)

The Cell Life Cycle (pp.85-91)

1. The cell life cycle is the series of changes that a cell goes through from the time it is formed until it divides.

2. Interphase is the nondividing phase of the cell life cycle. Interphase consists of G_1, S, and G_2 subphases. During G_1, the cell grows and centriole replication begins; during the S phase, DNA replicates; and during G_2, the final preparations for division are made.

3. DNA replication occurs before cell division; it ensures that all daughter cells have identical genes. The DNA helix uncoils, and each DNA nucleotide strand acts as a template for the formation of a complementary strand. Base pairing provides the guide for the proper positioning of nucleotides.

4. The products of the semiconservative replication of a DNA molecule are two DNA molecules identical to the parent molecule, each formed of one "old" and one "new" strand.

5. Cell division, essential for body growth and repair, occurs during the M phase. Cell division is stimulated by certain chemicals (including growth factors and some hormones) and increasing cell size. Lack of space and inhibitory chemicals deter cell division. Cell division is regulated by cyclin-Cdk complexes, of which one example is MPF. Cell division consists of two distinct phases: mitosis and cytokinesis.

6. Mitosis, consisting of prophase, metaphase, anaphase, and telophase, results in the parceling out of the replicated chromosomes to two daughter nuclei, each genetically identical to the mother nucleus. Cytokinesis, which begins late in mitosis, divides the cytoplasmic mass into two parts.

Protein Synthesis (p. 91)

7. A gene is defined as a DNA segment that provides the instructions for the synthesis of one polypeptide chain. Since the major structural materials of the body are proteins, and all enzymes are proteins, this amply covers the synthesis of all biological molecules.

8. The base sequence of DNA provides the information for protein structure. Each three-base sequence (triplet) calls for a particular amino acid to be built into a polypeptide chain.

9. The three varieties of RNA are synthesized on single strands of the DNA template. RNA nucleotides are joined following base-pairing rules.

10. Ribosomal RNA forms part of the protein synthesis sites; messenger RNA carries instructions for making a polypeptide chain from the DNA to the ribosomes; transfer RNA ferries amino acids to the ribosomes and recognizes codons on the mRNA strand specifying its amino acid.

11. Protein synthesis involves (1) transcription, synthesis of a complementary mRNA, and (2) translation, "reading" of the mRNA by tRNA and peptide bonding of the amino acids into the polypeptide chain. Ribosomes coordinate translation.

12. Soluble proteins that are damaged or no longer needed are targeted for destruction by attachment of ubiquitin. Such proteins are degraded by cytosolic enzymes or proteasomes.

3 *Cells: The Living Units*

Extracellular Materials (p. 96)

1. Extracellular materials are substances found outside the cells. These include body fluids, cellular secretions, and extracellular matrix. Extracellular matrix is particularly abundant in connective tissues.

4 TISSUE: THE LIVING FABRIC

CHAPTER SUMMARY

References to Interactive Physiology **IP** *appear below specific key chapter topics to help your review.*

Tissues are collections of structurally similar cells with related functions. The four primary tissues are epithelial, connective, muscle, and nervous tissues.

Epithelial Tissue (pp. 99-108)

1. Epithelial tissue is the covering, lining, and glandular tissue of the body. Its functions include protection, absorption, secretion, filtration, and sensory reception.

Special Characteristics of Epithelium (pp. 99-100)

2. Epithelial tissues exhibit a huge degree of cellularity, specialized contacts, polarity, avascularity, support from connective tissue, and high regenerative capacity.

Classification of Epithelia (pp. 100-105)

3. Epithelium is classified by arrangement as simple (one layer) or stratified (more than one) and by cell shape as squamous, cuboidal, or columnar. The terms denoting cell shape and arrangement are combined to describe the epithelium fully.

4. Simple squamous epithelium is a single layer of squamous cells. Highly adapted for filtration and exchange of substances. Forms walls of air sacs of the lungs and lines blood vessels. Contributes to serosae as mesothelium and forms the lining of all hollow circulatory system organs as endothelium.

5. Simple cuboidal epithelium is commonly active in secretion and absorption. Found in glands and in kidney tubules.

6. Simple columnar epithelium, specialized for secretion and absorption, consists of a single layer of tall columnar cells that exhibit microvilli and often goblet cells. Lines most of the digestive tract.

7. Pseudostratified columnar epithelium is a simple columnar epithelium that appears stratified. Its ciliated variety, rich in goblet cells, lines most of the upper respiratory passages.

8. Stratified squamous epithelium is multilayered; cells at the free edge are squamous. It is adapted to resist abrasion. It lines the esophagus and vagina; its keratinized variety forms the skin epidermis.

9. Stratified columnar epithelia are rare in the body, and are found chiefly in ducts of large glands.

10. Transitional epithelium is a modified stratified squamous epithelium, adapted for responding to stretch. It lines hollow urinary system organs.

Glandular Epithelia (pp. 106-108)

11. A gland is one or more cells specialized to secrete a product.

12. On the basis of site of product release, glands are classified as exocrine or endocrine. Glands are classified structurally as multicellular or unicellular.

13. Unicellular glands, also called goblet cells, are mucus-secreting single-celled glands.

14. Multicellular exocrine glands are classified according to duct structure as simple or compound, and according to the structure of their secretory parts as tubular, alveolar, or tubuloalveolar.

15. Multicellular exocrine glands of humans are classified functionally as merocrine or holocrine.

Connective Tissue (pp. 108-118)

1. Connective tissue is the most abundant and widely distributed tissue of the body. Its functions include support, protection, binding, insulation, and transportation (blood).

Common Characteristics of Connective Tissue (p. 108)

2. Connective tissues originate from embryonic mesenchyme and exhibit matrix. Depending on type, a connective tissue may be well vascularized (most), poorly vascularized (dense connective tissue), or avascular (cartilage).

Structural Elements of Connective Tissue (pp. 109-111)

3. The structural elements of all connective tissues are extracellular matrix and cells.

4. Extracellular matrix consists of ground substance and fibers. It may be fluid, gel-like, or firm.

5. Each connective tissue type has a primary cell type that can exist as a mitotic, matrix-secreting cell (blast) or as a mature cell (cyte) responsible for maintaining the matrix. The chief cell type of connective tissue proper is the fibroblast; that of cartilage is the chondroblast; that of bone is the osteoblast; and that of blood-forming tissue is the hematopoietic stem cell.

Types of Connective Tissue (pp. 111-118)

6. Embryonic connective tissue is called mesenchyme.

7. Connective tissue proper consists of loose and dense varieties. The loose connective tissues are

- Areolar: semifluid ground substance; all three fiber types loosely interwoven; a variety of cells; forms soft packing around body organs and the lamina propria; the prototype.
- Adipose: consists largely of adipocytes; scant matrix; insulates and protects body organs; provides reserve energy fuel. Brown fat, present only in infants, is more important for generating body heat.
- Reticular: finely woven reticular fibers in soft ground substance; the stroma of lymphoid organs and bone marrow.

8. Dense connective tissue proper includes

- Dense regular: dense parallel bundles of collagen fibers; few cells, little ground substance; high tensile strength; forms tendons, ligaments, aponeuroses; in cases where this tissue also contains numerous elastic fibers it is called elastic connective tissue.
- Dense irregular: like regular variety, but fibers are arranged in different planes; resists tension exerted from many different directions; forms the dermis of the skin and organ capsules.

9. Cartilage exists as

- Hyaline: firm ground substance containing collagen fibers; resists compression well; found in fetal skeleton, at articulating surfaces of bones, and trachea; most abundant type.
- Elastic cartilage: elastic fibers predominate; provides flexible support of the external ear and epiglottis.
- Fibrocartilage: coarse parallel collagen fibers; provides support with compressibility; forms intervertebral discs and knee cartilages.

4 *Tissue: The Living Fabric*

10. Bone (osseous tissue) consists of a hard, collagen-containing matrix embedded with calcium salts; forms the bony skeleton.

11. Blood consists of blood cells in a fluid matrix (plasma).

Epithelial Membranes: Coverings and Linings (pp. 118-121)

1. Epithelial membranes are simple organs, consisting of an epithelium bound to an underlying connective tissue layer. Include mucosae, serosae, and the cutaneous membrane.

Nervous Tissue (p. 121-122)

1. Nervous tissue forms organs of the nervous system. It is composed of neurons and supporting cells.

2. Neurons are branching cells that receive and transmit electrical impulses; involved in body regulation.

IP Nervous System I; topic: Anatomy Review, pages 1, 3.

Muscle Tissue (p. 122)

1. Muscle tissue consists of elongated cells specialized to contract and cause movement.

2. Based on structure and function, there are

- Skeletal muscle: attached to and moves the bony skeleton; cells are cylindrical and striated.
- Cardiac muscle: forms the walls of the heart; pumps blood; cells are branched and striated.
- Smooth muscle: in the walls of hollow organs; propels substances through the organs; cells are spindle shaped and lack striations.

Tissue Repair (pp. 122, 124-125)

1. Inflammation is the body's response to injury. Tissue repair begins during the inflammatory process. It may lead to regeneration, fibrosis, or both.

2. Tissue repair begins with organization, during which the blood clot is replaced by granulation tissue. If the wound is small and the damaged tissue is actively mitotic, the tissue will regenerate and cover the fibrous tissue. When a wound is extensive or the damaged tissue amitotic, it is repaired only by fibrous connective (scar) tissue.

5 THE INTEGUMENTARY SYSTEM

CHAPTER SUMMARY

The Skin (pp. 128-133)

1. The skin, or integument, is composed of two discrete tissue layers, an outer epidermis and a deeper dermis, resting on subcutaneous tissue, the hypodermis.

Epidermis (pp. 128-131)

2. The epidermis is an avascular, keratinized sheet of stratified squamous epithelium. Most epidermal cells are keratinocytes. Scattered among the keratinocytes in the deepest epidermal layers are melanocytes, Merkel cells, and Langerhans' cells.

3. From deep to superficial, the strata, or layers of the epidermis, are the basale, spinosum, granulosum, lucidum, and corneum. The stratum lucidum is absent in thin skin. The actively mitotic stratum basale is the source of new cells for epidermal growth. The most superficial layers are increasingly keratinized and less viable.

Dermis (pp. 131-132)

4. The dermis, composed mainly of dense, irregular connective tissue, is well supplied with blood vessels, lymphatic vessels, and nerves. Cutaneous receptors, glands, and hair follicles reside within the dermis.

5. The more superficial papillary layer exhibits dermal papillae that protrude into the epidermis above and the epidermal ridges that produce fingerprints.

6. In the deeper, thicker reticular layer, the connective tissue fibers are much more densely interwoven. Less dense regions between the collagen bundles produce cleavage, or tension, lines in the skin. Points of tight dermal attachment to the hypodermis produce dermal folds, or flexure lines.

Skin Color (pp. 132-133)

7. Skin color reflects the amount of pigments (melanin and carotene) in the skin and the oxygenation level of hemoglobin in blood.

8. Melanin production is stimulated by exposure to ultraviolet radiation in sunlight. Melanin, produced by melanocytes and transferred to keratinocytes, protects the keratinocyte nuclei from the damaging effects of UV radiation.

9. Skin color is affected by emotional state. Alterations in normal skin color (jaundice, bronzing, erythema, and others) may indicate certain disease states.

Appendages of the Skin (pp. 133-139)

1. Skin appendages, which derive from the epidermis, include hairs and hair follicles, nails, and glands (sweat and sebaceous).

Sweat (Sudoriferous) Glands (pp. 133-134)

2. Eccrine (merocrine) sweat glands, with a few exceptions, are distributed over the entire body surface. Their primary function is thermoregulation. They are simple coiled tubular glands that secrete a salt solution containing small amounts of other solutes. Their ducts usually empty to the skin surface via pores.

3. Apocrine sweat glands, which may function as scent glands, are found primarily in the axillary and anogenital areas. Their secretion is similar to eccrine secretion, but it also contains proteins and fatty substances on which bacteria thrive.

Sebaceous (Oil) Glands (pp. 134-135)

4. Sebaceous glands occur all over the body surface except for the palms and soles. They are simple alveolar glands; their oily holocrine secretion is called sebum. Sebaceous gland ducts usually empty into hair follicles.

5. Sebum lubricates the skin and hair, prevents water loss from the skin, and acts as a bactericidal agent. Sebaceous glands are activated (at puberty) and controlled by androgens.

Hairs and Hair Follicles (pp. 135-138)

6. A hair, produced by a hair follicle, consists of heavily keratinized cells. A typical hair has a central medulla, a cortex, and an outer cuticle and root and shaft portions. Hair color reflects the amount and kind of melanin present.

7. A hair follicle consists of an inner epidermal root sheath, enclosing the matrix (region of the hair bulb that produces the hair), and an outer connective tissue sheath derived from the dermis. A hair follicle is richly vascularized and well supplied with nerve fibers. Arrector pili muscles pull the follicles into an upright position and produce goose bumps.

8. Except for hairs of the scalp and around the eyes, hairs formed initially are fine vellus hairs; at puberty, under the influence of androgens, coarser, darker terminal hairs appear in the axillae and genital region.

9. The rate of hair growth varies in different body regions and with sex and age. Differences in life span of hairs account for differences in length on different body regions. Hair thinning reflects factors that lengthen follicular resting periods, age-related atrophy of hair follicles, and a delayed-action gene.

Nails (pp. 138-139)

10. A nail is a scalelike modification of the epidermis that covers the dorsum of a finger (or toe) tip. The actively growing region is the nail matrix.

Functions of the Integumentary System (pp. 139-140)

1. Protection. The skin protects by chemical barriers (the antibacterial nature of sebum and the acid mantle, and melanin), physical barriers (the hardened keratinized and lipid-rich surface), and biological barriers (phagocytes).

2. Body temperature regulation. The skin vasculature and sweat glands, regulated by the nervous system, play an important role in maintaining body temperature homeostasis.

3. Cutaneous sensation. Cutaneous sensory receptors respond to temperature, touch, pressure, and pain stimuli.

4. Metabolic functions. Vitamin D is synthesized from cholesterol by epidermal cells. Skin cells also play a role in some chemical conversions.

5. Blood reservoir. The extensive vascular supply of the dermis allows the skin to act as a blood reservoir.

6. Excretion. Sweat contains small amounts of nitrogenous wastes and plays a minor role in excretion.

Homeostatic Imbalances of Skin (pp. 140-142)

1. The most common skin disorders result from infections.

Skin Cancer (pp. 140-141)

2. The most common cause of skin cancer is exposure to ultraviolet radiation.

3. Basal cell carcinoma and squamous cell carcinoma are cured if they are removed before metastasis. Melanoma, a cancer of melanocytes, is less common but dangerous.

Burns (pp. 141-142)

4. In severe burns, the initial threat is loss of protein- and electrolyte-rich body fluids, which may lead to circulatory collapse. The second threat is overwhelming bacterial infection.

5. The extent of a burn may be evaluated by using the rule of nines. The severity of burns is indicated by the terms first degree, second degree, and third degree. Third-degree burns require grafting for successful recovery.

6 BONES AND SKELETAL TISSUES

CHAPTER SUMMARY

Skeletal Cartilages (p. 145)

Basic Structure, Types, and Locations (p. 145)

1. A skeletal cartilage exhibits chondrocytes housed in lacunae (cavities) within the extracellular matrix (ground substance and fibers). It contains large amounts of water (which accounts for its resilience), lacks nerve fibers, is avascular, and is surrounded by a fibrous perichondrium that resists expansion.

2. Hyaline cartilages appear glassy; the fibers are collagenic. They provide support with flexibility and resilience and are the most abundant skeletal cartilages, accounting for the articular, costal, respiratory, and nasal cartilages.

3. Elastic cartilages contain abundant elastic fibers, in addition to collagenic fibers, and are more flexible than hyaline cartilages. They support the outer ear and epiglottis.

4. Fibrocartilages, which contain thick collagen fibers, are the most compressible cartilages and are resistant to stretch. They form vertebral discs and knee joint cartilages.

Growth of Cartilage (p. 145)

5. Cartilages grow from within (interstitial growth) and by addition of new cartilage tissue at the periphery (appositional growth).

Classification of Bones (pp. 146-148)

1. Bones are classified as long, short, flat, or irregular on the basis of their shape and their proportion of compact or spongy bone.

Functions of Bones (p. 148)

1. Bones give the body shape; protect and support body organs; provide levers for muscles to pull on; store calcium and other minerals; and are the site of blood cell production.

Bone Structure (pp. 148-153)

Gross Anatomy (pp. 148-150)

1. A long bone is composed of a diaphysis (shaft) and epiphyses (ends). The medullary cavity of the diaphysis contains yellow marrow; the epiphyses contain spongy bone. The epiphyseal line is the remnant of the epiphyseal plate. Periosteum covers the diaphysis; endosteum lines inner bone cavities. Hyaline cartilage covers joint surfaces.

2. Flat bones consist of two thin plates of compact bone enclosing a diploë (spongy bone layer). Short and irregular bones resemble flat bones structurally.

3. In adults, hematopoietic tissue is found within the diploë of flat bones and occasionally within the epiphyses of long bones. In infants red marrow is also found in the medullary cavity.

Microscopic Structure of Bone (pp. 150-151)

4. The structural unit of compact bone, the osteon, consists of a central canal surrounded by concentric lamellae of bone matrix. Osteocytes, embedded in lacunae, are connected to each other and the central canal by canaliculi.

5. Spongy bone has slender trabeculae containing irregular lamellae, which enclose red marrow–filled cavities.

Chemical Composition of Bone (p. 152)

6. Bone is composed of living cells (osteoblasts, osteocytes, and osteoclasts) and matrix. The matrix includes organic substances that are secreted by osteoblasts and give the bone tensile strength. Its inorganic components, the hydroxyapatites (calcium salts), make bone hard.

Bone Markings (pp. 152-153

7. Bone markings are important anatomical landmarks that reveal sites of muscle attachment, points of articulation, and sites of blood vessels and nerve passage.

Bone Development (pp. 153-156)

Formation of the Bony Skeleton (p. 153)

1. Intramembranous ossification forms the clavicles and most skull bones. The ground substance of the bone matrix is deposited between collagen fibers within the fibrous membrane to form spongy bone. Eventually, compact bone plates enclose the diploë.

2. Most bones are formed by endochondral ossification of a hyaline cartilage model. Osteoblasts beneath the periosteum secrete bone matrix on the cartilage model, forming the bone collar. Deterioration of the cartilage model internally opens up cavities, allowing periosteal bud entry. Bone matrix is deposited around the cartilage remnants but is later broken down.

Postnatal Bone Growth (pp. 153-156)

3. Long bones increase in length by interstitial growth of the epiphyseal plate cartilage and its replacement by bone.

4. Appositional growth increases bone diameter/thickness.

Bone Homeostasis: Remodeling and Repair (pp. 156-161)

Bone Remodeling (pp. 156-158)

1. New bone is continually deposited and resorbed in response to hormonal and mechanical stimuli. Together these processes constitute bone remodeling.

2. An osteoid seam appears at areas of new bone formation; calcium salts are deposited a few days later.

3. Multinucleate osteoclasts release lysosomal enzymes and acids on bone surfaces to be resorbed. The dissolved products are transcytosed to the opposite face of the osteoclast for release to the extracellular fluid.

4. The hormonal mechanism of bone remodeling serves blood calcium homeostasis. When blood calcium levels decline, PTH is released and stimulates osteoclasts to digest bone matrix, releasing ionic calcium. When blood calcium levels rise, calcitonin is released, stimulating removal of calcium from the blood. Mechanical stress and gravity acting on the skeleton help maintain skeletal strength. Bones thicken, develop heavier prominences, or rearrange their trabeculae in sites where stressed.

Repair of Fractures (pp. 158-161)

5. Fractures are treated by open or closed reduction. The healing process involves formation of a hematoma, a fibrocartilaginous callus, a bony callus, and bone remodeling, in succession.

6 *Bones and Skeletal Tissues*

Homeostatic Imbalances of Bone (pp. 161-162)

1. Imbalances between bone formation and resorption underlie all skeletal disorders.

2. Osteomalacia and **rickets** occur when bones are inadequately mineralized. The bones become soft and deformed. The most frequent cause is inadequate vitamin D.

3. Osteoporosis is any condition in which bone breakdown outpaces bone formation, causing bones to become weak and porous. Postmenopausal women are particularly susceptible.

4. Paget's disease is characterized by excessive and abnormal bone remodeling.

7 THE SKELETON

CHAPTER SUMMARY

1. The axial skeleton forms the longitudinal axis of the body. Its principal subdivisions are the skull, vertebral column, and bony thorax. It provides support and protection (by enclosure).

2. The appendicular skeleton consists of the bones of the pectoral and pelvic girdles and the limbs. It allows mobility for manipulation and locomotion.

Part 1: The Axial Skeleton

The Skull (pp. 165-180)

1. The skull is formed by 22 bones. The cranium forms the vault and base of the skull, which protect the brain. The facial skeleton provides openings for the respiratory and digestive passages and attachment points for facial muscles.

2. Except for the temporomandibular joints, all bones of the adult skull are joined by immovable sutures.

3. Cranium. The eight bones of the cranium include the paired parietal and temporal bones and the single frontal, occipital, ethmoid, and sphenoid bones (see Table 7.1).

4. Facial bones. The 14 bones of the face include the paired maxillae, zygomatics, nasals, lacrimals, palatines, and inferior conchae and the single mandible and vomer bones (Table 7.1).

5. Orbits and nasal cavity. Both the orbits and the nasal cavities are complicated bony regions formed of several bones.

6. Paranasal sinuses. Paranasal sinuses occur in the frontal, ethmoid, sphenoid, and maxillary bones.

7. Hyoid bone. The hyoid bone, supported in the neck by ligaments, serves as an attachment point for tongue and neck muscles.

The Vertebral Column (pp. 181-188)

1. General characteristics. The vertebral column includes 24 movable vertebrae (7 cervical, 12 thoracic, and 5 lumbar) and the sacrum and coccyx.

2. The fibrocartilage intervertebral discs act as shock absorbers and provide flexibility to the vertebral column.

3. The primary curvatures of the vertebral column are the thoracic and sacral; the secondary curvatures are the cervical and lumbar. Curvatures increase spine flexibility.

4. General structure of vertebrae. With the exception of C_1 and C_2, all vertebrae have a body, two transverse processes, two superior and two inferior articular processes, a spinous process, and a vertebral arch.

5. Regional vertebral characteristics. Special features distinguish the regional vertebrae (see Table 7.2).

The Bony Thorax (pp. 188-190)

1. The bones of the thorax include the 12 rib pairs, the sternum, and the thoracic vertebrae. The bony thorax protects the organs of the thoracic cavity.

2. Sternum. The sternum consists of the fused manubrium, body, and xiphoid process.

3. Ribs. The first seven rib pairs are called true ribs; the rest are called false ribs. Ribs 11 and 12 are floating ribs.

Part 2: The Appendicular Skeleton

The Pectoral (Shoulder) Girdle* (pp. 190-194, 197)

1. Each pectoral girdle consists of one clavicle and one scapula. The pectoral girdles attach the upper limbs to the axial skeleton.

2. Clavicles. The clavicles hold the scapulae laterally away from the thorax. The sternoclavicular joints are the only attachment points of the pectoral girdle to the axial skeleton.

3. Scapulae. The scapulae articulate with the clavicles and with the humerus bones of the arms.

The Upper Limb* (pp. 194-199)

1. Each upper limb consists of 30 bones and is specialized for mobility.

2. Arm/forearm/hand. The skeleton of the arm is composed solely of the humerus; the skeleton of the forearm is composed of the radius and ulna; and the skeleton of the hand consists of the carpals, metacarpals, and phalanges.

The Pelvic (Hip) Girdle* (pp. 199-202, 208)

1. The pelvic girdle, a heavy structure specialized for weight bearing, is composed of two hip bones that secure the lower limbs to the axial skeleton. Together with the sacrum, the hip bones form the basinlike bony pelvis.

2. Each hip bone consists of three fused bones: ilium, ischium, and pubis; the acetabulum occurs at the point of fusion.

3. Ilium/ischium/pubis. The ilium is the superior flaring portion of the hip bone. Each ilium forms a secure joint with the sacrum posteriorly. The ischium is a curved bar of bone; we sit on the ischial tuberosities. The V-shaped pubic bones articulate anteriorly at the pubic symphysis.

4. Pelvic structure and childbearing. The male pelvis is deep and narrow with larger, heavier bones than those of the female. The female pelvis, which forms the birth canal, is shallow and wide.

The Lower Limb* (pp. 203-208)

1. Each lower limb consists of the thigh, leg, and foot and is specialized for weight bearing and locomotion.

2. Thigh. The femur is the only bone of the thigh. Its ball-shaped head articulates with the acetabulum.

3. Leg. The bones of the leg are the tibia, which participates in forming both the knee and ankle joints, and the fibula.

4. Foot. The bones of the foot include the tarsals, metatarsals, and phalanges. The most important tarsals are the calcaneus (heel bone) and the talus, which articulates with the tibia superiorly.

5. The foot is supported by three arches (lateral, medial, and transverse) that distribute body weight to the heel and ball of the foot.

---

*For associated bone markings, see the pages indicated in the section heads.*Media study tools that could provide you additional help in reviewing specific key topics of Chapter 8 are referenced below.*

---

8 JOINTS

CHAPTER SUMMARY

1. Joints, or articulations, are sites where bones meet. Their functions are to hold bones together and to allow various degrees of skeletal movement.

Classification of Joints (p. 211)

1. Joints are classified structurally as fibrous, cartilaginous, or synovial. They are classed functionally as synarthrotic, amphiarthrotic, or diarthrotic.

Fibrous Joints (pp. 211-212)

1. Fibrous joints occur where bones are connected by fibrous tissue; no joint cavity is present. Nearly all fibrous joints are synarthrotic.

2. Sutures/syndesmoses/gomphoses. The major types of fibrous joints are sutures, syndesmoses, and gomphoses.

Cartilaginous Joints (p. 212)

1. In cartilaginous joints, the bones are united by cartilage; no joint cavity is present.

2. Synchondroses/symphyses. Cartilaginous joints include synchondroses and symphyses. Synchondroses are synarthrotic; all symphyses are amphiarthrotic.

Synovial Joints (p. 213)

1. Most body joints are synovial joints, all of which are diarthrotic.

General Structure (pp. 213-215)

2. All synovial joints have a joint cavity enclosed by a fibrous capsule lined with synovial membrane and reinforced by ligaments, articulating bone ends covered with articular cartilage, and synovial fluid in the joint cavity. Some (e.g., the knee) contain fibrocartilage discs that absorb shock.

Bursae and Tendon Sheaths (pp. 215-216)

3. Bursae are fibrous sacs lined with synovial membrane and containing synovial fluid. Tendon sheaths are similar to bursae but are cylindrical structures that surround muscle tendons. Both allow adjacent structures to move smoothly over one another.

Factors Influencing the Stability of Synovial Joints (p. 216)

4. Articular surfaces providing the most stability have large surfaces and deep sockets and fit snugly together.

5. Ligaments prevent undesirable movements and reinforce the joint.

6. The tone of muscles whose tendons cross the joint is the most important stabilizing factor in many joints.

Movements Allowed by Synovial Joints (pp. 216-220)

7. When a skeletal muscle contracts, the insertion (movable attachment) moves toward the origin (immovable attachment). Three common types of movements can occur when muscles contract across joints: (a) gliding movements, (b) angular movements (which include flexion, extension, abduction, adduction, and circumduction), and (c) rotation.

8. Special movements include supination and pronation, inversion and eversion, protraction and retraction, elevation and depression, and opposition.

Types of Synovial Joints (pp. 220-224)

9. Synovial joints differ in their range of motion. Motion may be nonaxial (gliding), uniaxial (in one plane), biaxial (in two planes), or multiaxial (in all three planes).

10. The six major categories of synovial joints are plane joints (movement nonaxial), hinge joints (uniaxial), pivot joints (uniaxial, rotation permitted), condyloid joints (biaxial with angular movements in two planes), saddle joints (biaxial, like condyloid joints, but with freer movement), and ball-and-socket joints (multiaxial and rotational movement).

Selected Synovial Joints (pp. 224-230)

11. The shoulder joint is a ball-and-socket joint formed by the glenoid cavity of the scapula and the humeral head. The most freely movable joint of the body, it allows all angular and rotational movements. Its articular surfaces are shallow. Its capsule is lax and poorly reinforced by ligaments. The tendons of the biceps brachii and rotator cuff muscles help to stabilize it.

12. The hip joint is a ball-and-socket joint formed by the acetabulum of the coxal bone and the femoral head. It is highly adapted for weight bearing. Its articular surfaces are deep and secure. Its capsule is heavy and strongly reinforced by ligaments.

13. The elbow is a hinge joint in which the ulna (and radius) articulates with the humerus, allowing flexion and extension. Its articular surfaces are highly complementary and are the most important factor contributing to joint stability.

14. The knee joint is the largest joint in the body. It is a hinge joint formed by the articulation of the tibial and femoral condyles (and anteriorly by the patella and patellar surface of the femur). Extension, flexion, and (some) rotation are allowed. Its articular surfaces are shallow and condyloid. C-shaped menisci deepen the articular surfaces. The joint cavity is enclosed by a capsule only on the sides and posterior aspects. Several extracapsular ligaments and the intracapsular anterior and posterior cruciate ligaments help prevent displacement of the joint surfaces. Muscle tone of the quadriceps and semimembranosus muscles is important in knee stability.

Homeostatic Imbalances of Joints (pp. 230-232)

Common Joint Injuries (pp. 230-231)

1. Sprains involve stretching or tearing of joint ligaments. Because ligaments are poorly vascularized, healing is slow.

2. Cartilage injuries, particularly of the knee, are common in contact sports and may result from excessive twisting or high pressure. The avascular cartilage is unable to repair itself.

3. Dislocations involve displacement of the articular surfaces of bones. They must be reduced.

Inflammatory and Degenerative Conditions (pp. 231-233)

4. Bursitis and tendonitis are inflammations of a bursa and a tendon sheath, respectively.

5. Arthritis is joint inflammation or degeneration accompanied by stiffness, pain, and swelling. Acute forms generally result from bacterial infection. Chronic forms include osteoarthritis, rheumatoid arthritis, and gouty arthritis.

6. Osteoarthritis is a degenerative condition most common in the aged. Weight-bearing joints are most affected.

7. Rheumatoid arthritis, the most crippling arthritis, is an autoimmune disease involving severe inflammation of the joints.

8. Gouty arthritis, or gout, is joint inflammation caused by the deposit of urate salts in soft joint tissues.

9 MUSCLES AND MUSCLE TISSUE

CHAPTER SUMMARY

References to Interactive Physiology **IP** *appear below specific key chapter topics to help your review.*

Overview of Muscle Tissues (pp. 235-236, 238-239)

Muscle Types (p. 235)

1. Skeletal muscle is attached to the skeleton, is striated, and can be controlled voluntarily.

2. Cardiac muscle forms the heart, is striated, and is controlled involuntarily.

3. Smooth muscle, located chiefly in the walls of hollow organs, is controlled involuntarily. Its fibers are not striated.

Muscle Functions (pp. 235-236)

4. Muscles move internal and external body parts, maintain posture, stabilize joints, and generate heat.

Functional Characteristics of Muscle (p. 236)

5. Special functional characteristics of muscle include excitability, contractility, extensibility, and elasticity.

Skeletal Muscle (pp. 236-265)

Gross Anatomy of a Skeletal Muscle (pp. 236-238)

1. Skeletal muscle fibers (cells) are protected and strengthened by connective tissue coverings. Deep to superficial, these are endomysium, perimysium, and epimysium.

2. Skeletal muscle attachments (origins/insertions) may be direct or indirect via tendons or aponeuroses. Indirect attachments withstand friction better.

Microscopic Anatomy of a Skeletal Muscle Fiber (pp. 238-243)

3. Skeletal muscle fibers are long, striated, and multinucleate.

4. Myofibrils are contractile elements that occupy most of the cell volume. Their banded appearance results from a regular alternation of dark (A) and light (I) bands. Myofibrils are chains of sarcomeres; each sarcomere contains thick (myosin) and thin (actin) myofilaments arranged in a regular array. The heads of myosin molecules form cross bridges that interact with the thin filaments.

5. The sarcoplasmic reticulum (SR) is a system of membranous tubules surrounding each myofibril. Its function is to release and then sequester calcium ions.

6. T tubules are invaginations of the sarcolemma that run between the terminal cisternae of the SR. They allow the electrical stimulus to be delivered quickly to deep cell regions.

Contraction of a Skeletal Muscle Fiber (p. 243)

7. Muscle contraction is defined as the generation of force (tension) by the myosin cross bridges. Shortening of the muscle may or may not occur.

8. According to the sliding filament theory, the thin filaments are pulled toward the sarcomere centers by cross bridge (myosin head) activity of the thick filaments.

9. Sliding of the filaments is triggered by a rise in intracellular calcium ion levels. Troponin binding of calcium moves tropomyosin away from myosin binding sites on actin, allowing cross bridge binding. Myosin ATPases split ATP, which energizes the working strokes and is necessary for cross bridge detachment.

10. Regulation of skeletal muscle cell contraction involves (a) generation and transmission of an action potential along the sarcolemma and (b) excitation-contraction coupling.

11. The action potential is set up when acetylcholine released by a nerve ending binds to ACh receptors on the sarcolemma, causing changes in membrane permeability that allow ion flows that depolarize and then repolarize the membrane. Once initiated, the action potential is self-propagating and unstoppable.

12. In excitation-contraction coupling, the action potential is propagated down the T tubules, causing calcium to be released from the SR into the cell interior. Calcium initiates cross bridge activity and sliding of the filaments. Cross bridge activity ends when calcium is pumped back into the SR.

IP Muscular System CD-ROM; Topic: Sliding Filament Theory, pages 18–29.

Contraction of a Skeletal Muscle (pp. 250-255)

13. A motor unit is one motor neuron and all the muscle cells it innervates. The neuron's axon has several branches, each of which forms a neuromuscular junction with one muscle cell.

14. A skeletal muscle's response to a single brief threshold stimulus is a twitch. A twitch has three phases: the latent period (preparatory events occurring), the period of contraction (the muscle tenses and may shorten), and the period of relaxation (muscle tension declines and the muscle resumes its resting length).

15. Graded responses of muscles to rapid stimuli are wave summation and unfused and fused tetanus. A graded response to increasingly strong stimuli is multiple motor unit summation.

16. Isotonic contractions occur when the muscle shortens (concentric contraction) or lengthens (eccentric contraction) as the load is moved. Isometric contractions occur when muscle tension produces neither shortening nor lengthening.

IP Muscular System CD-ROM; Topic: Contraction of Motor Units, pages 1–11.

Muscle Metabolism (pp. 255-259)

17. The energy source for muscle contraction is ATP, obtained from a coupled reaction of creatine phosphate with ADP and from aerobic and anaerobic metabolism of glucose. When ATP use exceeds its production, muscle fatigue occurs.

18. When ATP is produced by nonaerobic pathways, lactic acid accumulates and an oxygen debt occurs. To return the muscles to their resting state, ATP must be produced aerobically and used to regenerate creatine phosphate and glycogen reserves and to oxidize accumulated lactic acid.

19. Only about 40% of energy released during ATP hydrolysis powers contractile activity. The rest is liberated as heat.

IP Muscular System CD-ROM; Topic: Muscle Metabolism, pages 1–7.

9 Muscles and Muscle Tissue

Force, Velocity, and Duration of Muscle Contraction (p. 259)

20. The force of muscle contraction is affected by the number and size of contracting muscle cells (the more and the larger the cells, the greater the force), the series-elastic elements, and the degree of muscle stretch.

21. In twitch contractions, the external tension exerted on the load is always less than the internal tension. When a muscle is tetanized, the external tension equals the internal tension.

22. When the thick and thin filaments are slightly overlapping, the muscle can generate maximum force. With excessive increase or decrease in muscle length, force declines.

23. Factors determining the velocity and duration of muscle contraction include the load (the greater the load, the slower the contraction) and muscle fiber types.

24. There are three types of muscle fibers: (1) fast glycolytic (fatigable) fibers, (2) slow oxidative (fatigue-resistant) fibers, and (3) intermediate fast oxidative (fatigue-resistant) fibers. Most muscles contain a mixture of fiber types.

Effect of Exercise on Muscles (pp. 262-265)

25. Regular aerobic exercise results in increased efficiency, endurance, strength, and resistance to fatigue of skeletal muscles and more efficient cardiovascular, respiratory, and neuromuscular functioning.

26. Resistance exercises cause skeletal muscle hypertrophy and large gains in skeletal muscle strength.

27. Complete immobilization of muscles leads to muscle weakness and severe atrophy.

28. Improper training and excessive exercise result in overuse injuries, which may be disabling.

Smooth Muscle (pp. 265-270)

Arrangement and Microscopic Structure of Smooth Muscle Fibers (pp. 265-266)

1. Smooth muscle fibers are spindle shaped and uninucleate; they display no striations.

2. Smooth muscle cells are most often arranged in sheets. They lack elaborate connective tissue coverings.

3. The SR is poorly developed; T tubules are absent. Actin and myosin filaments are present, but sarcomeres are not. Intermediate filaments and dense bodies form an intracellular network that harnesses the pull generated during cross bridge activity and transfers it to the extra–
cellular matrix.

Contraction of Smooth Muscle (pp. 266-270)

4. Smooth muscle fibers may be electrically coupled by gap junctions; the pace of contraction may be set by pacemaker cells.

5. Smooth muscle contraction is energized by ATP and is activated by a calcium pulse. However, calcium binds (to calmodulin) on the thick filaments rather than to troponin on the thin filaments.

6. Smooth muscle contracts for extended periods at low energy cost and without fatigue.

7. Neurotransmitters of the autonomic nervous system may inhibit or stimulate smooth muscle fibers. Smooth muscle contraction may also be initiated by pacemaker cells, hormones, or other local chemical factors that influence intracellular calcium levels, and by mechanical stretch.

8. Special features of smooth muscle contraction include the stress-relaxation response, the ability to generate large amounts of force when extensively stretched, and hyperplasia under certain conditions.

Types of Smooth Muscle (p. 270)

9. Single-unit smooth muscle has electrically coupled fibers that contract synchronously and often spontaneously.

10. Multiunit smooth muscle has independent, well-innervated fibers that lack gap junctions and pacemaker cells. Stimulation is via autonomic nerves (or hormones). Multiunit muscle contractions are rarely synchronous.

10 THE MUSCULAR SYSTEM

CHAPTER SUMMARY

Interactions of Skeletal Muscles in the Body (p. 273)

1. Skeletal muscles are arranged in opposing groups across body joints so that one group can reverse or modify the action of the other.

2. Muscles are classified as prime movers or agonists (bear the chief responsibility for producing movement), antagonists (reverse, or oppose, the action of another muscle), synergists (aid a prime mover by effecting the same action, stabilizing joints, or preventing undesirable movements), and fixators (function to immobilize a bone or a muscle's origin).

Naming Skeletal Muscles (pp. 273-274)

1. Criteria used to name muscles include a muscle's location, shape, relative size, fiber (fascicle) direction, number of origins, attachment sites (origin/insertion), and action. Several criteria are combined to name some muscles.

Muscle Mechanics: Importance of Leverage and Fascicle Arrangement (pp. 274-278)

1. A lever is a bar that moves on a fulcrum. When an effort is applied to the lever, a load is moved. In the body, bones are the levers, joints are the fulcrums, and the effort is exerted by skeletal muscles at their insertions.

2. When the effort is farther from the fulcrum than is the load, the lever operates at a mechanical advantage (is slow and strong). When the effort is exerted closer to the fulcrum than is the load, the lever operates at a mechanical disadvantage (is fast and promotes a large degree of movement).

3. First-class levers (effort-fulcrum-load) may operate at a mechanical advantage or disadvantage. Second-class levers (fulcrum-load-effort) all operate at a mechanical advantage. Third-class levers (fulcrum-effort-load) always operate at a mechanical disadvantage.

4. Common patterns of fascicle arrangement are parallel, fusiform, pennate, convergent, and circular. Muscles with fibers that run parallel to the long axis of the muscle shorten most; stocky pennate muscles shorten little but are the most powerful muscles.

Major Skeletal Muscles of the Body (pp. 278-331)

1. Muscles of the head that produce facial expression tend to be small and to insert into soft tissue (skin and other muscles) rather than into bone. These muscles open and close the eyes and mouth, compress the cheeks, allow smiling and other types of facial language (see Table 10.1*).

2. Muscles of the head involved in mastication include the masseter and temporalis that elevate the mandible and two deep muscle pairs that promote grinding and sliding jaw movements (see Table 10.2*). Extrinsic muscles of the tongue anchor the tongue and control its movements.

3. Deep muscles of the anterior neck promote swallowing movements, including elevation/depression of the hyoid bone, closure of the respiratory passages, and peristalsis of the pharynx (see Table 10.3*).

4. Neck muscles and deep muscles of the vertebral column promote head and trunk movements (see Table 10.4*). The deep muscles of the posterior trunk can extend large regions of the vertebral column (and head) simultaneously. Head flexion and rotation are effected by the anteriorly located sternocleidomastoid and scalene muscles.

5. Movements of quiet breathing are promoted by the diaphragm and the external intercostal muscles of the thorax (see Table 10.5*). Downward movement of the diaphragm increases intra-abdominal pressure.

6. The four muscle pairs forming the abdominal wall are layered like plywood to form a natural muscular girdle that protects, supports, and compresses abdominal contents. These muscles also flex and laterally rotate the trunk (see Table 10.6*).

7. Muscles of the pelvic floor and perineum (see Table 10.7*) support the pelvic viscera, resist increases in intra-abdominal pressure, inhibit urination and defecation, and aid erection.

8. Except for the pectoralis major and the latissimus dorsi, the superficial muscles of the thorax act to fix or promote movements of the scapula (see Table 10.8*). Scapular movements are effected primarily by posterior thoracic muscles.

9. Nine muscles cross the shoulder joint to effect movements of the humerus (see Table 10.9*). Of these, seven originate on the scapula and two arise from the axial skeleton. Four muscles contribute to the "rotator cuff" helping to stabilize the multiaxial shoulder joint. Generally speaking, muscles located anteriorly flex, rotate, and adduct the arm. Those located posteriorly extend, rotate, and adduct the arm. The deltoid muscle of the shoulder is the prime mover of shoulder abduction.

10. Muscles causing movements of the forearm form the flesh of the arm (see Table 10.10*). Anterior arm muscles are forearm flexors; posterior muscles are forearm extensors.

11. Movements of the wrist, hand, and fingers are effected mainly by muscles originating on the forearm (see Table 10.11*). Except for the two pronator muscles, the anterior forearm muscles are wrist and/or finger flexors; those of the posterior compartment are wrist and finger extensors.

12. The intrinsic muscles of the hand aid in precise movements of the fingers (Table 10.13*) and in opposition, which helps us grip things in our palms. These small muscles are divided into thenar, hypothenar, and mid-palmar groups.

13. Muscles crossing the hip and knee joints effect thigh and leg movements (see Table 10.14*). Anteromedial muscles include thigh flexors and/or adductors and knee extensors. Muscles of the posterior gluteal region extend and rotate the thigh. Posterior thigh muscles extend the hip and flex the knee.

14. Muscles in the leg act on the ankle and toes (see Table 10.15*). Anterior compartment muscles are largely ankle dorsiflexors. Lateral compartment muscles are plantar flexors and foot everters. Those of the posterior leg are plantar flexors. Intrinsic foot muscles support foot arches and help effect toe movements.

15. The intrinsic muscles of the foot (Table 10.17*) support the foot arches and help move the toes. Most occur in the sole, arranged in four layers. They resemble the small muscles in the palm of the hand.

---

*See specific table cited for detailed description of each muscle in the group.

11 FUNDAMENTALS OF THE NERVOUS SYSTEM

CHAPTER SUMMARY

References to Interactive Physiology **IP** *appear below specific key chapter topics to help your review.*

1. The nervous system bears a major responsibility for maintaining body homeostasis. Its chief functions are to monitor, integrate, and respond to information in the environment.

Organization of the Nervous System (pp. 334-335)

1. The nervous system is divided anatomically into the central nervous system (brain and spinal cord) and the peripheral nervous system (cranial and spinal nerves and ganglia).

2. The major functional divisions of the nervous system are the sensory (afferent) division, which conveys impulses to the CNS, and the motor (efferent) division, which conveys impulses from the CNS.

3. The efferent division includes the somatic (voluntary) system, which serves skeletal muscles, and the autonomic (involuntary) system, which innervates smooth and cardiac muscle and glands.

Histology of Nervous Tissue (pp. 335-343)

Supporting Cells (Neuroglia) (pp. 335-337)

1. Supporting cells (neuroglia) segregate and insulate neurons and assist neurons in various other ways.

2. CNS supporting cells include astrocytes, microglia, ependymal cells, and oligodendrocytes. Schwann cells and satellite cells are supporting cells found in the PNS.

Neurons (pp. 337-343)

3. Neurons have a cell body and cytoplasmic processes called axons and dendrites.

4. A bundle of nerve fibers is called a tract in the CNS and a nerve in the PNS. A collection of cell bodies is called a nucleus in the CNS and a ganglion in the PNS.

5. The cell body is the biosynthetic (and receptive) center of the neuron. Except for those found in ganglia, cell bodies are found in the CNS.

6. Some neurons have many dendrites, receptive sites that conduct signals from other neurons toward the nerve cell body. With few exceptions, all neurons have one axon, which generates and conducts nerve impulses away from the nerve cell body. Terminal endings of axons release neurotransmitter.

7. Transport along axons occurs via different mechanisms. Best understood is the bidirectional, ATP-dependent process that moves particulate material, neurotransmitters, and enzymes toward the axonal terminals and conducts substances destined for degradation back to the cell body. It involves microtubules, microfilaments, and motor proteins.

8. Large nerve fibers (axons) are myelinated. The myelin sheath is formed in the PNS by Schwann cells and in the CNS by oligodendrocytes. The sheath has gaps called nodes of Ranvier. Unmyelinated fibers are surrounded by supporting cells, but the membrane-wrapping process does not occur.

9. Anatomically, neurons are classified according to the number of processes issuing from the cell body as multipolar, bipolar, or unipolar.

10. Functionally, neurons are classified according to the direction of nerve impulse conduction. Sensory neurons conduct impulses toward the CNS, motor neurons conduct away from the CNS, and interneurons (association neurons) lie between sensory and motor neurons in the neural pathways.

IP Nervous System I CD-ROM; Topic: Anatomy Review Pages 1–12.

Neurophysiology (pp. 343-366)

Basic Principles of Electricity (pp. 343-344)

1. The measure of the potential energy of separated electrical charges is called voltage (*V*) or potential. Current (*I*) is the flow of electrical charge from one point to another. Resistance (*R*) is hindrance to current flow. The relationship among these is given by Ohm's law: $I = V/R$.

2. In the body, electrical charges are provided by ions; cellular plasma membranes provide resistance to ion flow. The membranes contain passive (open) and active (gated) channels.

IP Nervous System I CD-ROM; Topic: Ion Channels, Pages 1–10.

The Resting Membrane Potential: The Polarized State (pp. 345-346)

3. A resting neuron exhibits a resting membrane potential, which is −70 mV (inside negative), owing to differences in sodium and potassium ion concentrations inside and outside the cell.

4. The ionic differences result from greater permeability of the membrane to potassium than to sodium and from the operation of the sodium-potassium pump, which ejects $3Na^+$ from the cell for each $2K^+$ transported in.

IP Nervous System I CD-ROM; Topic: The Membrane Potential, Pages 1–16.

Membrane Potentials That Act as Signals (pp. 346-354)

5. Depolarization is a reduction in membrane potential (inside becomes less negative); hyperpolarization is an increase in membrane potential (inside becomes more negative).

6. Graded potentials are small, brief, local changes in membrane potential that act as short-distance signals. The current produced dissipates with distance.

7. An action potential, or nerve impulse, is a large, but brief, depolarization signal (and polarity reversal) that underlies long-distance neural communication. It is an all-or-none phenomenon.

8. Generation of an action potential involves three phases: (1) Increase in sodium permeability and reversal of the membrane potential to approximately +30 mV (inside positive). Local depolarization opens voltage-sensitive sodium gates; at threshold, depolarization becomes self-generating (driven by sodium ion influx). (2) Decrease in sodium permeability. (3) Increase in potassium permeability. Repolarization is ongoing during phases 2 and 3.

9. In nerve impulse propagation, each action potential provides the depolarizing stimulus for triggering an action potential in the next membrane patch. Regions that have just generated action potentials are refractory; hence, the nerve impulse is propagated in one direction only.

10. If threshold is reached, an action potential is generated; if not, depolarization remains local.

11. Action potentials are independent of stimulus strength: strong stimuli cause action potentials to be generated more frequently but not with greater amplitude.

12. During the absolute refractory period, a neuron cannot respond to another stimulus because it is already generating an action potential. During the relative refractory period the neuron's threshold is elevated because repolarization is ongoing.

13. In unmyelinated fibers, action potentials are produced in a wave all along the axon, that is, by continuous conduction. In myelinated fibers, action potentials are generated only at nodes of Ranvier and are propagated more rapidly by saltatory conduction.

IP Nervous System I CD-ROM; Topic: The Action Potential, Pages 1–18.

The Synapse (p. 354)

14. A synapse is a functional junction between neurons. The information-transmitting neuron is the presynaptic neuron; the neuron beyond the synapse is the postsynaptic neuron.

15. Electrical synapses allow ions to flow directly from one neuron to another; the cells are electrically coupled.

16. Chemical synapses are sites of neurotransmitter release and binding. When the impulse reaches the presynaptic axonal terminals, voltage-regulated Ca^{2+} channels open, and Ca^{2+} enters the cell and mediates neurotransmitter release. Neurotransmitters diffuse across the synaptic cleft and attach to postsynaptic membrane receptors, opening ion channels. After binding, the neurotransmitters are removed from the synapse by enzymatic breakdown or by reuptake into the presynaptic terminal or astrocytes.

IP Nervous System II CD-ROM; Topics: Anatomy Review, Pages 1–9, Ion Channels, Pages 1–8, Synaptic Transmission, Pages 1–7.

Postsynaptic Potentials and Synaptic Integration (pp. 357-360)

17. Binding of neurotransmitter at excitatory chemical synapses results in local graded depolarizations called EPSPs, caused by the opening of channels that allow simultaneous passage of Na^+ and K^+.

18. Neurotransmitter binding at inhibitory chemical synapses results in hyperpolarizations called IPSPs, caused by the opening of K^+ or Cl^- gates or both. IPSPs drive the membrane potential farther from threshold.

19. EPSPs and IPSPs summate temporally and spatially. The membrane of the axon hillock acts as a neuronal integrator.

20. Synaptic potentiation, in which the postsynaptic neuron's response is enhanced, is produced by intense repeated stimulation. Ionic calcium appears to mediate such effects, which may be the basis of learning.

21. Presynaptic inhibition is mediated by axoaxonal synapses that reduce the amount of neurotransmitter released by the inhibited neuron. Neuromodulation occurs when chemicals (often other than neurotransmitters) alter neuronal or neurotransmitter activity.

IP Nervous System II CD-ROM; Topic: Synaptic Potentials and Cellular Intergration, Pages 1–10.

Neurotransmitters and Their Receptors (pp. 360-366)

22. The major classes of neurotransmitters based on chemical structure are acetylcholine, biogenic amines, amino acids, and peptides.

23. Functionally, neurotransmitters are classified as (1) inhibitory or excitatory (or both) and (2) direct or indirect. Direct-acting neurotransmitters cause channel opening. Indirect-acting neurotransmitters act through second messengers and cause complex changes in target cell metabolism.

24. Neurotransmitter receptors are either channel-linked receptors that open ion channels, leading to fast changes in membrane potential, or G protein–linked receptors that oversee slow synaptic responses mediated by G proteins and intracellular second messengers. Second messengers most often activate kinases, which in turn act on ion channels or activate other proteins.

IP Nervous System II CD-ROM; Topic: Synaptic Transmission Pages 6–15.

Basic Concepts of Neural Integration (pp. 366-368)

Organization of Neurons: Neuronal Pools (pp. 366-367)

1. CNS neurons are organized into several types of neuronal pools, each with distinguishing patterns of synaptic connections called circuits.

Types of Circuits (pp. 367-368)

2. The four basic circuit types are diverging, converging, reverberating, and parallel after-discharge.

Patterns of Neural Processing (p. 368)

3. In serial processing, one neuron stimulates the next in sequence, producing specific, predictable responses, as in spinal reflexes. A reflex is a rapid, involuntary motor response to a stimulus.

4. Reflexes are mediated over neural pathways called reflex arcs. The minimum number of elements in a reflex arc is five: receptor, sensory neuron, integration center, motor neuron, and effector.

5. In parallel processing, which underlies complex mental functions, impulses are sent along several pathways to different integration centers.

12 THE CENTRAL NERVOUS SYSTEM

CHAPTER SUMMARY

The Brain (pp. 371-395)

1. The brain provides for voluntary movements, interpretation and integration of sensation, consciousness, and cognitive function.

Embryonic Development of the Brain (pp. 371-374)

2. The brain develops from the rostral portion of the embryonic neural tube.

3. Early brain development yields the three primary brain vesicles: the prosencephalon (cerebral hemispheres and diencephalon), mesencephalon (midbrain), and rhombencephalon (pons, medulla, and cerebellum).

4. Cephalization results in the envelopment of the diencephalon and superior brain stem by the cerebral hemispheres.

Regions and Organization of the Brain (p. 374)

5. In a widely used system, the adult brain is divided into the cerebral hemispheres, diencephalon, brain stem, and cerebellum.

6. The cerebral hemispheres and cerebellum have gray matter nuclei surrounded by white matter and an outer cortex of gray matter. The diencephalon and brain stem lack a cortex.

Ventricles of the Brain (p. 374)

7. The brain contains four ventricles filled with cerebrospinal fluid. The lateral ventricles are in the cerebral hemispheres; the third ventricle is in the diencephalon; the fourth ventricle is in the brain stem and connects with the central canal of the spinal cord.

The Cerebral Hemispheres (pp. 374-385)

8. The two cerebral hemispheres exhibit gyri, sulci, and fissures. The longitudinal fissure partially separates the hemispheres; other fissures or sulci subdivide each hemisphere into lobes.

9. Each cerebral hemisphere consists of the cerebral cortex, the cerebral white matter, and the basal nuclei (ganglia).

10. Each cerebral hemisphere receives sensory impulses from, and dispatches motor impulses to, the opposite side of the body. The body is represented in an upside-down fashion in the sensory and motor cortices.

11. Functional areas of the cerebral cortex include (1) motor areas: primary motor and premotor areas of the frontal lobe, the frontal eye field, and Broca's area in the frontal lobe of one hemisphere (usually the left); (2) sensory areas: primary somatosensory cortex, somatosensory association cortex, and gustatory area, in the parietal lobe; visual areas in the occipital lobe; olfactory and auditory areas in the temporal lobe; and a vestibular area in the insula; (3) association areas: prefrontal cortex in the frontal lobe; general interpretation area at junction of temporal, parietal, and occipital lobe on one side (usually the left); language areas, including the lateral prefrontal cortex, a large portion of the temporal lobe, Broca's area, Wernicke's area in one hemisphere (temporal lobe) only, usually the left, and affective language areas in one hemisphere (usually the right).

12. The cerebral hemispheres show lateralization of cortical function. In most people, the left hemisphere is dominant (i.e., specialized for language and mathematical skills); the right hemisphere is more concerned with visual-spatial skills and creative endeavors.

13. Fiber tracts of the cerebral white matter include commissures, association fibers, and projection fibers.

14. The paired basal nuclei (also called basal ganglia) include the lentiform nucleus (globus pallidus and putamen) and caudate nucleus. The basal nuclei are subcortical nuclei that help control muscular movements. Functionally they are closely associated with the substantia nigra of the midbrain.

The Diencephalon (pp. 385-388)

15. The diencephalon consists of the thalamus, hypothalamus, and epithalamus and encloses the third ventricle.

16. The thalamus is the major relay station for (1) sensory impulses ascending to the sensory cortex, (2) inputs from subcortical motor nuclei and the cerebellum traveling to the cerebral motor cortex, and (3) impulses traveling to association cortices from lower centers.

17. The hypothalamus is an important autonomic nervous system control center and a pivotal part of the limbic system. It maintains water balance and regulates thirst, eating behavior, gastrointestinal activity, body temperature, and the activity of the anterior pituitary gland.

18. The epithalamus consists of the pineal gland and the choroid plexus of the third ventricle.

The Brain Stem (pp. 388-392)

19. The brain stem includes the midbrain, pons, and medulla oblongata.

20. The midbrain contains the corpora quadrigemina (visual and auditory reflex centers), the red nucleus (subcortical motor centers), and the substantia nigra. The periaqueductal gray matter elicits the fear response and contains the motor nuclei of cranial nerves III and IV. The cerebral peduncles on its ventral face house the pyramidal fiber tracts. The midbrain surrounds the cerebral aqueduct.

21. The pons is mainly a conduction area. Its nuclei contribute to regulation of respiration and cranial nerves V–VII.

22. The pyramids (descending corticospinal tracts) form the ventral face of the medulla oblongata; these fibers cross over (decussation of the pyramids) before entering the spinal cord. Important nuclei in the medulla regulate respiratory rhythm, heart rate, and blood pressure and serve cranial nerves VIII–XII. The olivary nucleus and cough, sneezing, swallowing, and vomiting centers are in the medulla.

The Cerebellum (pp. 392-394)

23. The cerebellum consists of two hemispheres, marked by convolutions and separated by the vermis. It is connected to the brain stem by superior, middle, and inferior peduncles.

24. The cerebellum processes and interprets impulses from the motor cortex and sensory pathways and coordinates motor activity so that smooth, well-timed movements occur. It also plays a poorly understood role in cognition.

Functional Brain Systems (pp. 394-395)

25. The limbic system consists of numerous structures that encircle the diencephalon. It is the "emotional-visceral brain." It also plays a role in memory.

26. The reticular formation includes nuclei spanning the length of the brain stem. It maintains the alert state of the cerebral cortex (RAS) and its motor nuclei serve both somatic and visceral motor activities.

Higher Mental Functions (p. 395)

Brain Wave Patterns and the EEG (pp. 396-397)

1. Patterns of electrical activity of the brain are called brain waves; a record of this activity is an electroencephalogram (EEG). Brain wave patterns, identified by their frequencies, include alpha, beta, theta, and delta waves.

2. Epilepsy results from abnormal electrical activity of brain neurons. Involuntary muscle contractions and sensory auras are typical during such seizures.

Consciousness (p. 397)

3. Consciousness includes sensory perception, initiation and control of voluntary movement, and higher mental processing capabilities. It is described clinically on a continuum from alertness to drowsiness to stupor and finally to coma.

4. Human consciousness is thought to involve holistic information processing, which is (1) not localizable, (2) superimposed on other types of neural activity, and (3) totally interconnected.

5. Fainting (syncope) is a temporary loss of consciousness that usually reflects inadequate blood delivery to the brain. Coma is loss of consciousness in which the victim is unresponsive to stimuli.

Sleep and Sleep-Awake Cycles (pp. 397-400)

6. Sleep is a state of altered consciousness from which one can be aroused by stimulation. The two major types of sleep are non-rapid eye movement (NREM) sleep and rapid eye movement (REM) sleep.

7. During stages 1–4 of NREM sleep, brain waves become more irregular and increase in amplitude until delta wave sleep (stage 4) is achieved. REM sleep is indicated by a return to a stage 1 EEG. During REM, the eyes move rapidly under the lids. NREM and REM sleep alternate throughout the night.

8. Slow-wave sleep (stage 4 of NREM) appears to be restorative. REM sleep is important for emotional stability.

9. REM occupies half of an infant's sleep time and then declines to about 25% of sleep time by the age of ten years. Time spent in slow-wave sleep declines steadily throughout life.

10. Narcolepsy is involuntary lapses into sleep that occur without warning during waking periods. Insomnia is a chronic inability to obtain the amount or quality of sleep needed to function adequately. Sleep apnea is a temporary cessation of breathing during sleep due to hypoxia.

Memory (pp. 400-402)

11. Memory is the ability to recall one's thoughts. It is essential for learning and is part of consciousness.

12. Memory storage has two stages: short-term memory (STM) and long-term memory (LTM). Transfer of information from STM to LTM takes minutes to hours, but more time is required for LTM consolidation.

13. Fact memory is the ability to learn and consciously remember information. Skill memory is the learning of motor skills, which are then performed without conscious thought.

14. Fact (declarative) memory appears to involve the hippocampus, amygdala, diencephalon, basal forebrain, and prefrontal cortex. Skill (procedural) memory pathways are mediated by the corpus striatum.

15. The nature of memory traces in the human brain is not fully known, but NMDA receptors (essentially calcium channels), activated sequentially by depolarization and glutamate binding, play a major role in long-term potentiation (LTP). The calcium influx that follows NMDA receptor activation mobilizes enzymes that mediate events necessary for memory consolidation.

Protection of the Brain (pp. 402-406)

27. The brain is protected by bone, meninges, cerebrospinal fluid, and the blood-brain barrier.

28. The meninges from superficial to deep are the dura mater, the arachnoid mater, and the pia mater. They enclose the brain and spinal cord and their blood vessels. Inward folds of the inner layer of the dura mater secure the brain to the skull.

29. Cerebrospinal fluid (CSF), formed by the choroid plexuses from blood plasma, circulates through the ventricles and into the subarachnoid space. It returns to the dural venous sinuses via the arachnoid villi. CSF supports and cushions the brain and cord and helps to nourish them.

30. The blood-brain barrier reflects the relative impermeability of the epithelium of capillaries of the brain. It allows water, respiratory gases, essential nutrients, and fat-soluble molecules to enter the neural tissue, but prevents entry of other, water-soluble, potentially harmful substances.

Homeostatic Imbalances of the Brain (pp. 406-408)

31. Head trauma may cause brain injuries called concussions (reversible damage) or contusions (irreversible damage). When the brain stem is affected, unconsciousness (temporary or permanent) occurs. Trauma-induced brain injuries may be aggravated by intracranial hemorrhage or cerebral edema, both of which compress brain tissue.

32. Cerebrovascular accidents (strokes) result when blood circulation to brain neurons is impaired and brain tissue dies. The result may be hemiplegia, sensory deficits, or speech impairment.

33. Alzheimer's disease is a degenerative brain disease in which beta amyloid peptide deposits and neurofibrillar tangles appear. Marked by a deficit of ACh, it results in slow, progressive loss of memory and motor control and increasing dementia.

34. Parkinson's disease and Huntington's disease are neurodegenerative disorders of the basal nuclei. Both involve abnormalities of the neurotransmitter dopamine (too little or too much secreted) and are characterized by abnormal movements.

The Spinal Cord (pp. 408-419)

Gross Anatomy and Protection of the Spinal Cord (pp. 408-410)

1. The spinal cord, a two-way impulse conduction pathway and a reflex center, resides within the vertebral column and is protected by meninges and cerebrospinal fluid. It extends from the foramen magnum to the end of the first lumbar vertebra.

2. Thirty-one pairs of spinal nerve roots issue from the cord. The cord is enlarged in the cervical and lumbar regions, where spinal nerves serving the limbs arise.

12 *The Central Nervous System*

Embryonic Development of the Spinal Cord (p. 410)

3. The spinal cord develops from the neural tube. Its gray matter forms from the alar and basal plates. Fiber tracts form the outer white matter. The neural crest forms the sensory (dorsal root) ganglia.

Cross-Sectional Anatomy of the Spinal Cord (pp. 410-418)

4. The central gray matter of the cord is H shaped. Anterior horns mainly contain somatic motor neurons. Lateral horns contain visceral (autonomic) motor neurons. Posterior horns contain interneurons.

5. Axons of neurons of the lateral and anterior horns emerge in common from the cord via the ventral roots. Axons of sensory neurons (with cell bodies located in the dorsal root ganglion) enter the posterior aspect of the cord and form the dorsal roots. The ventral and dorsal roots combine to form the spinal nerves.

6. Each side of the white matter of the cord has posterior, lateral, and anterior columns (funiculi), and each funiculus contains a number of ascending and descending tracts. All tracts are paired and most decussate.

7. Ascending (sensory) tracts include the fasciculi gracilis and cuneatus, spinothalamic tracts, and spinocerebellar tracts.

8. Descending tracts include the pyramidal tracts (anterior and lateral corticospinal tracts) and a number of motor tracts originating from subcortical motor nuclei.

Spinal Cord Trauma and Disorders (pp. 418-419)

9. Injury to the anterior horn neurons or the ventral roots results in flaccid paralysis. (Injury to the upper motor neurons in the brain results in spastic paralysis.) If the dorsal roots or sensory tracts are damaged, paresthesias occur.

10. Poliomyelitis results from inflammation and destruction of the anterior horn neurons by the poliovirus. Paralysis and muscle atrophy ensue.

11. Amyotrophic lateral sclerosis results from destruction of the anterior horn neurons and the pyramidal tract. The victim loses the ability to swallow, speak, and breathe. Death occurs within five years.

Diagnostic Procedures for Assessing CNS Dysfunction (p. 419)

1. Diagnostic procedures used to assess neurological condition and function range from routine reflex testing to sophisticated techniques such as pneumoencephalography, cerebral angiography, CT scans, MRI scans, and PET scans.

13 THE PERIPHERAL NERVOUS SYSTEM AND REFLEX ACTIVITY

CHAPTER SUMMARY

Part 1: Sensory Receptors and Sensation

1. The peripheral nervous system consists of sensory receptors, nerves conducting impulses to and from the CNS, their associated ganglia, and motor endings.

Overview: The Route to Sensation and Perception (pp. 422-423)

2. Sensation (awareness and localization of a stimulus) and perception (assigning meaning to the sensation) are functions of the cerebral cortex of the brain.

3. The events that must occur are as follows: A stimulus excites a receptor; impulses are delivered to the appropriate region of the cerebral cortex for stimulus localization and perception; and, finally, interpretation of sensor input occurs in the cerebral cortex.

Overview of Sensory Receptors (pp. 423-424)

1. Sensory receptors are specialized to respond to environmental changes (stimuli).

2. Sensory receptors include the simple (general) receptors for pain, touch, pressure, and temperature found in the skin, as well as those found in skeletal muscles and tendons and in the visceral organs. Complex receptors (sense organs), consisting of sensory receptors and other cells, serve the special senses (vision, hearing, equilibrium, smell, and taste).

3. Receptors are classified according to stimulus detected as mechanoreceptors, thermoreceptors, photoreceptors, chemoreceptors, and nociceptors, and according to location as exteroceptors, interoceptors, and proprioceptors.

Simple Receptors: The General Senses (pp. 424-426)

1. The general sensory receptors are classified structurally as free (unencapsulated) or encapsulated dendritic endings of sensory neurons. The free endings are mainly receptors for temperature and pain, although two are for light touch (Merkel discs and root hair plexuses). The encapsulated dendritic endings, which are mechanoreceptors, include Meissner's corpuscles, Pacinian corpuscles, Krause's end bulbs, Ruffini's corpuscles, muscle spindles, Golgi tendon organs, and joint kinesthetic receptors.

Complex Receptors: The Special Senses (pp. 426-461)

Taste Buds and the Sense of Taste (pp. 426-428)

1. The taste buds are scattered in the oral cavity and pharynx but are most abundant on the tongue papillae.

2. Gustatory cells, the receptor cells of the taste buds, have gustatory hairs (microvilli) that serve as the receptor regions. The gustatory cells are excited by the binding of chemicals to receptors on their microvilli.

3. There are four recognized basic taste qualities—sweet, sour, salty, and bitter.

4. The taste sense is served by cranial nerves VII, IX, and X, which send impulses to the solitary nucleus of the medulla. From there, impulses are sent to the thalamus and the taste cortex.

The Olfactory Epithelium and the Sense of Smell (pp. 428-430)

5. The olfactory epithelium is located in the roof of the nasal cavity. The receptor cells are ciliated bipolar neurons. Their axons are the filaments of the olfactory nerve (cranial nerve I).

6. Individual olfactory neurons show a range of responsiveness to different chemicals. Olfactory cells bearing the same odorant receptors synapse in the same glomerulus type.

7. Olfactory neurons are excited by volatile chemicals that bind to receptors in the olfactory cilia.

8. Action potentials of the olfactory nerve filaments are transmitted to the olfactory bulb where the filaments synapse with mitral cells. The mitral cells send impulses via the olfactory tract to the olfactory cortex. Fibers carrying impulses from the olfactory receptors also project to the limbic system.

The Eye and Vision (p. 430)

1. The eye is enclosed in the bony orbit and cushioned by fat.

Accessory Structures of the Eye (pp. 431-433)

2. Eyebrows help to shade and protect the eyes.

3. Eyelids protect and lubricate the eyes by reflex blinking. Within the eyelids are the orbicularis oculi and levator palpebrae muscles, modified sebaceous glands, and sweat glands.

4. The conjunctiva is a mucosa that lines the eyelids and covers the anterior eyeball surface. Its mucus lubricates the eyeball surface.

5. The lacrimal apparatus consists of the lacrimal gland (which produces a saline solution containing mucus, lysozyme, and antibodies), the lacrimal canals, the lacrimal sac, and the nasolacrimal duct.

6. The extrinsic eye muscles (superior, inferior, lateral, and medial rectus and superior and inferior oblique) move the eyeballs.

Structure of the Eyeball (pp. 433-439)

7. The wall of the eyeball is made up of three layers, or tunics. The outermost fibrous tunic consists of the sclera and the cornea. The sclera protects the eye and gives it shape; the cornea allows light to enter the eye.

8. The middle pigmented vascular tunic (uvea) consists of the choroid, the ciliary body, and the iris. The choroid provides nutrients to the eye and prevents light scattering within the eye. The ciliary muscles of the ciliary body control lens shape; the iris controls the size of the pupil.

9. The sensory tunic, or retina, consists of an outer pigmented layer and an inner nervous layer. The neural layer contains photoreceptors (rods and cones), bipolar cells, and ganglion cells. Ganglion cell axons form the optic nerve, which exits via the optic disc ("blind spot").

10. The outer segments of the photoreceptors contain the light-absorbing pigment in membrane-bounded discs.

11. The posterior segment, behind the lens, contains vitreous humor, which helps support the eyeball and keep the retina in place. The anterior segment, anterior to the lens, is filled with aqueous humor, formed by capillaries in the ciliary processes and drained into the scleral venous sinus. Aqueous humor is a major factor in maintaining intraocular pressure.

12. The biconvex lens is suspended within the eye by the suspensory ligaments attached to the ciliary body. It is the only adjustable refractory structure of the eye.

Physiology of Vision (pp.439-447)

13. Light is made up of those wavelengths of the electromagnetic spectrum that excite the photoreceptors.

14. Light is refracted (bent) when passing from one transparent medium to another of different density, or when it strikes a curved surface. Concave lenses disperse light; convex lenses converge light and bring its rays to a focal point.

15. As light passes through the eye, it is bent by the cornea and the lens and focused on the retina. The cornea accounts for most of the refraction, but the lens allows active focusing for different distances.

16. Focusing for distance vision requires no special movements of the eye structures. Focusing for close-up vision requires accommodation (bulging of the lens), pupillary constriction, and convergence of the eyeballs. All three reflexes are controlled by cranial nerve III.

17. Refractory problems include myopia, hyperopia, and astigmatism.

18. Rods respond to low-intensity light and provide night and peripheral vision. Cones are bright-light, high-discrimination receptors that provide for color vision. Anything that must be viewed precisely is focused on the cone-rich fovea centralis.

19. The light-absorbing molecule retinal is combined with various opsins in the visual pigments. When struck by light, retinal changes shape (11-*cis* to all-*trans*) and releases opsin. Freed opsin activates transducin (a G protein subunit) which in turn activates PDE, an enzyme that breaks down cGMP, allowing the Na^+ gates to close. This results in hyperpolarization of the receptor cells and inhibits their release of neurotransmitter.

20. Rod visual pigment, rhodopsin, is a combination of retinal and opsin. The light-triggered changes in retinal cause hyperpolarization of the rods. Photoreceptors and bipolar cells generate local potentials only; action potentials are generated by the ganglion cells.

21. The three types of cones all contain retinal, but each has a different type of opsin. Each cone type responds maximally to one color of light: red, blue, or green. The chemistry of cone function is similar to that of rods.

22. During light adaptation, photopigments are bleached and rods are inactivated; then, as cones begin to respond to high-intensity light, high-acuity vision ensues. In dark adaptation, cones cease functioning, and visual acuity decreases; rod function begins when sufficient rhodopsin has accumulated.

23. The visual pathway to the brain begins with the optic nerve fibers (ganglion cell axons) from the retina. At the optic chiasma, fibers from the medial half of each retinal field cross over and continue on in the optic tracts to the thalamus. Thalamic neurons project to the optic cortex via the optic radiation. Fibers also project from the retina to the midbrain pretectal nuclei and the superior colliculi, and to the suprachiasmatic nucleus of the hypothalamus.

24. In stereoscopic vision, each eye receives a slightly different view of the visual field. These views are fused by the optic cortices to provide for depth perception.

25. Retinal processing involves the selective destruction of rod inputs so as to emphasize bright/dark contrasts and edges. (The horizontal cells and amacrine cells are local integrator cells of the retina that modify and process rod inputs to the ganglion cells.) Thalamic processing subserves high-acuity color vision and depth perception. Cortical processing involves neurons of the striate (primary) cortex, which receive inputs from the retinal ganglion cells, and neurons of the prestriate (association) cortices, which receive inputs from striate cortical cells and mostly integrate inputs concerned with color, form, and movement. Visual processing also proceeds anteriorly in the "what" and "where" processing streams via the temporal and parietal lobes, respectively.

The Ear: Hearing and Balance (pp. 447-458)

Structure of the Ear (pp. 447-450)

1. The auricle and external auditory canal compose the outer ear. The tympanic membrane, the boundary between the outer and middle ears, transmits sound waves to the middle ear.

2. The middle ear is a small chamber within the temporal bone, connected by the pharyngotympanic tube to the nasopharynx. The ossicles, which help to amplify sound, span the middle ear cavity and transmit sound vibrations from the eardrum to the oval window.

3. The inner ear consists of the bony labyrinth, within which the membranous labyrinth is suspended. The bony labyrinth chambers contain perilymph; the membranous labyrinth ducts and sacs contain endolymph.

4. The vestibule contains the saccule and utricle. The semicircular canals extend posteriorly from the vestibule in three planes. They contain the semicircular ducts.

5. The cochlea houses the cochlear duct (scala media), which contains the organ of Corti (hearing receptor). Within the cochlear duct, the hair (receptor) cells rest on the basilar membrane, and their hairs project into the gelatinous tectorial membrane.

Physiology of Hearing (pp. 451-453)

6. Sound originates from a vibrating object and travels in waves consisting of alternating areas of compression and rarefaction of the medium.

7. The distance from crest to crest on a sine wave is the sound's wavelength; the shorter the wavelength, the higher the frequency (measured in hertz). Frequency is perceived as pitch.

8. The amplitude of sound is the height of the peaks of the sine wave, which reflect the sound's intensity. Sound intensity is measured in decibels. Intensity is perceived as loudness.

9. Sound passing through the external auditory canal sets the eardrum into vibration at the same frequency. The ossicles amplify and deliver the vibrations to the oval window.

10. Pressure waves in cochlear fluids set specific basilar membrane fibers into resonance. At points of maximal membrane vibration, the hair cells of the organ of Corti are alternately depolarized and hyperpolarized by the vibratory motion. High-frequency sounds stimulate hair cells near the oval window; low-frequency sounds stimulate hair cells near the apex. Most auditory inputs are sent to the brain by inner hair cells. Outer hair cells amplify responsiveness of the inner hair cells.

11. Impulses generated along the cochlear nerve travel to the cochlear nuclei of the medulla and from there through several brain stem nuclei to the medial geniculate nucleus of the thalamus and then the auditory cortex. Each auditory cortex receives impulses from both ears.

12. Auditory processing is analytic; each tone is perceived separately. Perception of pitch is related to the position of the excited hair cells along the basilar membrane. Intensity perception reflects the fact that as sound intensity increases, basilar membrane mobility is increased and the frequency of impulse transmission to the cortex is enhanced. Cues for sound localization include the intensity and timing of sound arriving at each ear.

Homeostatic Imbalances of Hearing (pp. 454-455)

13. Conduction deafness results from interference with conduction of sound vibrations to the fluids of the inner ear. Sensorineural deafness reflects damage to neural structures.

14. Tinnitus is an early sign of sensorineural deafness; it may also result from the use of certain drugs.

15. Ménière's syndrome is a disorder of the membranous labyrinth. Symptoms include tinnitus, deafness, and vertigo. Excessive endolymph accumulation is the suspected cause.

Mechanisms of Equilibrium and Orientation (pp. 455-458)

16. The equilibrium receptor regions of the inner ear are called the vestibular apparatus.

17. The receptors for static equilibrium are the maculae of the saccule and utricle. A macula consists of hair cells with stereocilia and a kinocilium embedded in an overlying otolithic membrane. Linear movements cause the otolithic membrane to move, pulling on the hair cells. Movements toward the kinocilium depolarize the hair cells and increase the rate of impulse generation in the vestibular nerve fibers. Movements away from the kinocilium have the opposite effect.

18. The dynamic equilibrium receptor, the crista ampullaris within each semicircular duct, responds to angular or rotatory movements in one plane. It consists of a tuft of hair cells whose microvilli are embedded in the gelatinous cupula. Rotatory movements cause the endolymph to flow in the opposite direction, bending the cupula and either exciting or inhibiting the hair cells.

19. Impulses from the vestibular apparatus are sent via vestibular nerve fibers mainly to the vestibular complex of the brain stem and the cerebellum. These centers initiate responses that fix the eyes on objects and activate muscles to maintain balance.

Part 2: Transmission Lines, Nerves, and Associated Ganglia

Nerves and Associated Ganglia (p. 458)

1. A nerve is a bundle of neuron fibers in the PNS. Each fiber is enclosed by an endoneurium, fascicles of fibers are wrapped by a perineurium, and the whole nerve is bundled by the epineurium.

2. Nerves are classified according to the direction of impulse conduction of their fibers as sensory, motor, or mixed; most nerves are mixed. The efferent fibers may be somatic or autonomic.

3. Ganglia are collections of nerve cell bodies associated with nerves. Examples are the dorsal root (sensory) ganglia and autonomic (motor) ganglia.

4. Injured PNS fibers may regenerate if macrophages enter the area, phagocytize the debris, and release chemicals that cause axonal regrowth and promote Schwann cell proliferation. Schwann cells then form a channel to guide axon sprouts to their original contacts. Fibers in the CNS do not normally regenerate because the oligodendrocytes fail to aid the process, macrophages are largely excluded, and growth-inhibiting proteins are present in the surrounding tissue.

Cranial Nerves (pp. 461-468)

1. Twelve pairs of cranial nerves originate from the brain and issue through the skull to innervate the head and neck. Only the vagus nerves extend into the thoracic and abdominal cavities.

2. Cranial nerves are numbered from anterior to posterior in order of emergence from the brain. Their names reflect structures served or function or both. The cranial nerves include:

- The olfactory nerves (I): purely sensory; concerned with the sense of smell.
- The optic nerves (II): purely sensory; transmit visual impulses from the retina to the thalamus.
- The oculomotor nerves (III): primarily motor; emerge from the midbrain and serve four extrinsic eye muscles, the levator palpebrae superioris of the eyelid, and the intrinsic ciliary muscle of the eye and constrictor fibers of the iris; also carry proprioceptive impulses from the skeletal muscles served.
- The trochlear nerves (IV): primarily motor; emerge from the dorsal midbrain and carry motor and proprioceptor impulses to and from superior oblique muscles of the eyeballs.
- The trigeminal nerves (V): mixed nerves; emerge from the lateral pons; the major general sensory nerves of the face; each has three sensory divisions—ophthalmic, maxillary, and mandibular; the mandibular branch also contains motor fibers that innervate the chewing muscles.
- The abducens nerves (VI): primarily motor; emerge from the pons and serve the motor and proprioceptive functions of the lateral rectus muscles of the eyeballs.
- The facial nerves (VII): mixed nerves; emerge from the pons; major motor nerves of the face; also carry sensory impulses from the taste buds of anterior two-thirds of the tongue.
- The vestibulocochlear nerves (VIII): purely sensory; transmit impulses from the hearing and equilibrium receptors of the inner ears.
- The glossopharyngeal nerves (IX): mixed nerves; issue from the medulla; transmit sensory impulses from the taste buds of the posterior tongue, from the pharynx, and from chemo- and pressoreceptors of the carotid bodies and sinuses; innervate some pharyngeal muscles and parotid glands.
- The vagus nerves (X): mixed nerves; arise from the medulla; almost all motor fibers are autonomic parasympathetic fibers; motor efferents to, and sensory fibers from, the pharynx, larynx, and visceral organs of the thoracic and abdominal cavities.
- The accessory nerves (XI): motor only; consist of a cranial root arising from the medulla and a spinal root arising from the cervical spinal cord; cranial root supplies motor fibers to the pharynx and larynx; spinal root supplies somatic efferents to the trapezius and sternocleidomastoid muscles of the neck and carries proprioceptor afferents from the same muscles.

- The hypoglossal nerves (XII): motor only; issue from the medulla; carry somatic motor efferents to, and proprioceptive fibers from, the tongue muscles.

Spinal Nerves (pp. 468-479)

General Features of Spinal Nerves (pp. 468-470)

1. The 31 pairs of spinal nerves (all mixed nerves) are numbered successively according to the region of the spinal cord from which they issue.

2. Spinal nerves are formed by the union of dorsal and ventral roots of the spinal cord and are short, confined to the intervertebral foramina.

3. Branches of each spinal nerve include dorsal and ventral rami, a meningeal branch, and rami communicantes (ANS branches).

Innervation of Specific Body Regions (pp. 470-478)

4. Ventral rami, except T_2–T_{12}, form plexuses that serve the limbs.

5. Dorsal rami serve the muscles and skin of the posterior body trunk. T_2–T_{12} ventral rami give rise to intercostal nerves that serve the thorax wall and abdominal surface.

6. The cervical plexus (C_1–C_4) innervates the muscles and skin of the neck and shoulder. Its phrenic nerve serves the diaphragm.

7. The brachial plexus serves the shoulder, some thorax muscles, and the upper limb. It arises primarily from C_5–T_1. Proximal to distal, the brachial plexus has roots, trunks, divisions, and cords. The main nerves arising from the cords are the axillary, musculocutaneous, median, radial, and ulnar nerves.

8. The lumbar plexus (L_1–L_4) provides the motor supply to the anterior and medial thigh muscles and the cutaneous supply to the anterior thigh and part of the leg. Its chief nerves are the femoral and obturator.

9. The sacral plexus (L_4–S_4) supplies the posterior muscles and skin of the lower limb. Its principal nerve is the large sciatic nerve composed of the tibial and common fibular (peroneal) nerves.

10. Joints are innervated by the same nerves that serve the muscles acting at the joint. All spinal nerves except C_1 innervate specific segments of the skin called dermatomes.

Part 3: Motor Endings and Motor Activity

Peripheral Motor Endings (p. 479-480)

1. Motor endings are the PNS elements that activate effectors (muscle fibers) by releasing neurotransmitters.

2. Motor endings of somatic nerve fibers (axonal terminals) help to form elaborate neuromuscular junctions with skeletal muscle cells. Axonal terminals contain synaptic vesicles filled with acetylcholine, which (when released) signals the muscle cell to contract. An elaborate basal lamina fills the synaptic cleft.

3. Autonomic motor endings, called varicosities, are functionally similar, but structurally simpler, beaded terminals that innervate smooth muscle and glands. They do not form specialized neuromuscular junctions and generally a wider synaptic cleft separates them from their effector cells.

Motor Integration: From Intention to Effect (p. 479)

1. Motor mechanisms operate at the level of the effectors (muscle fibers), descending circuits, and control levels of motor behavior.

Levels of Motor Control (479-480)

2. The motor control hierarchy consists of the segmental level, the projection level, and the programs and instructions level.

3. The segmental level is the spinal cord circuitry that activates anterior horn motor neurons to stimulate the muscles. It directly controls reflexes and fixed-action patterns. Segmental circuits controlling locomotion are central pattern generators (CPGs).

4. The projection level consists of descending fibers that project to and control the segmental level. These fibers issue from the brain stem mortor areas (indirect [extrapyramidal] system) and cortical motor areas (direct [pyramidal] system). Command neurons in the brain stem appear to turn CPGs on and off, or to modulate them.

5. The programs and instructions level consists of the cerebellum and basal nuclei. These constitute the precommand areas that subconsciously integrate mechanisms mediated by the projection level.

Reflex Activity (pp. 480-486)

Components of a Reflex Arc (p. 481)

1. A reflex is a rapid, involuntary motor response to a stimulus. The reflex arc has five elements: receptor, sensory neuron, integration center, motor neuron, and effector.

Spinal Reflexes (pp. 481-486)

2. Testing of somatic spinal reflexes provides information on the integrity of the reflex pathway and the degree of excitability of the spinal cord.

3. Somatic spinal reflexes include stretch, deep tendon, flexor, crossed extensor, and superficial reflexes.

4. A stretch reflex, initiated by stretching of muscle spindles, causes contraction of the stimulated muscle and inhibits its antagonist. It is monosynaptic and ipsilateral. Stretch reflexes maintain muscle tone and body posture.

5. Deep tendon reflexes, initiated by stimulation of Golgi tendon organs by increased muscle tension, are polysynaptic reflexes. They cause relaxation of the stimulated muscle and contraction of its antagonist.

6. Flexor reflexes are initiated by painful stimuli. They are polysynaptic, ipsilateral reflexes that are protective in nature.

7. Crossed extensor reflexes consist of an ipsilateral flexor reflex and a contralateral extensor reflex.

8. Superficial reflexes (e.g., the plantar and abdominal reflexes) are elicited by cutaneous stimulation. They require functional cord reflex arcs and corticospinal pathways.

14 THE AUTONOMIC NERVOUS SYSTEM

CHAPTER SUMMARY

References to Interactive Physiology **IP** *appear below specific key chapter topics to help your review.*

1. The autonomic nervous system is the motor division of the PNS that controls visceral activities, with the goal of maintaining internal homeostasis.

Introduction to the Autonomic Nervous System (pp. 489-492)

Comparison of the Somatic and Autonomic Nervous Systems (pp. 489-491)

1. The somatic (voluntary) nervous system provides motor fibers to skeletal muscles. The autonomic (involuntary or visceral motor) nervous system provides motor fibers to smooth and cardiac muscles and glands.

2. In the somatic division, a single motor neuron forms the efferent pathway from the CNS to the effectors. The efferent pathway of the autonomic division consists of a two-neuron chain: the preganglionic neuron in the CNS and the ganglionic neuron in a ganglion.

3. Acetylcholine, the neurotransmitter of somatic motor neurons, is stimulatory to skeletal muscle fibers. Neurotransmitters released by autonomic motor neurons (acetylcholine and norepinephrine) may cause excitation or inhibition.

IP Nervous System II CD-ROM; Topic: Synaptic Transmission, pages 8–11.

The Divisions of the Autonomic Nervous System (p. 491)

4. The autonomic nervous system consists of two divisions, the parasympathetic and sympathetic, which normally exert antagonistic effects on many of the same target organs.

5. The parasympathetic division (the resting-digesting system) conserves body energy and maintains body activities at basal levels.

6. Parasympathetic effects include pupillary constriction, glandular secretion, increased digestive tract mobility, and smooth muscle activity leading to elimination of feces and urine.

7. The sympathetic division activates the body under conditions of emergency and is called the fight-or-flight system.

8. Sympathetic responses include dilated pupils, increased heart and respiratory rates, increased blood pressure, dilation of the bronchioles of the lungs, increased blood glucose levels, and sweating. During exercise, sympathetic vasoconstriction shunts blood from the skin and digestive viscera to the heart, brain, and skeletal muscles.

Anatomy of the Autonomic Nervous System (pp. 492-499)

Parasympathetic (Craniosacral) Division (pp. 493-494)

1. Parasympathetic preganglionic neurons arise from the brain stem and from the sacral (S_2–S_4) region of the cord.

2. Preganglionic fibers synapse with ganglionic neurons in intramural or terminal ganglia located in or close to their effector organs. Preganglionic fibers are long; postganglionic fibers are short.

3. Cranial fibers arise in the brain stem nuclei of cranial nerves III, VII, IX, and X and synapse in ganglia of the head, thorax, and abdomen. The vagus nerve serves virtually all organs of the thoracic and abdominal cavities.

4. Sacral fibers (S_2–S_4) issue from the lateral region of the cord and form pelvic splanchnic nerves that innervate the pelvic viscera. The preganglionic axons do not travel within rami communicantes or spinal nerves.

Sympathetic (Thoracolumbar) Division (pp. 494-498)

5. Preganglionic sympathetic neurons arise from the lateral horn of the spinal cord from the level of T_1 to L_2.

6. Preganglionic axons leave the cord via white rami communicantes and enter the chain (paravertebral) ganglia in the sympathetic trunk. An axon may synapse in a chain ganglion at the same or at a different level, or it may issue from the sympathetic chain without synapsing. Preganglionic fibers are short; postganglionic fibers are long.

7. When the synapse occurs in a chain ganglion, the postganglionic fiber may enter the spinal nerve ramus via the gray ramus communicans to travel to the body periphery. Postganglionic fibers issuing from the cervical ganglia also serve visceral organs and blood vessels of the head, neck, and thorax.

8. When synapses do not occur in the chain ganglia, the preganglionic fibers form splanchnic nerves (thoracic, lumbar, and sacral). Most splanchnic nerve fibers synapse in collateral ganglia, and the postganglionic fibers serve the abdominal viscera. Some splanchnic nerve fibers synapse with cells of the adrenal medulla.

Visceral Reflexes (pp. 498-499)

9. Visceral reflex arcs have the same components as somatic reflexes.

10. Cell bodies of visceral sensory neurons are located in dorsal root ganglia, sensory ganglia of cranial nerves, or autonomic ganglia. Visceral afferents are found in spinal nerves and in virtually all autonomic nerves.

Physiology of the Autonomic Nervous System (p. 499)

Neurotransmitters and Receptors (pp. 499-524)

1. Two major neurotransmitters, acetylcholine (ACh) and norepinephrine (NE), are released by autonomic motor neurons. On the basis of the neurotransmitter released, the fibers are classified as cholinergic or adrenergic.

2. ACh is released by all preganglionic fibers and all parasympathetic postganglionic fibers. NE is released by all sympathetic postganglionic fibers except those serving the sweat glands of the skin, some blood vessels within skeletal muscles, and the external genitalia (those fibers secrete ACh).

3. Neurotransmitter effects depend on the receptors to which the transmitter binds. Cholinergic (ACh) receptors are classified as nicotinic and muscarinic. Adrenergic (NE) receptors are classified as α_1 and α_2 and β_1, β_2, and β_3.

IP Nervous System II CD-ROM; Topic: Synaptic Transmission, pages 8-11, 14.

14 *The Autonomic Nervous System*

The Effects of Drugs (pp. 500-501)

4. Drugs that mimic, enhance, or inhibit the action of ANS neurotransmitters are used to treat conditions caused by excessive, inadequate, or inappropriate ANS functioning. Some drugs bind with only one receptor subtype, allowing specific ANS-mediated activities to be enhanced or blocked.

Interactions of the Autonomic Divisions (pp. 501-503)

5. Most visceral organs are innervated by both divisions; they interact in various ways but usually exert a dynamic antagonism. Antagonistic interactions mainly involve the heart, respiratory system, and gastrointestinal organs. Sympathetic activity increases heart and respiratory system activity and depresses gastrointestinal activity. Parasympathetic activity reverses these effects.

6. Most blood vessels are innervated only by sympathetic fibers and exhibit vasomotor tone. Parasympathetic activity dominates the heart and muscles of the gastrointestinal tract (which normally exhibit parasympathetic tone) and glands.

7. The two ANS divisions exert cooperative effects on the external genitalia.

8. Roles unique to the sympathetic division are blood pressure regulation, shunting of blood in the vascular system, thermoregulatory responses, stimulation of renin release by the kidneys, and metabolic effects.

9. Activation of the sympathetic division causes widespread, long-lasting mobilization of the fight-or-flight response. Parasympathetic effects are highly localized and short lived.

Control of Autonomic Functioning (pp. 503-504)

10. Autonomic function is controlled at several levels: (1) Reflex activity is mediated by the spinal cord and brain stem (particularly medullary) centers; (2) hypothalamic integration centers interact with both higher and lower centers to orchestrate autonomic, somatic, and endocrine responses; and (3) cortical centers influence autonomic functioning via connections with the limbic system; conscious controls of autonomic function are rare but possible, as illustrated by biofeedback training.

Homeostatic Imbalances of the Autonomic Nervous System (pp. 504-505)

1. Most autonomic disorders reflect problems with smooth muscle control. Abnormalities in vascular control, such as occur in hypertension, Raynaud's disease, and the mass reflex reaction, are most devastating.

15 THE ENDOCRINE SYSTEM

CHAPTER SUMMARY

1. The nervous and endocrine systems are the major controlling systems of the body. The nervous system exerts rapid controls via nerve impulses; the endocrine system's effects are mediated by hormones and are more prolonged.

The Endocrine System: An Overview (p. 507)

1. Endocrine organs are ductless, well-vascularized glands that release hormones directly into the blood or lymph. They are small and widely separated in the body.

2. The major endocrine organs are the pituitary, thyroid, parathyroid, adrenal, pineal, and thymus glands, as well as the pancreas and gonads. The hypothalamus is a neuroendocrine organ.

3. Hormonally regulated processes include reproduction; growth and development; mobilization of body defenses to stressors; maintaining electrolyte, water, and nutrient balance; and regulating cellular metabolism.

Hormones (pp. 507-515)

The Chemistry of Hormones (pp. 507-508)

1. Most hormones are steroids or amino acid derivatives.

Mechanisms of Hormone Action (pp. 508-511)

2. Hormones alter cell activity by stimulating or inhibiting characteristic cellular processes.

3. Cell responses to hormone stimulation may involve changes in membrane permeability; enzyme synthesis, activation, or inhibition; secretory activity; and gene activation.

4. Second-messenger mechanisms employing intracellular messengers and transduced by G proteins are a common means by which amino acid–based hormones interact with their target cells. In the cyclic AMP system, the hormone binds to a plasma membrane receptor that couples to a G protein. When the G protein is activated it, in turn, couples to adenylate cyclase, which catalyzes the synthesis of cyclic AMP from ATP. Cyclic AMP initiates reactions that activate protein kinases and other enzymes, leading to cellular response. The phosphatidyl inositol mechanism is another important second-messenger system. Other presumed "messengers" are cyclic GMP and calcium.

5. Steroid hormones (and thyroid hormone) enter their target cells and effect responses by activating DNA, initiating messenger RNA formation leading to protein synthesis.

Hormone–Target Cell Specificity (pp. 511-512)

6. The ability of a target cell to respond to a hormone depends on the presence of receptors, within the cell or on its plasma membrane, to which the hormone can bind.

7. Hormone receptors are dynamic structures. Changes in number and sensitivity of hormone receptors may occur in response to high or low levels of stimulating hormones.

Half-Life, Onset, and Duration of Hormone Activity (p. 512)

8. Blood levels of hormones reflect a balance between secretion and degradation/excretion. The liver and kidneys are the major organs that degrade hormones; breakdown products are excreted in urine and feces.

9. Hormone half-life and duration of activity are limited and vary from hormone to hormone.

Control of Hormone Release (pp. 512-515)

10. Endocrine organs are activated to release their hormones by humoral, neural, or hormonal stimuli. Negative feedback is important in regulating hormone levels in the blood.

11. The nervous system, acting through hypothalamic controls, can in certain cases override or modulate hormonal effects.

Major Endocrine Organs (pp. 515-538)

The Pituitary Gland (Hypophysis) (pp. 515-522)

1. The pituitary gland hangs from the base of the brain by a stalk and is enclosed by bone. It consists of a hormone-producing glandular portion (anterior pituitary) and a neural portion (posterior pituitary), which is an extension of the hypothalamus.

2. The hypothalamus (a) regulates the hormonal output of the anterior pituitary via releasing and inhibiting hormones and (b) synthesizes two hormones that it exports to the posterior pituitary for storage and later release.

3. Four of the six adenohypophyseal hormones are tropic hormones that regulate the function of other endocrine organs. Most anterior pituitary hormones exhibit a diurnal rhythm of release, which is subject to modification by stimuli influencing the hypothalamus.

4. Growth hormone (GH) is an anabolic hormone that stimulates growth of all body tissues but especially skeletal muscle and bone. It may act directly or indirectly via insulin-like growth factors (IGFs). GH mobilizes fats, stimulates protein synthesis, and inhibits glucose uptake and metabolism. Secretion is regulated by growth hormone–releasing hormone (GHRH) and growth hormoneinhibiting hormone (GHIH), or somatostatin. Hypersecretion causes gigantism in children and acromegaly in adults; hyposecretion in children causes pituitary dwarfism.

5. Thyroid-stimulating hormone (TSH) promotes normal development and activity of the thyroid gland. Thyrotropin-releasing hormone (TRH) stimulates its release; negative feedback of thyroid hormone inhibits it.

6. Adrenocorticotropic hormone (ACTH) stimulates the adrenal cortex to release corticosteroids. ACTH release is triggered by corticotropin-releasing hormone (CRH) and inhibited by rising glucocorticoid levels.

7. The gonadotropins—follicle-stimulating hormone (FSH) and luteinizing hormone (LH)—regulate the functions of the gonads in both sexes. FSH stimulates sex cell production; LH stimulates gonadal hormone production. Gonadotropin levels rise in response to gonadotropin-releasing hormone (GnRH). Negative feedback of gonadal hormones inhibits gonadotropin release.

8. Prolactin (PRL) promotes milk production in humans. Its secretion is prompted by prolactin-releasing hormone (PRH) and inhibited by prolactin-inhibiting hormone (PIH).

9. The neurohypophysis stores and releases two hypothalamic hormones, oxytocin and antidiuretic hormone (ADH).

10. Oxytocin stimulates powerful uterine contractions, which trigger labor and delivery of an infant, and milk ejection in nursing women. It also appears to promote sexual arousal and nurturing. Its release is mediated reflexively by the hypothalamus and represents a positive feedback mechanism.

11. Antidiuretic hormone stimulates the kidney tubules to reabsorb and conserve water; as urine output declines, blood volume and blood pressure rise. ADH is released in response to high solute concentrations in the blood and inhibited by low solute concentrations in the blood. Hyposecretion results in diabetes insipidus.

The Thyroid Gland (pp. 522-526)

12. The thyroid gland is located in the anterior throat. Thyroid follicles store thyroglobulin, a colloid from which thyroid hormone is derived.

13. Thyroid hormone (TH) includes thyroxine (T_4) and triiodothyronine (T_3), which increase the rate of cellular metabolism. Consequently, oxygen use and heat production rise.

14. Secretion of thyroid hormone, prompted by TSH, requires reuptake of the stored colloid by the follicle cells and splitting of the hormones from the colloid for release. Rising levels of thyroid hormone feed back to inhibit the pituitary and hypothalamus.

15. Most T_4 is converted to T_3 (the more active form) in the target tissues. These hormones appear to act via a steroidlike mechanism.

16. Hypersecretion of thyroid hormone results most importantly in Graves' disease; hyposecretion causes cretinism in infants and myxedema in adults.

17. Calcitonin, produced by the parafollicular (C) cells of the thyroid gland in response to rising blood calcium levels, depresses blood calcium levels by inhibiting bone matrix resorption and enhancing calcium deposit in bone.

The Parathyroid Glands (pp. 526-528)

18. The parathyroid glands, located on the dorsal aspect of the thyroid gland, secrete parathyroid hormone (PTH), which causes an increase in blood calcium levels by targeting bone, the intestine, and the kidneys. PTH is the antagonist of calcitonin.

19. PTH release is triggered by falling blood calcium levels and is inhibited by rising blood calcium levels.

20. Hyperparathyroidism results in hypercalcemia and all its effects and in extreme bone wasting. Hypoparathyroidism leads to hypocalcemia, evidenced by tetany and respiratory paralysis.

The Adrenal (Suprarenal) Glands (pp. 528-534)

21. The paired adrenal (suprarenal) glands sit atop the kidneys. Each adrenal gland has two functional portions, the cortex and the medulla.

22. Three groups of steroid hormones are produced by the cortex from cholesterol.

23. Mineralocorticoids (primarily aldosterone) regulate sodium ion reabsorption by the kidneys and thus indirectly regulate levels of other electrolytes that are coupled to sodium transport. Release of aldosterone is stimulated by the renin-angiotensin mechanism, rising potassium ion or falling sodium levels in the blood, and ACTH. Atrial natriuretic peptide inhibits aldosterone release.

24. Glucocorticoids (primarily cortisol) are important metabolic hormones that help the body resist stressors by increasing blood glucose, fatty acid and amino acid levels, and blood pressure. High levels of glucocorticoids depress the immune system and the inflammatory response. ACTH is the major stimulus for glucocorticoid release.

25. Gonadocorticoids (mainly androgens) are produced in small amounts throughout life.

26. Hypoactivity of the adrenal cortex results in Addison's disease. Hypersecretion can result in aldosteronism, Cushing's disease, and masculinization.

27. The adrenal medulla produces catecholamines (epinephrine and norepinephrine) in response to sympathetic nervous system stimulation. Its catecholamines enhance and prolong the fight-or-flight response to short-term stressors. Hypersecretion leads to symptoms typical of sympathetic nervous system overactivity.

The Pancreas (pp. 534-537)

28. The pancreas, located in the abdomen close to the stomach, is both an exocrine and an endocrine gland. The endocrine portion (pancreatic islets) releases insulin and glucagon (plus pancreatic polypeptide and somatostatin) to the blood.

29. Glucagon, released by alpha (α) cells when blood levels of glucose are low, stimulates the liver to release glucose to the blood.

30. Insulin is released by beta (β) cells when blood levels of glucose (and amino acids) are rising. It increases the rate of glucose uptake and metabolism by most body cells. Hyposecretion of insulin results in diabetes mellitus; cardinal signs are polyuria, polydipsia, and polyphagia.

The Gonads (p. 537)

31. The ovaries of the female, located in the pelvic cavity, release two main hormones. Secretion of estrogens by the ovarian follicles begins at puberty under the influence of FSH. Estrogens stimulate maturation of the female reproductive system and development of the secondary sex characteristics. Progesterone is released in response to high blood levels of LH. It works with estrogens in establishing the menstrual cycle.

32. The testes of the male begin to produce testosterone at puberty in response to LH (ICSH). Testosterone promotes maturation of the male reproductive organs, development of secondary sex characteristics, and production of sperm by the testes.

The Pineal Gland (p. 537)

33. The pineal gland is located in the diencephalon. Its primary hormone is melatonin, which influences daily rhythms and may have an antigonadotropic effect in humans.

The Thymus (p. 538)

34. The thymus gland, located in the upper thorax, declines in size and function with age. Its hormones, thymosins and thymopoietins, are important to the normal development of the immune response.

Other Hormone-Producing Structures (pp. 538-539)

1. Many body organs not normally considered endocrine organs contain isolated cell clusters that secrete hormones. Examples include the heart (atrial natriuretic peptide); gastrointestinal tract organs (gastrin, secretin, and others); the placenta (hormones of pregnancy—estrogen, progesterone, and others); the kidneys (erythropoietin); skin (cholecalciferol); and adipose tissue (leptin).

16 BLOOD

CHAPTER SUMMARY

References to Interactive Physiology **IP** *appear below specific key chapter topics to help your review.*

Overview: Composition and Functions of Blood (pp. 542-543)

Components (p. 542)

1. Blood is composed of formed elements and plasma. The hematocrit is a measure of one formed element, erythrocytes, as a percentage of total blood volume.

Physical Characteristics and Volume (p. 543)

2. Blood is a viscous, slightly alkaline fluid representing about 8% of total body weight. Blood volume of a normal adult is about 5 L.

Functions (p. 543)

3. Distribution functions include delivery of oxygen and nutrients to body tissues, removal of metabolic wastes, and transport of hormones.

4. Regulation functions are maintenance of body temperature, of constant blood pH, and of adequate fluid volume.

5. Protective functions include hemostasis and prevention of infection.

Blood Plasma (p. 543)

1. Plasma is a straw-colored, viscous fluid composed of 90% water. The remaining 10% is solutes, such as nutrients, respiratory gases, salts, hormones, and proteins. Plasma makes up 55% of whole blood.

2. Plasma proteins, most made by the liver, include albumin, globulins, and clotting proteins. Albumin is an important blood buffer and contributes to the osmotic pressure of blood.

Formed Elements (pp. 543-557)

1. Formed elements, accounting for 45% of whole blood, are erythrocytes, leukocytes, and platelets. All formed elements arise from hemocytoblasts in red bone marrow.

Erythrocytes (pp. 544-552)

2. Erythrocytes (red blood cells) are small biconcave cells containing large amounts of hemoglobin. They have no nucleus and few organelles. Spectrin allows the cells to change shape as they pass through tiny capillaries.

3. Oxygen transport is the major function of erythrocytes. In the lungs, oxygen binds to iron atoms in hemoglobin molecules, producing oxyhemoglobin. In body tissues, oxygen dissociates from iron, producing deoxyhemoglobin.

4. Red blood cells begin as hemocytoblasts and, through erythropoiesis, proceed from the proerythroblast (committed cell) stage to the erythroblast (early and late), normoblast, and reticulocyte stages. During this process, hemoglobin accumulates and the organelles and nucleus are extruded. Differentiation of reticulocytes is completed in the bloodstream.

5. Erythropoietin and testosterone enhance erythropoiesis.

6. Iron, vitamin B_{12}, and folic acid are essential for production of hemoglobin.

7. Red blood cells have a life span of approximately 120 days. Old and damaged erythrocytes are removed from the circulation by macrophages of the liver and spleen. Released iron from hemoglobin is stored as ferritin or hemosiderin to be reused. The balance of the heme group is degraded to bilirubin and secreted in bile. Amino acids of globin are metabolized or recycled.

IP Respiratory System CD-ROM; Topic: Gas Transport, pages 3–5, 11–17.

8. Erythrocyte disorders include anemias and polycythemia.

Leukocytes (pp. 552-553)

9. Leukocytes are white blood cells. All are nucleated, and all have crucial roles in defending against disease. Two main categories exist: granulocytes and agranulocytes.

10. Granulocytes include neutrophils, basophils, and eosinophils. Basophils contain histamine, which enhances migration of leukocytes to inflammatory sites and promotes vasodilation. Neutrophils are active phagocytes. Eosinophils attack parasitic worms and their numbers increase during allergic reactions.

11. Agranulocytes have crucial roles in immunity. They include lymphocytes, the "immune cells," and monocytes, which differentiate into macrophages.

12. Leukopoiesis is directed by colony-stimulating factors and interleukins released mainly by lymphocytes and macrophages.

13. Leukocyte disorders include leukemias and infectious mononucleosis.

Platelets (p. 557)

14. Platelets are fragments of large, multinucleate megakaryocytes formed in red marrow. When a blood vessel is damaged, platelets form a plug to help prevent blood loss and play a central role in the clotting cascade.

Hemostasis (pp. 557-563)

1. Hemostasis is prevention of blood loss. The three major phases of hemostasis are vascular spasms, platelet plug formation, and blood coagulation.

Coagulation (pp. 559-561)

2. Coagulation of blood may be initiated by either the intrinsic or the extrinsic pathway. Platelet phospholipid (PF_3) is crucial to both pathways. Tissue factor (thromboplastin) generated by tissue cell injury allows the extrinsic pathway to bypass many steps of the intrinsic pathway. A series of activated procoagulants oversees the intermediate steps of each cascade. The pathways converge as prothrombin is converted to thrombin.

Clot Retraction and Repair (p. 561)

3. After a clot is formed, clot retraction occurs. Serum is squeezed out and the ruptured vessel edges are drawn together. The vessel is repaired by smooth muscle, connective tissue, and endothelial cell proliferation and migration.

16 *Blood*

Fibrinolysis (pp. 561-562)

4. When healing is complete, clot digestion (fibrinolysis) occurs.

Factors Limiting Clot Growth or Formation (p. 562)

5. Abnormal expansion of clots is prevented by removal of coagulation factors in contact with rapidly flowing blood and by inhibition of activated blood factors. PGI_2 (prostacyclin) secreted by the endothelial cells helps prevent undesirable (unnecessary) clotting.

Disorders of Hemostasis (pp. 562-563)

6. Thromboembolytic disorders involve undesirable clot formation, which can occlude vessels.

7. Thrombocytopenia, a deficit of platelets, causes spontaneous bleeding from small blood vessels. Hemophilia is caused by a genetic deficiency of certain coagulation factors. Liver disease can also cause bleeding disorders because many coagulation proteins are formed by the liver.

Transfusion and Blood Replacement (pp. 563-566)

Transfusion of Whole Blood (pp. 563-566)

1. Whole blood transfusions are given to replace severe blood loss and to treat anemia or thrombocytopenia.

2. Blood group is based on agglutinogens (antigens) present on red blood cell membranes.

3. When mismatched blood is transfused, the recipient's agglutinins (plasma antibodies) clump the foreign RBCs; the clumped cells are then lysed. Blood vessels may be blocked by clumped RBCs; released hemoglobin may precipitate in the kidney tubules, causing renal shutdown.

4. Before whole blood can be transfused, it must be typed and cross matched so that transfusion reactions are avoided. The most important blood groups for which blood must be typed are the ABO and Rh groups.

Plasma and Blood Volume Expanders (p. 563)

5. Transfusions of plasma alone or plasma expanders are given when rapid replacement of blood volume is necessary.

Diagnostic Blood Tests (pp. 566-567)

1. Diagnostic blood tests can provide large amounts of information about the current status of the blood and of the body as a whole.

17 THE CARDIOVASCULAR SYSTEM: THE HEART

CHAPTER SUMMARY

References to Interactive Physiology **IP** *appear below specific key chapter topics to help your review.*

Heart Anatomy (pp. 569-580)

Size, Location, and Orientation (p. 569)

1. The human heart, about the size of a clenched fist, is located obliquely within the mediastinum of the thorax.

Coverings of the Heart (p. 569-570)

2. The heart is enclosed within a double sac made up of the outer fibrous pericardium and the inner serous pericardium (parietal and visceral layers). The pericardial cavity between the serous layers contains lubricating serous fluid.

Layers of the Heart Wall (p. 571)

3. Layers of the heart wall, from the interior out, are the endocardium, the myocardium (reinforced by a fibrous skeleton), and the epicardium (visceral layer of the serous pericardium).

Chambers and Associated Great Vessels (p. 571)

4. The heart has two superior atria and two inferior ventricles. Functionally, the heart is a double pump.

5. Entering the right atrium are the superior vena cava, the inferior vena cava, and the coronary sinus. Four pulmonary veins enter the left atrium.

6. The right ventricle discharges blood into the pulmonary trunk; the left ventricle pumps blood into the aorta.

Pathway of Blood Through the Heart (pp. 575-576)

7. The right heart is the pulmonary circuit pump. Oxygen-poor systemic blood enters the right atrium, passes into the right ventricle, through the pulmonary trunk to the lungs, and back to the left atrium via the pulmonary veins.

8. The left heart is the systemic circuit pump. Oxygen-laden blood entering the left atrium from the lungs flows into the left ventricle and then into the aorta, which provides the functional supply of all body organs. Systemic veins return the oxygen-depleted blood to the right atrium.

Coronary Circulation (pp. 576-577)

9. The right and left coronary arteries branch from the aorta and via their main branches (anterior and posterior interventricular, marginal, and circumflex arteries) supply the heart itself. Venous blood, collected by the cardiac veins (great, middle, and small), is emptied into the coronary sinus.

10. Blood delivery to the myocardium occurs during heart relaxation.

Heart Valves (pp. 577-578)

11. The atrioventricular valves (tricuspid and bicuspid) prevent backflow into the atria when the ventricles are contracting; the pulmonary and aortic semilunar valves prevent backflow into the ventricles when the ventricles are relaxing.

IP Cardiovascular System CD-ROM; Topic: Anatomy Review: The Heart, pages 1–10.

Properties of Cardiac Muscle Fibers (pp. 580-583)

Microscopic Anatomy (pp. 580-582)

1. Cardiac muscle cells are branching, striated, generally uninucleate cells. They contain myofibrils consisting of typical sarcomeres.

2. Adjacent cardiac cells are connected by intercalated discs containing desmosomes and gap junctions. The myocardium behaves as a functional syncytium because of electrical coupling provided by gap junctions.

Mechanism and Events of Contraction (pp. 582-583)

3. Action-potential generation in the contractile cardiac muscle mimics that of skeletal muscle. Membrane depolarization causes opening of sodium channels and sodium entry, which is responsible for the rising phase of the action potential curve. Depolarization also opens slow calcium channels; Ca^{2+} entry prolongs the period of depolarization (creates the plateau). The action potential is coupled to sliding of the myofilaments by ionic calcium released by the SR and entering from the extracellular space. Compared to skeletal muscle, cardiac muscle has a prolonged refractory period that prevents tetanization.

IP Cardiovascular System CD-ROM; Topic: Cardiac Action Potential, pages 11–18.

Energy Requirements (p. 583)

4. Cardiac muscle has abundant mitochondria and depends primarily on aerobic respiration to form ATP.

Heart Physiology (pp. 583-595)

Electrical Events (p. 583)

1. Certain noncontractile cardiac muscle cells exhibit automaticity and rhythmicity and can independently initiate action potentials. Such cells have an unstable resting potential called a pacemaker potential that gradually depolarizes, drifting toward threshold for firing. These cells compose the intrinsic conduction system of the heart.

2. The conduction, or nodal, system of the heart consists of the SA and AV nodes, the AV bundle and bundle branches, and the Purkinje fibers. This system coordinates the depolarization of the heart and ensures that the heart beats as a unit. The SA node has the fastest rate of spontaneous depolarization and acts as the heart's pacemaker; it sets the sinus rhythm.

3. Defects in the intrinsic conduction system can cause arrhythmias, fibrillation, and heart block.

4. The heart is innervated by the autonomic nervous system. Autonomic cardiac centers in the medulla include the sympathetic cardioacceleratory center, which projects to the T_1–T_5 region of the spinal cord, which in turn projects to the cervical and upper thoracic chain ganglia. Postganglionic fibers innervate the SA and AV nodes and the cardiac muscle fibers. The parasympathetic cardioinhibitory center exerts its influence via the vagus nerves (X), which project to the heart wall. Most parasympathetic fibers serve the SA and AV nodes.

5. An electrocardiogram is a graphic representation of the cardiac conduction cycle. The P wave reflects atrial depolarization. The QRS complex indicates ventricular depolarization; the T wave represents ventricular repolarization.

IP Cardiovascular System CD-ROM; Topic: Intrinsic Conduction System, pages 1–7; Topic: Cardiac Action Potential, pages 1–10.

Mechanical Events: The Cardiac Cycle (pp. 588-590)

6. A cardiac cycle consists of the events occurring during one heartbeat. During mid-to-late diastole, the ventricles fill and the atria contract. Ventricular systole consists of the isovolumetric contraction phase and the ventricular ejection phase. During early diastole, the ventricles are relaxed and are closed chambers until increasing atrial pressure forces the AV valves open and the cycle begins again. At a normal heart rate of 75 beats/min, a cardiac cycle lasts 0.8 s.

7. Pressure changes promote blood flow and valve opening and closing.

IP Cardiovascular System CD-ROM; Topic: Cardiac Cycle, pages 1–20.

Heart Sounds (pp. 590-591)

8. Normal heart sounds arise chiefly from the closing of heart valves. Abnormal heart sounds, called murmurs, usually reflect valve problems.

Cardiac Output (p. 590)

9. Cardiac output, typically 5 L/min, is the amount of blood pumped out by each ventricle in 1 minute. Stroke volume is the amount of blood pumped out by a ventricle with each contraction. Cardiac output = heart rate × stroke volume.

10. Stroke volume depends to a large extent on the degree of stretch of cardiac muscle by venous return. Approximately 70 ml, it is the difference between end diastolic volume (EDV) and end systolic volume (ESV). Anything that influences heart rate or blood volume influences venous return, hence stroke volume.

11. Activation of the sympathetic nervous system increases heart rate and contractility; parasympathetic activation decreases heart rate and contractility. Ordinarily, the heart exhibits vagal tone.

12. Chemical regulation of the heart is effected by hormones (epinephrine and thyroxine) and ions (sodium, potassium, and calcium). Imbalances in ions severely impair heart activity.

13. Other factors influencing heart rate are age, sex, exercise, and body temperature.

14. Congestive heart failure occurs when the pumping ability of the heart is inadequate to provide normal circulation to meet body needs. Right heart failure leads to systemic edema; left heart failure results in pulmonary edema.

IP Cardiovascular System CD-ROM; Topic: Cardiac Output, pages 1–10.

18 THE CARDIOVASCULAR SYSTEM: BLOODVESSELS

CHAPTER SUMMARY

References to Interactive Physiology **IP** *appear below specific key chapter topics to help your review.*

Overview of Blood Vessel Structure and Function (pp. 598-605)

1. Blood is transported throughout the body via a continuous system of blood vessels. Arteries transport blood away from the heart; veins carry blood back to the heart. Capillaries carry blood to tissue cells and are exchange sites.

Structure of Blood Vessel Walls (pp. 598-599)

2. All blood vessels except capillaries have three layers: tunica interna, tunica media, and tunica externa. Capillary walls are composed of the tunica interna only.

Arterial System (pp. 600-601)

3. Elastic (conducting) arteries are the large arteries close to the heart that expand and recoil to accommodate changing blood volume. Muscular (distributing) arteries carry blood to specific organs; they are less stretchy and more active in vasoconstriction. Arterioles regulate blood flow into capillary beds.

4. Arteriosclerosis is a degenerative vascular disease. Initiated by endothelial lesions, it progresses through fatty streak, atherosclerotic, and arteriosclerotic stages.

Capillaries (pp. 602-604)

5. Capillaries are microscopic vessels with very thin walls. Most exhibit clefts, which aid in the exchange between the blood and interstitial fluid. Spider-shaped cells called pericytes help to reinforce the external faces of capillaries.

6. Vascular shunts (metarterioles–thoroughfare channels) connect the terminal arteriole and venule at opposite ends of a capillary bed. Most true capillaries arise from and rejoin the shunt channels. The amount of blood flowing into the true capillaries is regulated by precapillary sphincters.

7. The most permeable capillaries are sinusoids (wide, tortuous channels). Fenestrated capillaries with pores are next most permeable. Least permeable are continuous capillaries, which lack pores.

Venous System (pp. 604-605)

8. Veins have comparatively larger lumens than arteries, and a system of valves prevents backflow of blood. Respiratory and skeletal muscle pumps aid return of venous blood to the heart.

9. Normally most veins are only partially filled with blood; thus, they can serve as blood reservoirs.

Vascular Anastomoses (p. 605)

10. The joining together to provide alternate channels for blood to reach the same organ is called an arterial anastomosis. Vascular anastomoses also form between veins and between arterioles and venules.

IP Cardiovascular System CD-ROM; Topic: Anatomy Review, Blood Vessel Structure and Function, pages 1–28.

PHYSIOLOGY OF CIRCULATION (pp. 605-623)

Introduction to Blood Flow, Blood Pressure, and Resistance (pp. 605-606)

1. Blood flow is the amount of blood flowing through a vessel, an organ, or the entire circulation in a given period of time. Blood pressure is the force per unit area exerted on a vessel wall by the contained blood. Resistance is opposition to blood flow; blood viscosity and blood vessel length and diameter contribute to resistance.

2. Blood flow is directly proportional to blood pressure and inversely proportional to resistance.

IP Cardiovascular System CD-ROM; Topic: Factors that Affect Blood Pressure, pages 1–15.

Systemic Blood Pressure (pp. 606-608)

1. Systemic blood pressure is highest in the aorta and lowest in the venae cavae. The steepest drop in BP occurs in the arterioles, where resistance is greatest.

2. Arterial BP depends on compliance of the elastic arteries and on how much blood is forced into them. Arterial blood pressure is pulsatile, and peaks during systole (systolic pressure). During diastole, as blood is forced distally in the circulation by the rebound of elastic arteries, arterial BP drops to its lowest value, called the diastolic pressure.

3. Pulse pressure is systolic pressure minus diastolic pressure. The mean arterial pressure (MAP) = diastolic pressure plus one-third of pulse pressure and is the pressure that keeps blood moving throughout the cardiac cycle.

4. Low capillary pressure (40 to 15 mm Hg) protects the delicate capillaries from rupture while still allowing adequate exchange across the capillary walls.

5. Venous pressure is nonpulsatile and low (declining to zero) because of the cumulative effects of resistance. Venous valves, large lumens, and functional adaptations (muscular and respiratory pumps) promote venous return.

Maintaining Blood Pressure (pp. 608-609)

1. Blood pressure varies directly with CO, PR, and blood volume. Vessel diameter is the major factor determining PR, and small changes in vessel (chiefly arteriolar) diameter significantly affect blood pressure.

IP Cardiovascular System CD-ROM; Topic: Measuring Blood Pressure, pages 1–13.

Short-Term Mechanisms: Neural Controls (pp. 609-610)

2. BP is regulated by autonomic neural reflexes involving baroreceptors or chemoreceptors, the vasomotor center (a sympathetic center that regulates blood vessel diameter), and vasomotor fibers, which act on vascular smooth muscle.

3. Activation of the receptors by falling BP (and to a lesser extent by a rise in blood CO_2, or falling blood pH or O_2 levels) stimulates the vasomotor center to increase vasoconstriction and the cardioacceleratory center to increase heart rate and contractility. Rising BP inhibits the vasomotor center (permitting vasodilation) and activates the cardioinhibitory center.

4. Higher brain centers (cerebrum and hypothalamus) may modify neural controls of BP via medullary centers.

Short-Term Mechanisms: Chemical Controls (pp. 610-612)

5. Bloodborne chemicals that increase BP by promoting vasoconstriction include epinephrine and NE (these also increase heart rate and contractility), ADH, angiotensin II

(generated in response to renin release by kidney cells), and PDGF and endothelin released by vascular endothelium cells.

6. Chemicals that reduce BP by promoting vasodilation include atrial natriuretic peptide (also causes a decline in blood volume), nitric oxide released by the vascular endothelium, inflammatory chemicals, and alcohol.

Long-Term Mechanisms: Renal Regulation (p. 613)

7. The kidneys directly regulate blood pressure by regulating blood volume. Rising BP enhances filtrate formation and fluid losses in urine; falling BP causes the kidneys to retain more water, increasing blood volume.

8. Indirect renal regulation of blood volume involves the renin-angiotensin mechanism, a hormonal mechanism. When BP falls, the kidneys release renin, which triggers the formation of angiotensin II (a vasoconstrictor) and release of aldosterone, which causes salt and water to be retained.

IP Cardiovascular System CD-ROM; Topic: Blood Pressure Regulation, pages 1–31.

Monitoring Circulatory Efficiency (pp. 613-615)

9. Pulse and blood pressure measurements are used to assess cardiovascular efficiency.

10. The pulse is the alternating expansion and recoil of arterial walls with each heartbeat. Pulse points are also pressure points.

11. Blood pressure is routinely measured by the auscultatory method. Normal blood pressure in adults is 120/80 (systolic/diastolic). Hypotension is rarely a problem. Hypertension is the major cause of myocardial infarct, stroke, and renal disease.

IP Cardiovascular System CD-ROM; Topic: Measuring Blood Pressure, pages 11, 12.

Alterations in Blood Pressure (pp. 615-616)

12. Hypotension, or low blood pressure (systolic pressure below 100 mm Hg), is a sign of health in the well conditioned. In other individuals it warns of poor nutrition, disease, or circulatory shock.

13. Chronic hypertension (high blood pressure) is persistent BP readings of 140/90 or higher. It indicates increased peripheral resistance, which strains the heart and promotes vascular complications of other organs, particularly the eyes and kidneys. Risk factors are high-fat, high-salt diet, obesity, advanced age, smoking, stress, and being a member of the black race or a family with a history of hypertension.

IP Cardiovascular System CD-ROM; Topic: Measuring Blood Pressure, pages 11, 12.

Blood Flow Through Body Tissues (pp. 616-623)

1. Blood flow is involved in delivering nutrients and wastes to and from cells, gas exchange, absorbing nutrients, and forming urine.

Velocity of Blood Flow (p. 617)

2. Blood flows fastest where the cross-sectional area of the vascular bed is least (aorta), and slowest where the cross-sectional area is greatest (capillaries). The slow flow in capillaries allows time for nutrient-waste exchanges.

Autoregulation: Local Regulation of Blood Flow (pp. 617-618)

3. Autoregulation is the local adjustment of blood flow to individual organs based on their immediate requirements. It is largely controlled by local chemical factors that cause vasodilation of arterioles serving the area and open the precapillary sphincters. Myogenic controls respond to changes in blood pressure.

IP Cardiovascular CD-ROM; Topic: Autoregulation and Capillary Dynamics, pages 1–13.

Blood Flow in Special Areas (pp. 618-620)

4. In most instances, autoregulation is controlled by oxygen deficits and accumulation of local metabolites. However, autoregulation in the brain is controlled primarily by a drop in pH and by myogenic mechanisms; and vasodilation of pulmonary circuit vessels occurs in response to high levels of oxygen.

Blood Flow Through Capillaries and Capillary Dynamics (pp. 620-622)

5. Nutrients, gases, and other solutes smaller than plasma proteins cross the capillary wall by diffusion. Water-soluble substances move through the clefts or fenestrations; fat-soluble substances pass through the lipid portion of the endothelial cell membrane.

6. Fluid flows occurring at capillary beds reflect the relative effect of outward (net hydrostatic pressure) forces minus the effect of inward (net osmotic pressure) forces. In general, fluid flows out of the capillary bed at the arterial end and reenters the capillary blood at the venule end.

IP Cardiovascular CD-ROM; Topic: Autoregulation and Capillary Dynamics, pages 14–38.

7. The small net loss of fluid and protein into the interstitial space is collected by lymphatic vessels and returned to the cardiovascular system.

Circulatory Shock (pp. 622-623)

8. Circulatory shock occurs when blood perfusion of body tissues is inadequate. Most cases of shock reflect low blood volume (hypovolemic shock), abnormal vasodilation (vascular shock), or pump failure (cardiogenic shock).

Circulatory Pathways: Blood Vessels of the Body (pp. 623-646)

1. The pulmonary circulation transports O_2-poor, CO_2-laden blood to the lungs for oxygenation and carbon dioxide unloading. Blood returning to the right atrium of the heart is pumped via the pulmonary trunk, to the lungs by the right ventricle. Blood issuing from the lungs is returned to the left atrium by the pulmonary veins. (See Table 20.3 and Figure 20.17.)

2. The systemic circulation transports oxygenated blood from the left ventricle to all body tissues via the aorta and its branches. Venous blood returning from the systemic circuit is delivered to the right atrium via the venae cavae.

3. Tables 20.3 to 20.13 and Figures 20.17b to 20.28 illustrate and describe vessels of the systemic circulation.

19 THE LYMPHATIC SYSTEM

CHAPTER SUMMARY

1. Lymphatic vessels, lymph nodes, and other lymphoid organs and tissues make up the lymphatic system. This system returns fluids that have leaked from the blood vascular system back to the blood, protects the body by removing foreign material from the lymph stream, and provides a site for immune surveillance.

Lymphatic Vessels (pp. 649-651)

Distribution and Structure of Lymphatic Vessels (pp. 649-650)

1. Lymphatic vessels form a one-way network—lymphatic capillaries, collecting vessels, trunks, and ducts—in which fluid flows only toward the heart. The right lymphatic duct drains lymph from the right arm and right side of the upper body; the thoracic duct receives lymph from the rest of the body. These ducts empty into the blood vascular system at the junction of the internal jugular and subclavian veins in the neck.

Lymph Transport (pp. 650-651)

2. The flow of lymphatic fluid is slow; it is maintained by skeletal muscle contraction, pressure changes in the thorax, and (possibly) contractions of the lymphatic vessels. Backflow is prevented by valves.

3. Lymphatic capillaries are exceptionally permeable, admitting proteins and particulate matter from the interstitial space.

4. Pathogens and cancer cells may spread through the body via the lymphatic stream.

Lymphoid Cells, Tissues, and Organs: An Overview (pp. 651-652)

Lymphoid Cells (p. 652)

1. The cells in lymphoid tissues include lymphocytes (immunocompetent cells called T cells or B cells), plasma cells (antibody-producing offspring of B cells), macrophages (phagocytes that function in the immune response), and reticular cells that form the lymphoid tissue stroma.

Lymphoid Tissue (p. 652)

2. Lymphoid tissue is reticular connective tissue. It houses macrophages and a continuously changing population of lymphocytes. It is an important element of the immune system.

3. Lymphoid tissue may be diffuse or packaged into dense follicles. Follicles often display germinal centers (areas where B cells are proliferating).

Lymphoid Organs (p. 652)

4. Lymphoid organs are discrete encapsulated structures containing both diffusely arranged and dense reticular tissue. The main lymphoid organs are lymph nodes, the spleen, thymus, tonsils, and follicle aggregates.

Lymph Nodes (pp. 653-654)

Structure of a Lymph Node (pp. 653-654)

1. Lymph nodes, clustered along lymphatic vessels, filter lymph. Each lymph node has a fibrous capsule, a cortex, and a medulla. The cortex contains mostly lymphocytes, which act in immune responses; the medulla contains macrophages, which engulf and destroy viruses, bacteria, and other foreign debris, as well as lymphocytes and plasma cells.

Circulation in the Lymph Nodes (p. 654)

2. Lymph enters the lymph nodes via afferent lymphatic vessels and exits via efferent vessels. There are fewer efferent vessels; therefore, lymph flow stagnates within the lymph node, allowing time for its cleansing.

Other Lymphoid Organs (pp. 654-657)

1. Unlike lymph nodes, the spleen, thymus, tonsils, and Peyer's patches do not filter lymph. However, most lymphoid organs contain both macrophages and lymphocytes.

Spleen (pp. 654-656)

2. The spleen provides a site for lymphocyte proliferation and immune function, and destroys aged or defective red blood cells and bloodborne pathogens. It also stores and releases the breakdown products of hemoglobin as necessary, stores platelets, acts as a hematopoietic site in the fetus.

Thymus (p. 656)

3. The thymus is most functional during youth. Its hormones cause T lymphocytes to become immunocompetent.

Tonsils and Aggregates of Lymphoid Follicles (pp. 656-657)

4. Peyer's patches of the intestinal wall, lymphatic follicles of the appendix, tonsils of the pharynx, and follicles in the bronchial walls of the respiratory tract are known as MALT (mucosa-associated lymphatic tissue). They prevent pathogens in the respiratory and digestive tracts from penetrating the mucous membrane lining.

20 THE IMMUNE SYSTEM: INNATE AND ADAPTIVE BODY DEFENSES

CHAPTER SUMMARY

Part 1: Innate (Nonspecific) Defenses (pp. 660-668)

Surface Barriers: Skin and Mucosae (pp. 660-661)

1. Skin and mucous membranes constitute the first line of defense. Their role is to prevent pathogens from entering the body. Protective membranes line all body cavities and organs exposed to the exterior.

2. Surface membranes provide mechanical barriers to pathogens. Some have structural modifications and produce secretions that enhance their defensive effects: The skin's acidity, lysozyme, mucus, keratin, and ciliated cells are examples.

Internal Defenses: Cells and Chemicals (pp. 661-668)

1. The nonspecific cellular and chemical defenses provide the body's second line of defense.

Phagocytes (pp. 661-662)

2. Phagocytes (macrophages, neutrophils, and the like) engulf and destroy pathogens that breach epithelial barriers. This process is facilitated when antibodies or complement to which the phagocyte's receptors can bind attach to the pathogen's surface. Cell killing is enhanced by the respiratory burst.

Natural Killer Cells (p. 662)

3. Natural killer cells are large granular lymphocytes that act nonspecifically to kill virus-infected and malignant cells.

Inflammation: Tissue Response to Injury (p. 662)

4. The inflammatory response prevents the spread of harmful agents, disposes of pathogens and dead tissue cells, and promotes healing. Exudate is formed; protective leukocytes enter the area; the area is walled off by fibrin; and tissue repair occurs.

5. The cardinal signs of inflammation are swelling, redness, heat, and pain. These result from vasodilation and increased permeability of blood vessels induced by inflammatory chemicals. If the inflamed area is a joint, movement may be impaired.

Antimicrobial Proteins (pp. 666-668)

6. When complement (a group of plasma proteins) is fixed on a foreign cell's membrane, lysis of the target cell occurs. Complement also enhances phagocytosis and the inflammatory and adaptive immune responses.

7. Interferons are a group of related proteins synthesized by virus-infected cells and certain immune cells that prevent viruses from multiplying in other body cells.

Fever (p. 668)

8. Fever enhances the body's fight against pathogens by increasing metabolism, which speeds up defensive actions and repair processes, and by prompting the liver and spleen to sequester iron and zinc needed for bacterial multiplication.

Part 2: Adaptive (Specific) Defenses (pp. 669-693)

1. The immune system recognizes something as foreign and acts to immobilize, neutralize, or remove it. The adaptive immune response is antigen-specific, systemic, and has memory. It provides the body's third line of defense.

Antigens (pp. 669-670)

1. Antigens are substances capable of generating an immune response.

Complete Antigens and Haptens (pp. 669-670)

2. Complete antigens have both immunogenicity and reactivity. Incomplete antigens or haptens must combine with a body protein before becoming immunogenic.

Antigenic Determinants (p. 670)

3. Antigenic determinants are the portions of antigen molecules that are recognized as foreign. Most antigens have many such sites.

Self-Antigens: MHC Proteins (p. 670)

4. Major histocompatibility complex (MHC) proteins are membrane-bound glycoproteins that mark our cells as "self." Class I MHC proteins are found on all body cells (except RBCs); the class II variety is found on surfaces of cells that function in the adaptive immune response.

Cells of the Adaptive Immune System: An Overview (pp. 670-673)

1. Lymphocytes arise from the hemocytoblasts of the bone marrow. T cells develop immunocompetence in the thymus and confer cell-mediated immunity. B cells develop immunocompetence in the bone marrow and provide humoral immunity. Immunocompetent lymphocytes seed the lymphoid organs, where the antigen challenge occurs, and circulate between the blood, lymph, and lymphoid organs.

2. Immunocompetence is signaled by the appearance of antigen-specific receptors on the surfaces of the lymphocytes.

3. Antigen-presenting cells (APCs) include dendritic cells, macrophages, and activated B lymphocytes. They phagocytize pathogens and present antigenic determinants on their surfaces for recognition by T cells.

Humoral Immune Response (pp. 673-680)

Clonal Selection and Differentiation of B Cells (pp. 673-674)

1. Clonal selection and differentiation of B cells occur when antigens bind to their receptors, causing them to proliferate. Most of the clone members become plasma cells, which secrete antibodies. This is the primary adaptive immune response.

Immunological Memory (p. 674)

2. Other clone members become memory B cells, capable of mounting a rapid attack against the same antigen in subsequent encounters (secondary adaptive immune responses). The memory cells provide humoral immunological memory.

3. Active humoral immunity is acquired during an infection or via vaccination and provides immunological memory. Passive immunity is conferred when a donor's antibodies are injected into the bloodstream, or when the mother's antibodies cross the placenta. Its protection is short-lived; immunological memory is not established.

20 The Immune System: Innate and Adaptive Body Defenses

Antibodies (pp. 671-680)

4. The antibody monomer consists of four polypeptide chains, two heavy and two light, connected by disulfide bonds. Each chain has both a constant and a variable region. Constant regions determine antibody function and class. Variable regions enable the antibody to recognize its appropriate antigen.

5. Five classes of antibodies exist: IgM, IgA, IgD, IgG, and IgE. They differ structurally and functionally.

6. Antibody functions include complement fixation and antigen neutralization, precipitation, and agglutination.

7. Monoclonal antibodies are pure preparations of a single antibody type useful in diagnostic tests and in treatment for some types of cancer. They are prepared by injecting an antigen into a laboratory animal, harvesting its B cells, and fusing them with myeloma cells.

Cell-Mediated Immune Response (pp. 680-689)

Clonal Selection and Differentiation of T Cells (pp. 680-683)

1. Immunocompetent helper (T_H) and cytotoxic (T_C) T cells are activated by binding simultaneously to an antigen and a MHC protein displayed on the surface of an APC. Some type of costimulatory signal (physical or chemical) is also essential. Clonal selection occurs and the clone members differentiate into the appropriate effector T cells that mount the primary immune response. Some clone members become memory T cells.

Specific T Cell Roles (pp. 684-688)

2. Helper T cells release cytokines that help activate other immune cells and interact directly with B cells bound to antigen. Cytotoxic T cells directly attack and lyse infected cells and cancer cells. Suppressor T cells help terminate normal immune responses by releasing suppressor factors that dampen the activity of helper T cells and B cells. Delayed hypersensitivity T cells release cytokines that enlist macrophages in (nonspecific) cell killing. Gamma delta T cells which inhabit the intestine are more like NK cells than other T cells.

3. The immune response is enhanced by cytokines such as interleukin 1 released by macrophages, and interleukin 2, MIF, γ interferon, and others released by activated T cells.

Organ Transplants and Prevention of Rejection (p. 689)

4. Grafts or foreign organ transplants are rejected by cell-mediated responses unless the patient is immunosuppressed. Infections are major complications in such patients.

Homeostatic Imbalances of Immunity (pp. 689-693)

Immunodeficiencies (pp. 689-691)

1. Immunodeficiency diseases include severe combined immunodeficiency (SCID) syndromes and acquired immune deficiency syndrome (AIDS). Overwhelming infections are fatal because the immune system is unable to combat them.

Autoimmune Diseases (p. 691)

2. Autoimmune disease occurs when the body regards its own tissues as foreign and mounts an immune attack against them. Examples include rheumatoid arthritis and multiple sclerosis.

Hypersensitivities (pp. 691-693)

3. Hypersensitivity, or allergy, is an abnormally intense reaction to an allergen following the initial immune response. Immediate hypersensitivities mounted by antibodies include anaphylaxis and atopy. Subacute hypersensitivities, involving both antibodies and complement, include antibody-mediated cytotoxic and immune-complex hypersensitivities. Cell-mediated hypersensitivity is called delayed hypersensitivity.

21 THE RESPIRATORY SYSTEM

CHAPTER SUMMARY

References to Interactive Physiology **IP** *appear below specific key chapter topics to help your review.*

1. Respiration involves four processes: ventilation, external respiration, internal respiration, and transport of respiratory gases in the blood. Both the respiratory system and the cardiovascular system are involved in respiration.

Functional Anatomy of the Respiratory System (pp. 696-710)

2. Respiratory system organs are divided functionally into conducting zone structures (nose to bronchioles), which filter, warm, and moisten incoming air; and respiratory zone structures (respiratory bronchioles to alveoli), where gas exchanges occur.

The Nose and the Paranasal Sinuses (pp. 696-699)

3. The nose provides an airway for respiration; warms, moistens, and cleanses incoming air; and houses the olfactory receptors.

4. The external nose is shaped by bone and cartilage plates. The nasal cavity, which opens to the exterior, is divided by the nasal septum. Paranasal sinuses and nasolacrimal ducts drain into the nasal cavities.

The Pharynx (pp. 699-700)

5. The pharynx extends from the base of the skull to the level of C_6. The nasopharynx is an air conduit; the oropharynx and laryngopharynx are common passageways for food and air. Pairs of tonsils are found in the oropharynx and nasopharynx.

The Larynx (pp. 700-702)

6. The larynx, or voice box, contains the vocal cords. It also provides a patent airway and serves as a switching mechanism to route food and air into the proper channels.

7. The epiglottis prevents food or liquids from entering the respiratory channels during swallowing.

The Trachea (pp. 702-704)

8. The trachea extends from the larynx to the primary bronchi. The trachea is reinforced by C-shaped cartilage rings, which keep the trachea patent, and its mucosa is ciliated.

The Bronchi and Subdivisions: The Bronchial Tree (pp. 704-709)

9. The right and left main bronchi run into their respective lungs, within which they continue to subdivide into smaller and smaller passageways.

10. The terminal bronchioles lead into respiratory zone structures: alveolar ducts, alveolar sacs, and finally alveoli. Gas exchange occurs in the alveoli, across the respiratory membrane.

11. As the respiratory conduits become smaller, cartilage is reduced in amount and finally lost; the mucosa thins, and smooth muscle in the walls increases.

IP Respiratory System CD-ROM; Topic: Anatomy Review, page 6.

The Lungs and Pleural Coverings (pp. 709-710)

12. The lungs, the paired organs of gas exchange, flank the mediastinum in the thoracic cavity. Each is suspended in its own pleural cavity via its root and has a base, an apex, and medial and costal surfaces. The right lung has three lobes; the left has two.

13. The lungs are primarily air passageways/chambers, supported by an elastic connective tissue stroma.

14. The pulmonary arteries carry blood returned from the systemic circulation to the lungs, where gas exchange occurs. The pulmonary veins return newly oxygenated (and most venous) blood back to the heart to be distributed throughout the body. The bronchial arteries provide the nutrient blood supply of the lungs.

15. The parietal pleura lines the thoracic wall and mediastinum; the pulmonary pleura covers external lung surfaces. Pleural fluid reduces friction during breathing movements.

IP Respiratory System CD-ROM; Topic: Anatomy Review: Respiratory Structure, pages 1–5.

Mechanics of Breathing (pp. 710-718)

Pressure Relationships in the Thoracic Cavity (pp. 711-712)

1. Intrapulmonary pressure is the pressure within the alveoli. Intrapleural pressure is the pressure within the pleural cavity; it is always negative relative to intrapulmonary and atmospheric pressures.

IP Respiratory System CD-ROM; Topic: Pulmonary Ventilation, pages 7–9.

Pulmonary Ventilation: Inspiration and Expiration (pp. 712-714)

2. Gases travel from an area of higher pressure to an area of lower pressure.

3. Inspiration occurs when the diaphragm and intercostal muscles contract, increasing the dimensions (and volume) of the thorax. As the intrapulmonary pressure drops, air rushes into the lungs until the intrapulmonary and atmospheric pressures are equalized.

4. Expiration is largely passive, occurring as the inspiratory muscles relax and the lungs recoil. When intrapulmonary pressure exceeds atmospheric pressure, gases flow from the lungs.

IP Respiratory System CD-ROM; Topic: Pulmonary Ventilation, pages 3–6, 11–13.

Physical Factors Influencing Pulmonary Ventilation (pp. 714-716)

5. Friction in the air passageways causes resistance, which decreases air passage and causes breathing movements to become more strenuous. The greatest resistance to air flow occurs in the midsize bronchi.

6. Surface tension of alveolar fluid acts to reduce alveolar size and collapse the alveoli. This tendency is resisted in part by surfactant.

21 *The Respiratory System*

7. Lung compliance depends on elasticity of lung tissue and flexibility of the bony thorax. When either is impaired, expiration becomes an active process, requiring energy expenditure.

IP Respiratory System CD-ROM; Topic: Pulmonary Ventilation, pages 14–18.

Respiratory Volumes and Pulmonary Function Tests (p. 716)

8. The four respiratory volumes are tidal, inspiratory reserve, expiratory reserve, and residual. The four respiratory capacities are vital, functional residual, inspiratory, and total lung. Respiratory volumes and capacities may be measured by spirometry.

9. Anatomical dead space is the air-filled volume (about 150 ml) of the conducting passageways. If alveoli become nonfunctional in gas exchange, their volume is added to the anatomical dead space, and the sum is the total dead space.

10. Alveolar ventilation is the best index of ventilation efficiency because it accounts for anatomical dead space.

AVR = (TV - anatomical dead space) x respiratory rate (ml/breath)

11. The FVC and FEV tests, which determine the rate at which VC air can be expelled, are particularly valuable in distinguishing between obstructive and restrictive disease.

Nonrespiratory Air Movements (p. 718)

12. Nonrespiratory air movements are voluntary or reflex actions that clear the respiratory passageways or express emotions.

Gas Exchanges in the Body (pp. 718-723)

Basic Properties of Gases (pp. 718-720)

1. Gaseous movements in the body occur by bulk flow and by diffusion.

2. Dalton's law states that each gas in a mixture of gases exerts pressure in proportion to its percentage in the total mixture.

3. Henry's law states that the amount of gas that will dissolve in a liquid is proportional to the partial pressure of the gas. Solubility of the gas in the liquid and the temperature are other important factors.

IP Respiratory System CD-ROM; Topic: Gas Exchange, pages 1–6.

Composition of Alveolar Gas (p. 720)

4. Alveolar gas contains more carbon dioxide and water vapor and considerably less oxygen than atmospheric air.

Gas Exchanges Between the Blood, Lungs, and Tissues (pp. 721-723)

5. External respiration is the process of gas exchange that occurs in the lungs. Oxygen enters the pulmonary capillaries; carbon dioxide leaves the blood and enters the alveoli. Factors influencing this process include the partial pressure gradients, the thickness of the respiratory membrane, surface area available, and the matching of alveolar ventilation and pulmonary perfusion.

6. Internal respiration is the gas exchange that occurs between the systemic capillaries and the tissues. Carbon dioxide enters the blood, and oxygen leaves the blood and enters the tissues.

IP Respiratory System CD-ROM; Topic: Gas Exchange, pages 6–11, 15–16.

Transport of Respiratory Gases by Blood (pp. 723-727)

Oxygen Transport (pp. 723-726)

1. Molecular oxygen is carried bound to hemoglobin in the blood cells. The amount of oxygen bound to hemoglobin depends on the P_{O_2} and P_{CO_2} of blood, blood pH, the presence of BPG, and temperature. A small amount of oxygen gas is transported dissolved in plasma. Nitric oxide carried by hemoglobin aids the delivery of O_2 and pickup of CO_2 in the tissues by causing vasodilation.

2. Hypoxia occurs when inadequate amounts of oxygen are delivered to body tissues. When this occurs, the skin and mucosae may become cyanotic.

Carbon Dioxide Transport (pp. 726-728)

3. CO_2 is transported in the blood dissolved in plasma, chemically bound to hemoglobin, and (primarily) as bicarbonate ion in plasma. Loading and unloading of O_2 and CO_2 are mutually beneficial.

4. Accumulation of CO_2 leads to acidosis; depletion of CO_2 from blood leads to respiratory alkalosis.

IP Respiratory System CD-ROM; Topic: Gas Transport, pages 1–15.

Control of Respiration (pp. 728-733)

Neural Mechanisms and Generation of Breathing Rhythm (pp. 728-729)

1. Medullary respiratory centers are the inspiratory center (dorsal respiratory group) and the ventral respiratory group. The inspiratory center is responsible for the rhythmicity of breathing.

2. The pneumotaxic center (and perhaps other respiratory centers in the pons) influence the activity of the medullary inspiratory center.

Factors Influencing the Rate and Depth of Breathing (pp. 730-733)

3. Pulmonary irritant reflexes are initiated by dust, mucus, fumes, and pollutants.

4. The inflation (Hering-Breuer) reflex is a protective reflex initiated by extreme overinflation of the lungs; it acts to initiate expiration.

5. Emotions, pain, body temperature changes, and other stressors can alter respiration by acting through hypothalamic centers. Respiration can also be controlled voluntarily for short periods of time.

6. Important chemical factors modifying baseline respiratory rate and depth are arterial levels of CO_2, H^+, and O_2.

7. An increasing P_{CO_2} is the most powerful respiratory stimulant. It acts (via release of H^+ in the CSF) on the central chemoreceptors to cause a reflexive increase in the rate and depth of breathing. Hypocapnia depresses respiration and results in hypoventilation and, possibly, apnea.

8. Acidosis and a decline in blood P_{O_2} act on peripheral chemoreceptors and enhance the response to CO_2.

9. Arterial P_{O_2} levels below 60 mm Hg constitute the hypoxic drive.

IP Respiratory System CD-ROM; Topic: Control of Respiration, pages 6–14.

21 *The Respiratory System*

Respiratory Adjustments During Exercise and at High Altitudes (pp. 733-734)

Effects of Exercise (p. 733)

1. As exercise begins, there is an abrupt increase in ventilation (hyperpnea) followed by a more gradual increase. When exercise stops, there is an abrupt decrease in ventilation followed by a gradual decline to baseline values.

2. P_{O2}, P_{CO2}, and blood pH remain quite constant during exercise and hence do not appear to account for changes in ventilation. Psychological factors and proprioceptor inputs may contribute.

Effects of High Altitude (pp. 733-734)

3. At high altitudes, there is a decrease in arterial P_{O2} and hemoglobin saturation levels because of the decrease in barometric pressure compared to sea level. Hyperventilation helps restore gas exchange to physiological levels.

4. Long-term acclimatization involves increased erythropoiesis.

Homeostatic Imbalances of the Respiratory System (pp. 734-736)

1. Two major respiratory disorders are COPD (emphysema and chronic bronchitis) and lung cancer; a significant cause is cigarette smoking. A third major disorder is asthma. Tuberculosis is re-emerging as a major health problem.

Chronic Obstructive Pulmonary Disease (COPD) (pp. 734-735)

2. Emphysema is characterized by permanent enlargement and destruction of alveoli. The lungs lose their elasticity, and expiration becomes an active process.

3. Chronic bronchitis is characterized by excessive mucus production in the lower respiratory passageways, which severely impairs ventilation and gas exchange. Patients may become cyanotic as a result of chronic hypoxia.

Asthma (p. 735)

4. An obstructive condition caused by an immune response that causes its victims to wheeze and gasp for air as their inflamed respiratory passages constrict. Marked by exacerbations and periods of relief from symptoms.

Tuberculosis (pp. 735-736)

5. Tuberculosis (TB), an infectious disease caused by an airborne bacterium, mainly affects the lungs. Although most infected individuals remain asymptomatic by walling off the bacteria in tubercles, when immunity is depressed disease symptoms ensue. Recent TB increases in AIDS patients and some patients' failure to complete drug therapy have produced multidrug-resistant TB strains.

Lung Cancer (p. 736)

6. Lung cancer, promoted by free radicals and other carcinogens, is extremely aggressive and metastasizes rapidly.

22 THE DIGESTIVE SYSTEM

CHAPTER SUMMARY

Overview of the Digestive System (pp. 739-745)

1. The digestive system includes organs of the alimentary canal (mouth, pharynx, esophagus, stomach, small and large intestines) and accessory digestive system organs (teeth, tongue, salivary glands, liver, gallbladder, and pancreas).

Digestive Processes (pp. 740-741)

2. Digestive system activities include six functional processes: ingestion, or food intake; propulsion, or movement of food through the tract; mechanical digestion, or processes that physically mix or break foods down into smaller fragments; chemical digestion, or food breakdown by enzymatic action; absorption, or transport of products of digestion through the intestinal mucosa into the blood; and defecation, or elimination of the undigested residues (feces) from the body.

Basic Functional Concepts (pp. 741-742)

3. The digestive system controls the environment within its lumen to ensure optimal conditions for digestion and absorption of foodstuffs.

4. Receptors and hormone-secreting cells in the alimentary canal wall respond to stretch and chemical signals that result in stimulation or inhibition of GI secretory activity or motility. The alimentary canal has a local (intrinsic) nerve supply.

Digestive System Organs: Relationships and Structural Plan (pp. 742-745)

5. The parietal and visceral layers of the peritoneum are continuous with one another via several extensions (mesentery, falciform ligament, lesser and greater omenta), and are separated by a potential space containing serous fluid, which decreases friction during organ activity.

6. The digestive viscera is served by the splanchnic circulation, consisting of arterial branches of the celiac trunk and aorta and the hepatic portal circulation.

7. All organs of the GI tract have the same basic pattern of tissue layers in their walls; that is, all have a mucosa, a submucosa, a muscularis, and a serosa (or adventitia). Intrinsic nerve plexuses (enteric nervous system) are found within the wall.

Part 1: Functional Anatomy of the Digestive System (pp. 745-783)

The Mouth, Pharynx, and Esophagus (pp. 745-754)

1. Food enters the GI tract via the mouth, which is continuous with the oropharynx posteriorly. The boundaries of the mouth are the lips and cheeks, palate, and tongue.

2. The oral mucosa is stratified squamous epithelium, an adaptation seen where abrasion occurs.

3. The tongue is mucosa-covered skeletal muscle. Its intrinsic muscles allow it to change shape; its extrinsic muscles allow it to change position.

4. Saliva is produced by many small buccal glands and three pairs of major salivary glands—parotid, submandibular, and sublingual—that secrete their product into the mouth via ducts. Largely water, saliva also contains ions, proteins, metabolic wastes, lysozyme, defensins, IgA, salivary amylase, a cyanide compound, and mucin.

5. Saliva moistens and cleanses the mouth; moistens foods, aiding their compaction; dissolves food chemicals to allow for taste; and begins chemical digestion of starch (salivary amylase). Saliva output is increased by parasympathetic reflexes initiated by activation of chemical and pressure receptors in the mouth and by conditioned reflexes. The sympathetic nervous system depresses salivation.

6. The 20 deciduous teeth begin to be shed at the age of six and are gradually replaced during childhood and adolescence by the 32 permanent teeth.

7. Teeth are classed as incisors, canines, premolars, and molars. Each tooth has an enamel-covered crown and a cementum-covered root. The bulk of the tooth is dentin, which surrounds the central pulp cavity. A periodontal ligament secures the tooth to the bony alveolus.

8. Food propelled from the mouth passes through the oropharynx and laryngopharynx. The mucosa of the pharynx is stratified squamous epithelium; skeletal muscles in its wall (constrictor muscles) move food toward the esophagus.

9. The esophagus extends from the laryngopharynx and joins the stomach at the cardiac orifice, which is surrounded by the gastroesophageal sphincter.

10. The esophageal mucosa is stratified squamous epithelium. Its muscularis is skeletal muscle superiorly and changes to smooth muscle inferiorly. It has an adventitia rather than a serosa.

11. The mouth and associated accessory organs accomplish food ingestion and mechanical digestion (chewing and mixing), initiate the chemical digestion of starch (salivary amylase), and propel food into the pharynx (buccal phase of swallowing).

12. Teeth function to masticate food. Chewing is initiated voluntarily and is then controlled reflexively.

13. The tongue mixes food with saliva, compacts it into a bolus, and initiates swallowing (the voluntary phase). The pharynx and esophagus are primarily food conduits that conduct food to the stomach by peristalsis. The swallowing center in the medulla and pons controls this phase reflexively. When the peristaltic wave approaches the gastroesophageal sphincter, the sphincter relaxes to allow food entry to the stomach.

The Stomach (pp. 754-764)

1. The C-shaped stomach lies in the upper left quadrant of the abdomen. Its major regions are the cardia, fundus, body, and pyloric region. When empty, its internal surface exhibits rugae.

2. The stomach mucosa is simple columnar epithelium dotted with gastric pits that lead into gastric glands. Secretory cells in the gastric glands include pepsinogen-producing chief cells; parietal cells, which secrete hydrochloric acid and intrinsic factor; mucous neck cells, which produce mucus; and enteroendocrine cells, which secrete hormones.

3. The mucosal barrier, which protects the stomach from self-digestion and HCl, reflects the fact that the mucosal cells are connected by tight junctions, secrete a thick mucus, and are quickly replaced when damaged.

22 The Digestive System

4. The stomach muscularis contains a third layer of obliquely oriented smooth muscle that allows it to churn and mix food.

5. Protein digestion is initiated in the stomach by activated pepsin and requires acidic conditions (provided by HCl). Few substances are absorbed.

6. Gastric secretory activity is controlled by both nervous and hormonal factors. The three phases of gastric secretion are the cephalic, gastric, and intestinal. For the most part stimuli acting on the head and stomach (cephalic and gastric respectively) stimulate gastric secretion. Most stimuli acting on the small intestine trigger the enterogastric reflex and release of secretin, CCK, and GIP, all of which inhibit gastric secretory activity. Sympathetic activity also inhibits gastric secretion.

7. Mechanical digestion in the stomach is triggered by stomach distension and coupled to food propulsion and stomach emptying. Food movement into the duodenum is controlled by the pylorus and feedback signals from the small intestine. Pacemaker cells in the smooth muscle sheet set the maximal rate of peristalsis.

The Small Intestine and Associated Structures (p. 764)

1. The small intestine extends from the pyloric sphincter to the ileocecal valve. Its three subdivisions are the duodenum, jejunum, and ileum. The common bile duct and pancreatic duct join to form the hepatopancreatic ampulla and empty their secretions into the duodenum through the hepatopancreatic sphincter (of Oddi).

2. The duodenal submucosa contains elaborate mucus-secreting duodenal glands (Brunner's glands); that of the ileum contains Peyer's patches (lymph follicles). The duodenum is covered with an adventitia rather than a serosa.

3. Circular folds, villi, and microvilli increase the intestinal surface area for digestion and absorption.

4. The small intestine is the major digestive and absorptive organ. Intestinal juice is largely water and is relatively enzyme-poor. The major stimuli for its release are stretch and chemicals.

5. The liver is a lobed organ overlying the stomach. Its digestive role is to produce bile, which it secretes into the common hepatic duct.

6. The structural and functional units of the liver are the hepatic lobules. Blood flowing to the liver via the hepatic artery and hepatic portal vein flows into its sinusoids from which Kupffer cells remove debris and hepatocytes remove nutrients. Hepatocytes store glucose as glycogen, use amino acids to make plasma proteins, and detoxify metabolic wastes and drugs.

7. Bile is made continuously by the hepatocytes. Bile salts, secretin, and vagal stimulation stimulate bile production.

8. The gallbladder, a muscular sac that lies beneath the right liver lobe, stores and concentrates bile.

9. Bile contains electrolytes, a variety of fatty substances, bile salts, and bile pigments in an aqueous medium. Bile salts are emulsifying agents; they disperse fats and form water-soluble micelles, which solubilize the products of fat digestion.

10. Cholecystokinin released by the small intestine stimulates the gallbladder to contract and the hepatopancreatic sphincter to relax, allowing bile (and pancreatic juice) to enter the duodenum.

11. The pancreas is retroperitoneal between the spleen and small intestine. Its exocrine product, pancreatic juice, is carried to the duodenum via the pancreatic duct.

12. Pancreatic juice is an HCO_3^--rich fluid containing enzymes that digest all categories of foods. Secretion of pancreatic juice is controlled by intestinal hormones and the vagus nerves.

13. Mechanical digestion and propulsion in the small intestine mix chyme with digestive juices and bile and force the residues, largely by segmentation, through the ileocecal valve. Pacemaker cells set the rate of segmentation. Ileocecal valve opening is controlled by the gastroileal reflex and gastrin.

The Large Intestine (pp. 778-783)

1. The subdivisions of the large intestine are the cecum (and appendix), colon (ascending, transverse, descending, and sigmoid portions), rectum, and anal canal. It opens to the body exterior at the anus.

2. The mucosa of most of the large intestine is simple columnar epithelium containing abundant goblet cells. The longitudinal muscle in the muscularis is reduced to three bands (teniae coli), which pucker its wall, producing haustra.

3. The major functions of the large intestine are absorption of water, and some electrolytes (and vitamins made by enteric bacteria), and defecation (evacuation of food residues from the body).

4. The defecation reflex is triggered when feces enter the rectum. It involves parasympathetic reflexes leading to the contraction of the rectal walls and is aided by Valsalva's maneuver.

Part 2: Physiology of Chemical Digestion and Absorption (pp.783-789)

Chemical Digestion (pp. 783-786)

1. Chemical digestion is accomplished by hydrolysis, catalyzed by enzymes.

2. Most chemical digestion is done in the small intestine by intestinal (brush border) enzymes and, more importantly, by pancreatic enzymes. Alkaline pancreatic juice neutralizes the acidic chyme and provides the proper environment for operation of the enzymes. Both pancreatic juice (the main source of lipases) and bile are necessary for normal fat breakdown.

Absorption (pp. 786-789)

1. Virtually all of the foodstuffs and most of the water and electrolytes are absorbed in the small intestine. Except for fat digestion products, fat-soluble vitamins, and most water-soluble vitamins (which are absorbed by diffusion), most nutrients are absorbed by active transport processes.

2. Fat breakdown products are solubilized by bile salts (in micelles), resynthesized to triglycerides in the intestinal mucosal cells, and combined with other lipids and protein as chylomicrons that enter the lacteals. Other absorbed substances enter the villus blood capillaries and are transported to the liver via the hepatic portal vein.

23 NUTRITION, METABOLISM, AND BODY TEMPERATURE REGULATION

CHAPTER SUMMARY

References to Interactive Physiology IP *appear below specific key chapter topics to help your review.*

Nutrition (pp. 792-804)

1. Nutrients include water, carbohydrates, lipids, proteins, vitamins, and minerals. The bulk of the organic nutrients is used as fuel to produce cellular energy (ATP). The energy value of foods is measured in kilocalories (kcal).

2. Essential nutrients are those that cannot be synthesized by body cells and must be ingested in the diet.

Carbohydrates (p. 793)

3. Carbohydrates are obtained primarily from plant products. Absorbed monosaccharides other than glucose are converted to glucose by the liver.

4. Monosaccharides are used primarily for cellular fuel. Small amounts are used for nucleic acid synthesis and to glycosylate plasma membranes.

5. Minimum carbohydrate requirement for adults is 100 g/day.

Lipids (pp. 793-794)

6. Most dietary lipids are triglycerides. The primary sources of saturated fats are animal products; unsaturated fats are present in plant products. The major source of cholesterol is egg yolk.

7. Linoleic and linolenic acids are essential fatty acids.

8. Neutral fats provide reserve energy, cushion body organs, and insulate the body. Phospholipids are used to synthesize plasma membranes and myelin. Cholesterol is used in plasma membranes and is the structural basis of vitamin D, steroid hormones, and bile salts.

9. Fats should represent 30% or less of caloric intake, and saturated fats should be replaced by unsaturated fats if possible. Cholesterol intake should be restricted to 250 mg or less daily.

Proteins (pp. 794-796)

10. Animal products provide high-quality protein containing all (8) essential amino acids. Most plant products lack one or more of the essential amino acids.

11. Amino acids are the structural building blocks of the body and of important regulatory molecules.

12. Protein synthesis can and will occur if all essential amino acids are present and sufficient carbohydrate (or fat) calories are available to produce ATP. Otherwise, amino acids will be burned for energy.

13. Nitrogen balance occurs when protein synthesis equals protein loss.

14. A dietary intake of 0.8 g of protein/kg of body weight is recommended for adults.

Vitamins (pp.796-797)

15. Vitamins are organic compounds needed in minute amounts. Most act as coenzymes.

16. Except for vitamin D and the K and B vitamins made by enteric bacteria, vitamins are not made in the body.

17. Water-soluble vitamins (B and C) are not stored to excess in the body. Fat-soluble vitamins include vitamins A, D, E, and K; all but vitamin K are stored and can accumulate to toxic amounts.

Minerals (pp. 797, 801-804)

18. Besides calcium, phosphorus, potassium, sulfur, sodium, chloride, and magnesium, the body requires trace amounts of at least a dozen other minerals.

19. Minerals are not used for energy. Some are used to mineralize bone; others are bound to organic compounds or exist as ions in body fluids, where they play various roles in cell processes and metabolism.

20. Mineral uptake and excretion are carefully regulated to prevent mineral toxicity. The richest sources of minerals are animal products, vegetables, and legumes.

Metabolism (pp. 805-829)

Overview of Metabolic Processes (pp. 805-808)

1. Metabolism encompasses all chemical reactions necessary to maintain life. Metabolic processes are either anabolic or catabolic.

2. Cellular respiration refers to catabolic processes during which energy is released and some is captured in ATP bonds.

3. Energy is released when organic compounds are oxidized. Cellular oxidation is accomplished primarily by the removal of hydrogen (electrons). When molecules are oxidized, others are simultaneously reduced by accepting hydrogen (or electrons).

4. Most enzymes catalyzing oxidation-reduction reactions require coenzymes as hydrogen acceptors. Two important coenzymes in these reactions are NAD^+ and FAD.

5. In animal cells, the two mechanisms of ATP synthesis are substrate-level phosphorylation and oxidative phosphorylation.

IP Muscular System CD-ROM; Topic: Muscle Metabolism, pages 3–8.

Carbohydrate Metabolism (pp. 808-816)

6. Carbohydrate metabolism is essentially glucose metabolism.

7. Phosphorylation of glucose on entry into cells effectively traps it in most tissue cells.

8. Glucose is oxidized to carbon dioxide and water via three successive pathways: glycolysis, Krebs cycle, and electron transport chain. Some ATP is harvested in each pathway, but the bulk is captured in the electron transport chain.

9. Glycolysis is a reversible pathway in which glucose is converted into two pyruvic acid molecules; two molecules of reduced NAD^+ are formed, and there is a net gain of two ATPs. Under aerobic conditions, pyruvic acid enters the Krebs cycle; under anaerobic conditions, it is reduced to lactic acid.

10. The Krebs cycle is fueled by pyruvic acid (and fatty acids). To enter the cycle, pyruvic acid is converted to acetyl CoA. The acetyl CoA is then oxidized and decarboxylated. Complete oxidation of two pyruvic acid molecules yields 6 CO_2, 8

23 Nutrition, Metabolism, and Body Temperature Regulation

$NADH + H^+$, 2 $FADH_2$, and a net gain of 2 ATP. Much of the energy originally present in the bonds of pyruvic acid is now present in the reduced coenzymes.

11. In the electron transport chain, (a) reduced coenzymes are oxidized by delivering hydrogen to a series of oxidation-reduction acceptors; (b) hydrogen is split into hydrogen ions and electrons (as electrons run downhill from acceptor to acceptor, the energy released is used to pump H^+ into the mitochondrial intermembrane space, which creates an electrochemical proton gradient); (c) the energy stored in the electrochemical proton gradient drives H^+ back through ATP synthase, which uses the energy to form ATP; (d) H^+ and electrons are combined with oxygen to form water.

12. For each glucose molecule oxidized to carbon dioxide and water, there is a net gain of 36 ATP: 4 ATP from substrate-level phosphorylation and 34 ATP from oxidative phosphorylation. The shuttle for reduced NAD^+ produced in the cytosol uses 2 ATP of that amount.

13. When cellular ATP reserves are high, glucose catabolism is inhibited and glucose is converted to glycogen (glycogenesis) or to fat (lipogenesis). Much more fat than glycogen is stored.

14. Gluconeogenesis is the formation of glucose from noncarbohydrate (fat or protein) molecules. It occurs in the liver when blood glucose levels begin to fall.

IP Muscular System CD-ROM; Topic: Muscle Metabolism, pages 10–22.

Lipid Metabolism (pp. 816-818)

15. End products of lipid digestion (and cholesterol) are transported in blood in the form of chylomicrons.

16. Glycerol is converted to glyceraldehyde-PO_4 and enters the Krebs cycle or is converted to glucose.

17. Fatty acids are oxidized by beta oxidation into acetic acid fragments. These are bound to coenzyme A and enter the Krebs cycle as acetyl CoA. Dietary fats not needed for energy or structural materials are stored in adipose tissue.

18. There is a continual turnover of fats in fatty depots. Breakdown of fats to fatty acids and glycerol is called lipolysis.

19. When excessive amounts of fats are used, the liver converts acetyl CoA to ketone bodies and releases them to the blood. Excessive levels of ketone bodies (ketosis) lead to metabolic acidosis.

20. All cells use phospholipids and cholesterol to build their plasma membranes. The liver forms many functional molecules (lipoproteins, tissue factor, etc.) from lipids.

Protein Metabolism (pp. 818-820)

21. To be oxidized for energy, amino acids are converted to keto acids that can enter the Krebs cycle. This involves transamination, oxidative deamination, and keto acid modification.

22. Amine groups removed during deamination (as ammonia) are combined with carbon dioxide by the liver to form urea. Urea is excreted in urine.

23. Deaminated amino acids may also be converted to fatty acids and glucose.

24. Amino acids are the body's most important building blocks. Nonessential amino acids are made in the liver by transamination.

25. In adults, most protein synthesis serves to replace tissue proteins and to maintain nitrogen balance.

26. Protein synthesis requires the presence of the essential amino acids. If any are lacking, amino acids are used as energy fuels.

Catabolic-Anabolic Steady State of the Body (pp. 820-821)

27. The amino acid pool provides amino acids for synthesis of proteins and amino acid derivatives, ATP synthesis, and energy storage. To be stored, amino acids are first converted to fats or glycogen.

28. The carbohydrate-fat pool primarily provides fuels for ATP synthesis and other molecules that can be stored as energy reserves.

29. The nutrient pools are connected by the bloodstream; fats, carbohydrates, and proteins may be interconverted via common intermediates.

Absorptive and Postabsorptive States: Events and Controls (pp. 821-826)

30. During the absorptive state (during and shortly after a meal), glucose is the major energy source; needed structural and functional molecules are made; excesses of carbohydrates, fats, and amino acids are stored as glycogen and fat.

31. Events of the absorptive state are controlled by insulin, which enhances the entry of glucose (and amino acids) into cells and accelerates its use for ATP synthesis or storage as glycogen or fat.

32. The postabsorptive state is the period when bloodborne fuels are provided by breakdown of energy reserves. Glucose is made available to the blood by glycogenolysis, lipolysis, and gluconeogenesis. Glucose sparing begins and, if fasting is prolonged (4–5 days), the brain also begins to metabolize ketone bodies.

33. Events of the postabsorptive state are controlled largely by glucagon and the sympathetic nervous system, which mobilize glycogen and fat reserves and trigger gluconeogenesis.

Role of the Liver in Metabolism (pp. 827-829)

34. The liver is the body's main metabolic organ and it plays a crucial role in processing (or storing) virtually every nutrient group. It helps maintain blood energy sources, metabolizes hormones, and detoxifies drugs and other substances.

35. The liver synthesizes cholesterol, catabolizes cholesterol and secretes it in the form of bile salts, and makes lipoproteins.

36. LDLs transport triglycerides and cholesterol from the liver to the tissues, whereas HDLs transport cholesterol from the tissues to the liver (for catabolism and elimination).

37. Excessively high LDL levels are implicated in atherosclerosis, cardiovascular disease, and strokes.

Body Energy Balance (pp. 829-837)

1. Body energy intake (derived from food oxidation) is precisely balanced by energy output (heat, work, and energy storage). Eventually, all of the energy intake is converted to heat.

23 Nutrition, Metabolism, and Body Temperature Regulation

2. When energy balance is maintained, weight remains stable. When excess amounts of energy are stored, obesity results (condition of excessive fat storage, 20% or more above the norm).

Regulation of Food Intake (pp. 830-831)

3. The hypothalamus and other brain centers are involved in the regulation of eating behavior.

4. Factors thought to be involved in regulating food intake include (a) neural signals from the gut to the brain, (b) nutrient signals related to total energy storage (e.g., large fatty reserves and increased plasma levels of glucose and amino acids depress hunger and eating); (c) plasma concentrations of hormones that control events of the absorptive and postabsorptive states, and provide feedback signals to brain feeding centers; (d) body temperature; and (e) psychological factors.

Metabolic Rate and Body Heat Production (pp. 831-833)

5. Energy used by the body per hour is the metabolic rate.

6. Basal metabolic rate (BMR), reported in kcal/m^2/h, is the measurement obtained under basal conditions: the person is at comfortable room temperature, supine, relaxed, and in the postabsorptive state. BMR indicates energy needed to drive only the resting body processes.

7. Factors influencing metabolic rate include age, sex, size, body surface area, thyroxine levels, specific dynamic action of foods, and muscular activity.

Regulation of Body Temperature (pp. 833-837)

8. Body temperature reflects the balance between heat production and heat loss and is normally 35.6–37.8°C, which is optimal for physiological activities.

9. At rest, most body heat is produced by the liver, heart, brain, kidneys, and endocrine organs. Activation of skeletal muscles causes dramatic increases in body heat production.

10. The body core (organs within the skull and the ventral body cavity) generally has the highest temperature. The shell (the skin) is the heat-exchange surface, and is usually coolest.

11. Blood serves as the major heat-exchange agent between the core and the shell. When skin capillaries are flushed with blood and the skin is warmer than the environment, heat is lost from the body. When blood is withdrawn to deep organs, heat loss from the shell is inhibited.

12. Heat-exchange mechanisms include radiation, conduction, convection, and evaporation. Evaporation, the conversion of water to water vapor, requires the absorption of heat. For each gram of water vaporized, about 0.5 kcal of heat is absorbed.

13. The hypothalamus acts as the body's thermostat. Its heat-promotion and heat-loss centers receive inputs from peripheral and central thermoreceptors, integrate these inputs, and initiate responses leading to heat loss or heat promotion.

14. Heat-promoting mechanisms include vasoconstriction of skin vasculature, increase in metabolic rate (via release of norepinephrine), and shivering. If environmental cold is prolonged, the thyroid gland is stimulated to release more thyroxine.

15. When heat must be removed from the body, dermal blood vessels are dilated, allowing heat loss through radiation, conduction, and convection. When greater heat loss is mandated (or the environmental temperature is so high that radiation and conduction are ineffective), sweating is initiated. Evaporation of perspiration is an efficient means of heat loss as long as the humidity is low.

16. Profuse sweating can lead to heat exhaustion, indicated by a rise in temperature, a drop in blood pressure, and collapse. When the body cannot rid itself of surplus heat, body temperature rises to the point where all thermoregulatory mechanisms become ineffective—a potentially lethal condition called heat stroke.

17. Fever is controlled hyperthermia, which follows thermostat resetting to higher levels by prostaglandins and initiation of heat-promotion mechanisms, evidenced by the chills. When the disease process is reversed, heat-loss mechanisms are initiated.

24 THE URINARY SYSTEM

CHAPTER SUMMARY

References to Interactive Physiology **IP** *appear below specific key chapter topics to help your review.*

Kidney Anatomy (pp. 840-849)

Location and External Anatomy (pp. 840-841)

1. The paired kidneys are retroperitoneal in the superior lumbar region.

2. A renal capsule, an adipose capsule, and renal fascia surround each kidney. The fatty adipose capsule helps hold the kidneys in position.

Internal Anatomy (pp. 842-843)

3. A kidney has a superficial cortex, a deeper medulla consisting mainly of medullary pyramids, and a medial pelvis. Extensions of the pelvis (calyces) surround and collect urine draining from the apices of the medullary pyramids.

Blood and Nerve Supply (p. 843)

4. The kidneys receive 25% of the total cardiac output/minute.

5. The vascular pathway through a kidney is as follows: renal artery → segmental arteries → lobar arteries → interlobar arteries → arcuate arteries → interlobular arteries → afferent arterioles → glomeruli → efferent arterioles → peritubular capillary beds → interlobular veins → arcuate veins → interlobar veins → renal vein.

6. The nerve supply of the kidneys is derived from the renal plexus.

Nephrons (pp. 843-849)

7. Nephrons are the structural and functional units of the kidneys.

8. Each nephron consists of a glomerulus (a high-pressure capillary bed) and a renal tubule. Subdivisions of the renal tubule (from the glomerulus) are the glomerular capsule, proximal convoluted tubule, loop of Henle, and distal convoluted tubule. A second capillary bed, the low-pressure peritubular capillary bed, is closely associated with the renal tubule of each nephron.

9. The more numerous cortical nephrons are located almost entirely in the cortex; only a small part of their loop of Henle penetrates into the medulla. Juxtamedullary nephrons are located at the cortex-medulla junction, and their loop of Henle dips deeply into the medulla. Instead of directly forming peritubular capillaries, the efferent arterioles of many of the juxtamedullary nephrons form unique bundles of straight vessels, called vasa recta, that serve tubule segments in the medulla. Juxtamedullary nephrons and the vasa recta play an important role in establishing the medullary osmotic gradient.

10. Collecting ducts receive urine from many nephrons and help concentrate urine. They form the medullary pyramids.

11. The juxtaglomerular apparatus is at the point of contact between the afferent arteriole and the first part of the distal convoluted tubule. It consists of the juxtaglomerular (JG) cells and the macula densa.

IP Urinary System CD-ROM; Topics: Anatomy Review, pages 1–20.

12. The filtration membrane consists of the fenestrated glomerular endothelium, the intervening basement membrane, and the podocyte-containing visceral membrane of the glomerular capsule. It permits free passage of substances smaller than (most) plasma proteins.

Kidney Physiology: Mechanisms of Urine Formation (pp. 849-864)

1. Functions of the nephrons include filtration, tubular reabsorption, and tubular secretion. Via these functional processes, the kidneys eliminate nitrogenous metabolic wastes, and regulate the volume, composition, and pH of the blood.

Glomerular Filtration (p. 850)

2. The glomeruli function as filters. High glomerular blood pressure (55 mm Hg) occurs because the glomeruli are fed and drained by arterioles, and the afferent arterioles are larger in diameter than the efferent arterioles.

3. About one-fifth of the plasma flowing through the kidneys is filtered from the glomeruli into the renal tubules.

4. Usually about 10 mm Hg, the net filtration pressure (NFP) is determined by the relationship between forces favoring filtration (glomerular hydrostatic pressure) and forces that oppose it (capsular hydrostatic pressure and blood colloid osmotic pressure).

5. The glomerular filtration rate (GFR) is directly proportional to the net filtration pressure and is about 125 ml/min (180 L/day).

6. Renal autoregulation, which enables the kidneys to maintain a relatively constant renal blood flow and glomerular filtration rate, involves a myogenic mechanism and a tubuloglomerular feedback mechanism mediated by the macula densa.

7. Strong sympathetic nervous system activation causes constriction of the afferent arterioles, which decreases filtrate formation and stimulates renin release by the JG cells.

IP Urinary System CD-ROM; Topic: Glomular Filtration, pages 1–15.

8. The renin-angiotensin mechanism mediated by the JG cells raises systemic blood pressure via generation of angiotensin II, which promotes aldosterone secretion.

Tubular Reabsorption (pp. 853-858)

9. During tubular reabsorption, needed substances are removed from the filtrate by the tubule cells and returned to the peritubular capillary blood. The primary active transport of Na^+ by a Na^+-K^+ ATPase pump at the basolateral membrane accounts for Na^+ reabsorption and establishes the electrochemical gradient that drives the reabsorption of most other solutes and H_2O. Na^+ enters at the luminal surface of the tubule cell via facilitated diffusion or via diffusion through a channel.

10. Passive tubular reabsorption is driven by electrochemical gradients established by active reabsorption of sodium ions. Water, many anions, and various other substances (for example, urea) are reabsorbed passively by diffusion via transcellular or paracellular pathways.

11. Secondary active tubular reabsorption occurs by cotransport with Na^+ via protein carriers. Transport of such substances is limited by the number of carriers available. Substances reabsorbed actively include nutrients and some ions.

12. Certain substances (creatinine, drug metabolites, etc.) are not reabsorbed or are reabsorbed incompletely because of the lack of carriers, their size, or nonlipid solubility.

13. The proximal tubule cells are most active in reabsorption. Most of the nutrients, 65% of the water and sodium ions, and the bulk of actively transported ions are reabsorbed in the proximal convoluted tubules.

14. Reabsorption of additional sodium ions and water occurs in the distal tubules and collecting ducts and is hormonally controlled. Aldosterone increases the reabsorption of sodium (and obligatory water reabsorption); antidiuretic hormone enhances water reabsorption by the collecting ducts.

Tubular Secretion (p. 858)

15. Tubular secretion is a means of adding substances to the filtrate (from the blood or tubule cells). It is an active process that is important in eliminating drugs, urea, and excess ions and in maintaining the acid-base balance of the blood.

Regulation of Urine Concentration and Volume (pp. 858-863)

16. The graduated hyperosmolality of the medullary fluids (largely due to the cycling of NaCl and urea) ensures that the filtrate reaching the distal convoluted tubule is dilute (hypoosmolar). This allows urine with osmolalities ranging from 65 to 1200 mOsm to be formed.

- The descending limb of the loop of Henle is permeable to water, which leaves the filtrate and enters the medullary interstitium. The filtrate and medullary fluid at the tip of the loop of Henle are hyperosmolar.
- The thick ascending limb is impermeable to water, but Na^+ and Cl^- are actively transported out of the filtrate into the interstitial space. The filtrate becomes more dilute as it continues to lose salt. Na^+ and Cl^- move passively out of the thin portion of the ascending limb.
- As filtrate flows through the collecting ducts in the inner medulla, urea diffuses into the interstitial space. Some urea enters the ascending limb and is recycled.
- The blood flow in the vasa recta is sluggish, and the contained blood equilibrates with the medullary interstitial fluid. Hence, blood entering and exiting the medulla in the vasa recta is isotonic to blood plasma and the high solute concentration of the medulla is maintained.

17. In the absence of antidiuretic hormone, dilute urine is formed because the dilute filtrate reaching the collecting duct is simply allowed to pass from the kidneys.

18. As blood levels of antidiuretic hormone rise, the collecting ducts become more permeable to water, and water moves out of the filtrate as it flows through the hyperosmotic medullary areas. Consequently, more concentrated urine is produced, and in smaller amounts.

IP Urinary System CD-ROM; Topics: Early Filtrate Processing, pages 1–22; Late Filtrate Processing, pages 1–13.

Renal Clearance (p. 863)

19. Renal clearance is the volume flow rate (ml/min) at which the kidneys clear the plasma of a particular solute. Studies of renal clearance provide information about renal function or the course of renal disease.

Characteristics and Composition of Urine (pp. 863-864)

20. Urine is typically clear, yellow, aromatic, and slightly acidic. Its specific gravity ranges from 1.001 to 1.035.

21. Urine is 95% water; solutes include nitrogenous wastes (urea, uric acid, and creatinine) and various ions (always sodium, potassium, sulfate, and phosphate).

22. Substances not normally found in urine include glucose, proteins, erythrocytes, pus, hemoglobin, and bile pigments.

23. Daily urinary volume is typically 1.5–1.8 L, but this depends on the state of hydration of the body.

Ureters (pp. 864-865)

1. The ureters are slender tubes running retroperitoneally from each kidney to the bladder. They conduct urine by peristalsis from the renal pelvis to the urinary bladder.

Urinary Bladder (pp. 865-866)

1. The urinary bladder, which functions to store urine, is a distensible muscular sac that lies posterior to the pubic symphysis. It has two inlets (ureters) and one outlet (urethra) that outline the trigone. In males, the prostate gland surrounds its outlet.

2. The bladder wall consists of a transitional epithelium-containing mucosa, a three-layered detrusor muscle, and an adventitia.

Urethra (p. 867)

1. The urethra is a muscular tube that conveys urine from the bladder to the body exterior.

2. Where the urethra leaves the bladder, it is surrounded by an internal urethral sphincter, an involuntary smooth muscle sphincter. Where it passes through the urogenital diaphragm, the voluntary external urethral sphincter is formed by skeletal muscle.

3. In females the urethra is 3–4 cm long and conducts only urine. In males it is 20 cm long and conducts both urine and semen.

Micturition (pp. 867-869)

1. Micturition is emptying of the bladder.

2. Stretching of the bladder wall by accumulating urine initiates the micturition reflex, in which parasympathetic fibers, in response to signals from the micturition center of the pons, cause the detrusor muscle to contract and the internal urethral sphincter to relax (open).

3. Because the external sphincter is voluntarily controlled, micturition can usually be delayed temporarily.

25 FLUID, ELECTROLYTE, AND ACID-BASE BALANCE

CHAPTER SUMMARY

References to Interactive Physiology **IP** *appear below specific key chapter topics to help your review.*

Body Fluids (pp. 871-874)

Body Water Content (p. 871)

1. Water accounts for 45–75% of body weight, depending on age, sex, and amount of body fat.

Fluid Compartments (p. 871)

2. About two-thirds (25 L) of body water is found within cells in the intracellular fluid (ICF) compartment; the balance (15 L) is in the extracellular fluid (ECF) compartment. The ECF includes plasma and interstitial fluid.

Composition of Body Fluids (pp. 871-872)

3. Solutes dissolved in body fluids include electrolytes and nonelectrolytes. Electrolyte concentration is expressed in mEq/L.

4. Plasma contains more proteins than does interstitial fluid; otherwise, extracellular fluids are similar. The most abundant ECF electrolytes are sodium, chloride, and bicarbonate ions.

5. Intracellular fluids contain large amounts of protein anions and potassium, magnesium, and phosphate ions.

IP Fluid, Electrolyte, and Acid/Base Balance CD-ROM; Topic: Introduction to Body Fluids, pages 1–8.

Fluid Movement Among Compartments (pp. 872-874)

6. Fluid exchanges between compartments are regulated by osmotic and hydrostatic pressures: (a) Filtrate is forced out of the capillaries by hydrostatic pressure and pulled back in by oncotic pressure. (b) Water moves freely between the ECF and the ICF by osmosis, but solute movements are restricted by size, charge, and dependence on active transport. (c) Water flows always follow changes in ECF osmolality.

7. Plasma links the internal and external environments.

IP Fluid, Electrolyte, and Acid/Base Balance CD-ROM; Topic: Introduction to Body Fluids, pages 19–23.

Water Balance (pp. 874-877)

1. Sources of body water are ingested foods and fluids and metabolic water.

2. Water leaves the body via the lungs, skin, gastrointestinal tract, and kidneys.

Regulation of Water Intake: The Thirst Mechanism (p. 875)

3. Increased plasma osmolality or decreased plasma volume triggers the thirst mechanism, mediated by hypothalamic osmoreceptors. Thirst, inhibited by distension of the gastrointestinal tract by ingested water and then by osmotic signals, may be damped before body needs for water are met.

Regulation of Water Output (pp. 875-876)

4. Obligatory water loss is unavoidable and includes insensible water losses from the lungs, the skin, in feces, and about 500 ml of urine output daily.

5. Beyond obligatory water loss, the volume of urinary output depends on water intake and loss via other routes and reflects the influence of antidiuretic hormone and aldosterone on the renal tubules.

Disorders of Water Balance (pp. 876-877)

6. Dehydration occurs when water loss exceeds water intake over time. It is evidenced by thirst, dry skin, and decreased urine output. A serious consequence is circulatory collapse.

7. Hypotonic hydration occurs when body fluids are excessively diluted and cells become swollen by water entry. The most serious consequence is cerebral edema.

8. Edema is an abnormal accumulation of fluid in the interstitial space, which may impair blood circulation.

IP Fluid, Electrolyte, and Acid/Base Balance CD-ROM; Topic: Water Homeostasis, pages 1–27.

Electrolyte Balance (pp. 877-885)

1. Most electrolytes (salts) are obtained from ingested foods and fluids. Salts, particularly NaCl, are often ingested in excess of need.

2. Electrolytes are lost in perspiration, feces, and urine. The kidneys are most important in regulating electrolyte balance.

The Central Role of Sodium in Fluid and Electrolyte Balance (pp. 877-879)

3. Sodium salts are the most abundant solutes in ECF. They exert the bulk of ECF osmotic pressure and control water volume and distribution in the body.

4. Na^+ transport by the renal tubule cells is coupled to and helps regulate K^+, Cl^-, HCO_3^-, and H^+ concentrations in the ECF.

Regulation of Sodium Balance (pp. 879-883)

5. Sodium ion balance is linked to water balance and blood pressure regulation and involves both neural and hormonal controls.

6. Declining blood pressure and falling filtrate osmolality stimulate the juxtaglomerular cells to release renin. Renin, via angiotensin II, enhances systemic blood pressure and aldosterone release.

7. Cardiovascular system baroreceptors sense changing arterial blood pressure, prompting changes in sympathetic vasomotor activity. Rising arterial pressure leads to vasodilation and enhanced Na^+ and water loss in urine. Falling arterial pressure promotes vasoconstriction and conserves Na^+ and water.

8. Atrial natriuretic peptide, released by certain atrial cells in response to rising blood pressure (or blood volume), causes systemic vasodilation and inhibits renin, aldosterone, and ADH release. Hence, it enhances Na^+ and water excretion, reducing blood volume and blood pressure.

9. Estrogens and glucocorticoids increase renal retention of sodium. Progesterone promotes enhanced sodium and water excretion in urine.

Regulation of Potassium Balance (pp. 883-84)

10. About 85% of filtered potassium is reabsorbed by the more proximal regions of the nephrons.

11. The main thrust of renal regulation of K^+ is to excrete it. Potassium ion secretion by the principal cells of the cortical collecting ducts is enhanced by increased plasma K^+ content and aldosterone. Type A cells of the collecting duct reabsorb small amounts of K^+ during K^+ deficit.

25 *Fluid, electrolyte, and acid-base balance*

Regulation of Calcium and Phosphate Balance (p. 884)

12. Calcium balance is regulated primarily by parathyroid hormone, which targets the bones, intestine, and kidneys, thereby enhancing blood Ca^{2+} levels. Active reabsorption occurs primarily in the DCT.

13. Calcitonin accelerates the deposit of Ca^{2+} in bone and inhibits its release from bone matrix. However, its influence on the kidneys is relatively minor.

Regulation of Magnesium Balance (p. 885)

14. Magnesium levels are regulated to counteract excesses or deficits in the ECF. The mechanism is unclear.

Regulation of Anions (p. 885)

15. When blood pH is normal or slightly high, chloride is the major anion accompanying sodium reabsorption. In acidosis, chloride is replaced by bicarbonate.

16. Reabsorption of most other anions appears to be regulated by their T_m.

IP Fluid, Electrolyte, and Acid/Base Balance CD-ROM; Topic: Electrolyte Homeostasis, pages 1–38.

Acid-Base Balance (pp. 885-893)

1. Acids are proton (H^+) donors; bases are proton acceptors. Acids that dissociate completely in solution are strong acids; those that dissociate incompletely are weak acids. Strong bases are more effective proton acceptors than are weak bases.

2. The homeostatic pH range of arterial blood is 7.35 to 7.45. A higher pH represents alkalosis; a lower pH reflects acidosis.

3. Some acids enter the body in foods, but most are generated by breakdown of phosphorus-containing proteins, incomplete oxidation of fats or glucose, and the loading and transport of carbon dioxide in the blood.

4. Acid-base balance is achieved by renal regulation of bicarbonate ion (hence, hydrogen ion) concentration of body fluids.

IP Fluid, Electrolyte, and Acid/Base Balance CD-ROM; Topic: Acid/Base Homeostasis, pages 1–15.

Chemical Buffer Systems (pp. 885-886)

5. Chemical buffers are single or paired sets (a weak acid and its salt) of molecules that act rapidly to resist excessive shifts in pH by releasing or binding H^+.

6. Chemical buffers of the body include the bicarbonate, phosphate, protein, and ammonium ion buffer systems.

IP Fluid, Electrolyte, and Acid/Base Balance CD-ROM; Topic: Acid/Base Homeostasis, pages 16–26.

Bicarbonate Buffer System (pp. 886-887)

7. Respiratory regulation of acid-base balance of the blood utilizes the bicarbonate buffer system and the fact that carbon dioxide and water are in reversible equilibrium with H_2CO_3.

Physiological Buffer Systems (p. 887)

8. Acidosis activates the respiratory center to increase respiratory rate and depth, which eliminates more CO_2 and causes blood pH to rise. Alkalosis depresses the respiratory center, resulting in CO_2 retention and a fall in blood pH.

IP Fluid, Electrolyte, and Acid/Base Balance CD-ROM; Topic: Acid/Base Homeostasis, pages 27–28.

9. The kidneys provide the major long-term mechanism for controlling acid-base balance by maintaining stable HCO_3^- levels in the ECF. Metabolic acids (organic acids other than carbonic acid) can be eliminated from the body only by the kidneys.

10. Secreted hydrogen ions come from the dissociation of carbonic acid generated within the tubule cells.

11. Tubule cells are impermeable to bicarbonate in the filtrate, but they can conserve filtered bicarbonate ions indirectly by absorbing HCO_3^- generated within them (by dissociation of carbonic acid to HCO_3^- and H^+). For each HCO_3^- (and Na^+) reabsorbed, one H^+ is secreted into the filtrate where it combines with HCO_3^-.

12. To generate and add new HCO_3^- to plasma to counteract acidosis, either of two mechanisms may be used:

- Secreted H^+, buffered by bases other than HCO_3^-, is excreted from the body in urine (the major urine buffer is the phosphate buffer system).
- NH_4^+ (derived from glutamine catabolism) is excreted in urine.

13. To counteract alkalosis, bicarbonate ion is secreted into the filtrate and H^+ is reabsorbed.

IP Fluid, Electrolyte, and Acid/Base Balance; Topic: Acid/Base Homeostasis, pages 29–37.

Abnormalities of Acid-Base Balance (pp. 891-892)

14. Classification of acid-base imbalances as metabolic or respiratory indicates the cause of the acidosis or alkalosis.

15. Respiratory acidosis results from carbon dioxide retention; respiratory alkalosis occurs when carbon dioxide is eliminated faster than it is produced.

16. Metabolic acidosis occurs when fixed acids (lactic acid, ketone bodies, and others) accumulate in the blood or when bicarbonate is lost from the body; metabolic alkalosis occurs when bicarbonate levels are excessive.

17. Extremes of pH for life are 7.0 and 7.8.

18. Compensations occur when the respiratory system or kidneys act to reverse acid-base imbalances resulting from abnormal or inadequate functioning of the alternate system. Respiratory compensations involve changes in respiratory rate and depth. Renal compensations modify blood levels of HCO_3^-.

IP Fluid, Electrolyte, and Acid/Base Balance CD-ROM; Topic: Acid/Base Homeostasis, pages 38–59.

Assessing Acid-Base Balance Using Blood Values (pp. 892-893)

19. Determining whether a patient is in acidosis or alkalosis, the cause of the condition, and whether or not the balance is being compensated is possible by scrutinizing blood values in a prescribed manner.

26 THE REPRODUCTIVE SYSTEM

CHAPTER SUMMARY

1. The function of the reproductive system is to produce offspring. The gonads produce gametes (sperm or ova) and sex hormones. All other reproductive organs are accessory organs.

Anatomy of the Male Reproductive System (pp. 895-900)

The Scrotum (p. 896)

1. The scrotum contains the testes. It provides a temperature slightly lower than that of the body, as required for viable sperm production.

The Testes (pp. 896-898)

2. Each testis is covered externally by a tunica albuginea that extends internally to divide the testis into many lobules. Each lobule contains sperm-producing seminiferous tubules and interstitial cells that produce androgens.

The Penis (p. 898)

3. The penis, the male copulatory organ, is largely erectile tissue (corpus spongiosum and corpora cavernosa). Engorgement of the erectile tissue with blood causes the penis to become rigid, an event called erection.

4. The male perineum is the region encompassed by the pubic symphysis, ischial tuberosities, and coccyx.

The Male Duct System (pp. 898-899)

5. The epididymis hugs the external surface of the testis and serves as a site for sperm maturation and storage.

6. The ductus (vas) deferens, extending from the epididymis to the urethra, propels sperm into the urethra by peristalsis during ejaculation. Its terminus fuses with the duct of the seminal vesicle, forming the ejaculatory duct.

7. The urethra extends from the urinary bladder to the tip of the penis. It conducts semen and urine to the body exterior.

Accessory Glands (pp. 899-900)

8. The accessory glands produce the bulk of the semen, which contains fructose from the seminal vesicles, activating fluid from the prostate gland, and mucus from the bulbourethral glands.

Semen (p. 900)

9. Semen is an alkaline fluid that dilutes and transports sperm. Important chemicals in semen are nutrients, prostaglandins, and seminalplasmin. An ejaculation contains 2–5 ml of semen, with 50 to 130 million sperm/ml in normal adult males.

Physiology of the Male Reproductive System (pp. 900-909)

Male Sexual Response (pp. 900-901)

1. Erection is controlled by parasympathetic reflexes.

2. Ejaculation is expulsion of semen from the male duct system, promoted by the sympathetic nervous system. Ejaculation is part of male orgasm, which also includes pleasurable sensations and increased pulse and blood pressure.

Spermatogenesis (pp. 901-907)

3. Spermatogenesis, production of male gametes in the seminiferous tubules, begins at puberty.

4. Meiosis, the basis of gamete production, consists of two consecutive nuclear divisions without DNA replication in between. Meiosis reduces the chromosomal number by half and introduces genetic variability. Events unique to meiosis include synapsis and crossover of homologous chromosomes.

5. Spermatogonia divide by mitosis to maintain the germ cell line. Some of their progeny become primary spermatocytes, which undergo meiosis I to produce secondary spermatocytes. Secondary spermatocytes undergo meiosis II, each producing a total of four haploid *(n)* spermatids.

6. Spermatids are converted to functional sperm by spermiogenesis, during which superfluous cytoplasm is stripped away and an acrosome and a flagellum (tail) are produced.

7. Sustentacular cells form the blood-testis barrier, nourish spermatogenic cells, move them toward the lumen of the tubules, and secrete fluid for sperm transport.

Hormonal Regulation of Male Reproductive Function (pp. 907-909)

8. GnRH, produced by the hypothalamus, stimulates the anterior pituitary gland to release FSH and LH (ICSH). FSH causes sustentacular cells to produce androgen-binding protein (ABP). LH stimulates interstitial cells to release testosterone, which binds to ABP, stimulating spermatogenesis. Testosterone and inhibin (produced by sustentacular cells) feed back to inhibit the hypothalamus and anterior pituitary.

9. Maturation of hormonal controls occurs during puberty and takes about three years.

10. Testosterone stimulates maturation of the male reproductive organs and triggers the development of the secondary sex characteristics of the male. It exerts anabolic effects on the skeleton and skeletal muscles, stimulates spermatogenesis, and is responsible for sex drive.

Anatomy of the Female Reproductive System (pp. 909-917)

1. The female reproductive system produces gametes and sex hormones and houses a developing infant until birth.

The Ovaries (pp. 910-911)

2. The ovaries flank the uterus laterally and are held in position by the ovarian and suspensory ligaments and mesovaria.

3. Within each ovary are oocyte-containing follicles at different stages of development and corpora lutea.

The Female Duct System (pp. 911-915)

4. The uterine tube, supported by the mesosalpinx, extends from near the ovary to the uterus. Its fibriated and ciliated distal end creates currents that help move an ovulated oocyte into the uterine tube. Cilia of the uterine tube mucosa help propel the oocyte toward the uterus.

5. The uterus has fundus, body, and cervical regions. It is supported by the broad, lateral cervical, uterosacral, and round ligaments.

6. The uterine wall is composed of the outer perimetrium, the myometrium, and the inner endometrium. The endometrium consists of a functional layer (stratum functionalis), which sloughs off periodically unless an embryo has

implanted, and an underlying basal layer (stratum basalis), which rebuilds the functional layer.

7. The vagina extends from the uterus to the exterior. It is the copulatory organ and allows passage of the menstrual flow and a baby.

The External Genitalia (p. 915)

8. The female external genitalia (vulva) include the mons pubis, labia majora and minora, clitoris, and the urethral and vaginal orifices. The labia majora house the mucus-secreting vestibular glands.

The Mammary Glands (pp. 916-917)

9. The mammary glands lie over the pectoral muscles of the chest and are surrounded by adipose and fibrous connective tissue. Each mammary gland consists of many lobules, which contain milk-producing alveoli.

Physiology of the Female Reproductive System (pp. 917-925)

Oogenesis (pp. 917-919)

1. Oogenesis, the production of eggs, begins in the fetus. Oogonia, the diploid stem cells of female gametes, are converted to primary oocytes before birth. The infant female's ovaries contain about 2 million primary oocytes arrested in prophase of meiosis I.

2. At puberty, meiosis resumes. Each month, one primary oocyte completes meiosis I, producing a large secondary oocyte and a tiny first polar body. Meiosis II of the secondary oocyte produces a functional ovum and a second polar body, but does not occur unless the secondary oocyte is penetrated by a sperm.

3. The ovum contains most of the primary oocyte's cytoplasm. The polar bodies are nonfunctional and degenerate.

The Ovarian Cycle (pp. 919-920)

4. During the follicular phase (days 1–14), several primary follicles begin to mature. The follicle cells proliferate and produce estrogens, and a connective tissue capsule (theca) is formed around the maturing follicle. Generally, only one follicle per month completes the maturation process and protrudes from the ovarian surface. Late in this phase, the oocyte in the dominant follicle completes meiosis I. Ovulation occurs, usually on day 14, releasing the secondary oocyte into the peritoneal cavity. Other developing follicles deteriorate.

5. In the luteal phase (days 15–28), the ruptured follicle is converted to a corpus luteum, which produces progesterone and estrogen for the remainder of the cycle. If fertilization does not occur, the corpus luteum degenerates in about ten days.

Hormonal Regulation of the Ovarian Cycle (pp. 920-922)

6. Beginning at puberty, the hormones of the hypothalamus, anterior pituitary, and ovaries interact to establish and regulate the ovarian cycle. Establishment of the mature cyclic pattern, indicated by menarche, takes about four years.

7. The hormonal events of each ovarian cycle are as follows: (1) GnRH stimulates the anterior pituitary to release FSH and LH, which stimulate follicle maturation and estrogen production. (2) When blood estrogen reaches a certain level, positive feedback exerted on the hypothalamic-pituitary axis causes a sudden release of LH that stimulates the primary oocyte to continue meiosis and triggers ovulation. LH then causes conversion of the ruptured follicle to a corpus luteum and stimulates its secretory activity. (3) Rising levels of progesterone and estrogen inhibit the hypothalamic-pituitary axis, the corpus luteum deteriorates, ovarian hormones drop to their lowest levels, and the cycle begins anew.

The Uterine (Menstrual) Cycle (pp. 922-923)

8. Varying levels of ovarian hormones in the blood trigger events of the uterine cycle.

9. During the menstrual phase of the uterine cycle (days 1–5), the functional layer sloughs off in menses. During the proliferative phase (days 6–14), rising estrogen levels stimulate its regeneration, making the uterus receptive to implantation about one week after ovulation. During the secretory phase (days 15–28), the uterine glands secrete glycogen, and endometrial vascularity increases further.

10. Falling levels of ovarian hormones during the last few days of the ovarian cycle cause the spiral arteries to become spastic and cut off the blood supply of the functional layer, and the uterine cycle begins again with menstruation.

Extrauterine Effects of Estrogens and Progesterone (pp. 924-925)

11. Estrogen promotes oogenesis. At puberty, it stimulates the growth of the reproductive organs and the growth spurt and promotes the appearance of the secondary sex characteristics.

12. Progesterone cooperates with estrogen in breast maturation and regulation of the uterine cycle.

Menopause (pp. 924-926)

13. During menopause, ovarian function declines, and ovulation and menstruation cease. Hot flashes and mood changes may occur. Postmenopausal events include atrophy of the reproductive organs, bone mass loss, and increasing risk for cardiovascular disease.

Female Sexual Response (p. 926)

14. The female sexual response is similar to that of males. Orgasm in females is not accompanied by ejaculation and is not necessary for conception.

Sexually Transmitted Diseases (pp. 926-927)

1. Sexually transmitted diseases (STDs) are infectious diseases spread via sexual contact. Gonorrhea, syphilis, chlamydia, and some forms of vaginitis are bacterial diseases; if untreated, they can cause sterility. Syphilis has broader consequences than most other sexually transmitted bacterial diseases since it can infect organs throughout the body. Genital herpes and genital warts, viral infections, are implicated in cervical cancer. AIDS, a condition of immune suppression, can also be transmitted sexually.