CHAPTER 16: URINARY SYSTEM AND EXCRETION

16.1 Urinary System
Excretion is the removal of metabolic wastes from the body. Metabolic wastes are byproducts of various metabolic reactions in the body. Nitrogenous wastes such as urea and uric acid, produced by breakdown of proteins, can be harmful if accumulated in large amount in our body. In addition body also needs to rid of excessive salts consumed in food to maintain appropriate salt-water balance.

Functions of the Urinary System
The urinary system functions to filter blood and remove metabolic wastes by producing urine and conducts urine to outside the body. As the kidneys produce urine they excrete metabolic wastes, maintain water-salt balance, maintain acid-base balance, and secrete hormones. An important hormone secreted by kidneys is erythropoietin which stimulates red blood cell production.

Organs of the Urinary System
The urinary system consists of the kidneys, ureters, urinary bladder, and urethra.

Kidneys
The kidneys are paired organs located near the small of the back.

Ureters
The ureters conduct urine from the kidneys to the bladder.

Urinary Bladder
The urinary bladder has 3 opening, 2 for ureters and one for urethra. The urinary bladder stores urine until it is expelled from the body.

Urethra
The urethra is a small tube that extends from the urinary bladder to an external opening. Urethra is shorter in females than in males. In males, the urethra carries urine during urination and semen during ejaculation.

Urination
When the urinary bladder fills to about 250 ml with urine, stretch receptors send sensory nerve impulses to the spinal cord.

16.2 Anatomy of the Kidney and Excretion
The renal cortex is an outer, granulated layer. The renal medulla is the inner layer. The renal pelvis is a central space continuous with the ureter.

Anatomy of a Nephron
Nephrons are the microscopic anatomical unit of excretion in kidneys. The kidney is composed of over one million nephrons. Each nephron has its own blood supply including two capillary regions.

Parts of a Nephron
Each nephron is composed of a glomerular capsule, a proximal convoluted tubule, the loop of the nephron, the distal convoluted tubule, and the collecting duct.

Urine Formation
Urine formation is divided into glomerular filtration, tubular reabsorption, and tubular secretion.

Glomerular Filtration
The glomerular filtrate contains small dissolved molecules in approximately the same concentration as plasma. Formed elements and plasma proteins are not filterable.

Tubular Reabsorption
Tubular reabsorption occurs as molecules and ions are passively and actively reabsorbed from the nephron into the blood. Most water, nutrients, and required salts are reabsorbed.

Tubular Secretion
Tubular secretion removes substances from the blood and adds them to the tubular fluid.

16.3 Regulatory Functions of the Kidneys
The kidneys maintain the water-salt balance of the blood within normal limits. In this way, they also maintain the blood volume and blood pressure.
Process of Water Reabsorption
The excretion of hypertonic urine is dependent upon the reabsorption of water from the loop of the nephron and the collecting duct.

Reabsorption of Salt
The kidneys regulate the salt balance in blood by controlling the excretion and reabsorption of various ions. Hormones regulate the reabsorption of sodium.

Establishment of a Solute Gradient
The long loop of a nephron is situated within an osmotic gradient in the tissues of the renal medulla.

Reabsorption of Water
Water is reabsorbed at the loop of the nephron and the collecting duct. Hormones control the amount of water that is reabsorbed.

Acid-Base Balance
The pH scale can be used to indicate the basicity or the acidity of body fluids. The normal pH for body fluids is about 7.4.

Acid-Base Buffer Systems
A buffer is a chemical or a combination of chemicals that can take up excess hydrogen ions or excess hydroxide ions. These reactions temporarily prevent any significant change in blood pH.

Respiratory Center
The respiratory center in the medulla oblongata increases the breathing rate if the hydrogen ion concentration of the blood rises.

The Kidneys
Only the kidneys can rid the body of a wide range of acidic and basic substances and otherwise adjust the pH. The kidneys are slower acting than the other two mechanisms, but they have a more powerful effect on pH.

CHAPTER 17: NERVOUS SYSTEM

17.1 Nervous Tissue
The nervous system is divided into the central nervous system, consisting of the brain and spinal cord, and the peripheral nervous system, consisting of nerves that carry messages to and from the central nervous system. The nervous system contains two types of cells: neurons and neuroglia.

Types of Neurons and Neuron Structure
There are three classes of neurons: sensory neurons, interneurons, and motor neurons. Sensory neurons carry impulses from sense organs to central nervous system (CNS). Interneurons reside only in CNS and connect sensory neurons with motor neurons or other interneurons. Motor neurons take messages away from CNS to an effector (e.g. muscle, organ, gland etc).

All neurons have three parts: a cell body, dendrites, and an axon. Dendrites bring the messages to the cell body; axons take messages away from the cell body.

Myelin Sheath
Some axons are covered by a protective myelin sheath which is made of Schwann cells that wrap themselves around axons. The myelin sheath serves as an excellent insulator and plays an important role in nerve regeneration. It also gives nerves their white glistening appearance.

The Nerve Impulse
The nature of a nerve impulse can be characterized by voltage changes.

Resting Potential
When the axon is not conducting an impulse, the inside is negatively charged, and the outside is positively charged. There is approximately a –65 mV potential difference across the membrane. This charge difference is due to the action of the sodium-potassium pump that actively transports sodium out of and potassium into the axon.
**Action Potential**
An action potential is a rapid change in polarity across an axonal membrane as the nerve impulse occurs. It is an all-or-none phenomenon.

**Sodium Gates Open**
When the action potential begins, the gates of the sodium channels open and sodium flows into the axon. The membrane potential changes from $-65 \text{ mV}$ to $+40 \text{ mV}$.

**Potassium Gates Open**
Second, the gates of the potassium channels open, and potassium flows outside the axon. This repolarizes the axon.

**Transmission Across a Synapse**
Every axon branches into many fine endings, each tipped with an axon terminal. Each terminal lies very close to either the dendrite or cell body of another neuron. This is called a chemical synapse. Communication between the two neurons is carried out by molecules called neurotransmitters that are stored in synaptic vesicles in the axon terminals and released when nerve impulses reach the axon terminal.

**Synaptic Integration**
A neuron is on the receiving end of many excitatory and inhibitory signals. Synaptic integration is the summing up of these signals.

**Neurotransmitters**
At least 25 different neurotransmitters have been identified. Once a neurotransmitter has been released into a synaptic cleft and initiated a response, it is removed from the cleft.

**17.2 The Central Nervous System**
The spinal cord and the brain make up the central nervous system (CNS). Both are protected by bones; brain by skull and spinal cord by vertebrae. In addition both are also wrapped with protective membranes called meninges. Space between meninges is filled with cerebrospinal fluid that further protects CNS.

**The Spinal Cord**
The spinal cord extends from the base of the brain through a large opening in the skull and into the vertebral canal.

**Structure of the Spinal Cord**
The spinal nerves project from the cord between the vertebrae. Fluid-filled intervertebral disks cushion and separate the vertebrae. A cross section of the spinal cord shows a central canal, gray matter, and white matter.

**Functions of the Spinal Cord**
The spinal cord provides a means of communication between the brain and the peripheral nerves that leave the cord. The spinal cord is also the center for thousands of reflex arcs.

**17.4 The Peripheral Nervous System**
The peripheral nervous system is composed of nerves and ganglia. Nerves are bundles of axons called nerve fibers. Ganglia are collections of cell bodies. 12 pairs of cranial nerves are attached to brain; some contain only sensory input nerve fibers, some contain only motor output fibers and others are mixture of both sensory and motor nerve fibers. All the 31 pairs of spinal nerves that meet spinal cord, on the other hand, are mixed nerves containing both sensory and motor nerve fibers.

**Somatic System**
The peripheral nervous system is subdivided into the somatic system and the autonomic system. The somatic system serves the skin, skeletal muscles, and tendons. Some actions in the somatic system are due to reflexes, which are automatic responses to a stimulus.

**The Reflex Arc**
Reflexes are programmed, built-in circuits that allow for protection and survival. They require no conscious thought. Nerve impulses travel from the sensory neuron to the spinal cord and back to the motor neuron resulting in quick, involuntary reflex actions.
Autonomic System
The autonomic system regulates the activity of cardiac and smooth muscle and glands. This system functions automatically and usually in an involuntary manner, innervate all internal organs, and utilize two motor neurons that synapse at a ganglion.

CHAPTER 18: SENSES
18.1 Sensory Receptors and Sensations
Sensory receptors are specialized cells that detect certain types of stimuli. Interoceptors receive stimuli from inside the body and are therefore responsible for maintaining homeostasis. While exteroceptors detect stimuli from outside the body.

**Types of Sensory Receptors**
Sensory receptors can be classified into four categories: chemoreceptors, photoreceptors, mechanoreceptors, and thermoreceptors.

**How Sensation Occurs**
Sensory receptors respond to environmental stimuli by generating nerve impulses. Detection occurs when environmental changes stimulate sensory receptors. Sensation, which is conscious perception of stimuli, occurs when nerve impulses arrive at the cerebral cortex of the brain. Sensory adaptation is a decrease in response to a stimulus that is constantly present.

18.2 Somatic Senses
Those senses whose receptors are associated with the skin, muscles, joints, and viscera are considered the somatic senses. They can be categorized into three types: proprioceptors, cutaneous receptors, and pain receptors.

**Proprioceptors**
Proprioceptors are mechanoreceptors involved in reflex actions that maintain muscle tone, and thereby the body’s equilibrium and posture.

**Cutaneous Receptors**
The dermis of the skin contains cutaneous receptors that make the skin sensitive to touch, pressure, pain, and temperature.

**Pain Receptors**
The skin and many internal organs and tissues have pain receptors that are sensitive to chemicals released by damaged cells.

18.3 Senses of Taste and Smell
Taste and smell are called chemical senses because their receptors are sensitive to molecules in the food we eat and the air we breathe.

**Sense of Taste**
The sensory receptors for the sense of taste, the taste cells, are located in taste buds. Different taste cells can detect at least the four primary types of taste (Salty, sour, bitter and sweet).

**How the Brain Receives Taste Information**
The brain appears to survey the overall pattern of incoming sensory impulses and to take a “weighted average” of their taste messages as the perceived taste.

**Sense of Smell**
Our sense of smell is dependent on olfactory cells located within olfactory epithelium. Olfactory cells are modified neurons.

**How the Brain Receives Odor Information**
An odor contains many odor molecules, which activate a characteristic combination of receptor proteins. The olfactory bulbs have direct connections to the limbic system and its centers for emotions and memory.

18.4 Sense of Vision
Vision requires the work of the eyes and the brain.

**Anatomy and Physiology of the Eye**
The eyeball has three layers: the sclera, the choroid, and the retina. The retina contains photoreceptors called rod cells and cone cells.
Function of the Lens
The lens, assisted by the cornea and the humors, focuses images on the retina.

Visual Pathway to the Brain
The pathway for vision begins once light has been focused on the photoreceptors in the retina.

Function of Photoreceptors
The photoreceptors in the eye are of two types—rod cells and cone cells. Rods are very sensitive to light, and are therefore suited to night vision. The cones allow us to detect the fine detail and the color of an object.

Function of the Retina
The retina has three layers of neurons: the rod and cone cells, the bipolar cells, and the ganglion cells. The rod and cone cells are sensitive to light. They synapse with bipolar cells, which in turn synapse with ganglion cells whose axons become the optic nerve.

Blind Spot
There are no rods and cones where the optic nerve exits the retina. This is your blind spot.

From the Retina to the Visual Cortex
The axons of ganglion cells in the retina assemble to form the optic nerves that carry nerve impulses from the eyes to the optic chiasma.

18.5 Sense of Hearing
The ear has two sensory functions: hearing and balance. The sensory receptors for both of these are hair cells with stereocilia that are sensitive to mechanical stimulation.

Anatomy of the Ear
The outer ear collects and funnels sound into the auditory canal. The middle ear transmits sound from the tympanic membrane to the oval window. The inner ear is filled with fluid. The cochlea of the inner ear functions in hearing.

Auditory Pathway to the Brain
Hearing requires the ear, the cochlear nerve, and the auditory cortex of the brain.

Through the Auditory Canal and Middle Ear
The process of hearing begins when sound waves enter the auditory canal. The tympanic membrane passes these vibrations through the malleus, incus, and stapes to the oval window.

From the Cochlea to the Auditory Cortex
The cochlear canal contains the spiral organ. It consists of little hair cells and a gelatinous material called the tectorial membrane. When the hair cells embedded in the tectorial membrane bend, the nerve impulses begin in the cochlear nerve and travel to the brain. When they reach the auditory cortex in the temporal lobe, they are interpreted as a sound.

18.6 Sense of Equilibrium
Mechanoreceptors in the semicircular canals detect rotation and/or angular movement of the head, while mechanoreceptors in the utricle and saccule detect movement of the head in the vertical or horizontal planes.

Rotational Equilibrium Pathway
Rotational equilibrium involves the three semicircular canals, which are arranged so that there is one in each dimension of space.

Gravitational Equilibrium Pathway
Gravitational equilibrium depends on the utricle and the saccule, two membranous sacs located in the vestibule. Both of these sacs contain little hair cells, whose stereocilia are embedded within a gelatinous material called an otolithic membrane.

CHAPTER 19: MUSCULOSKELETAL SYSTEM

19.1 Anatomy and Physiology of Bone
Together, the bones and muscles comprise the musculoskeletal system.

Organization of Tissues in the Skeleton
Bones are classified by their shape. Bone tissues include the periosteum, medullary cavity, and epiphyses. Both red and yellow bone marrow can be found in long bones.

**Structure of Bone and Associated Tissues**

The primary connective tissues of the skeleton are bone, cartilage, and dense fibrous connective tissue. All connective tissues contain cells separated by a matrix that contains fibers.

**Bone**

Bone tissue is strong because the matrix contains mineral salts, notably calcium phosphate. Compact bone is highly organized, while spongy bone has an unorganized appearance. The spaces of spongy bone are often filled with red bone marrow.

**Cartilage**

Cartilage is not as strong as bone, but it is more flexible because the matrix is gel-like and contains many collagenous and elastic fibers.

**Dense Fibrous Connective Tissue**

Ligaments bind bone to bone while tendons connect muscle to bone at joints.

**Bone Growth and Remodeling**

Bones are composed of living tissues. In the adult, bone is continually being broken down and built up again, a process called remodeling. Osteoblasts are the bone cells responsible for building bones while osteoclasts are responsible for breaking down bone tissue.

**19.2 Bones of the Skeleton**

The functions of the skeleton include: supporting the body, protecting soft body parts, producing blood cells, storing minerals and fat, and permitting flexible body movement.

**Classification of the Bones**

The approximately 206 bones of the skeleton are classified as either axial (along the midline) or appendicular (the limbs along with their girdles).

**The Axial Skeleton**

The axial skeleton consists of the skull, hyoid bone, vertebral column, rib cage, and ossicles.

**The Appendicular Skeleton**

The appendicular skeleton consists of the bones within the pectoral and pelvic girdles and their attached limbs.

**Joints**

Bones are jointed at the joints, which are classified as fibrous, cartilaginous, or synovial based on their structure and their ability to move. Three types of synovial joints are

- **Hinge joints:** permit movement in one direction only (e.g. Knee, elbow)
- **Pivot joints:** permit rotation around an axis (e.g. neck, forearm)
- **Ball and socket joints:** Most flexible joint; allow movement in all planes (e.g. hips and shoulders)

**19.3 Skeletal Muscles**

Humans have three types of muscle tissue: smooth, cardiac, and skeletal.

**Skeletal Muscles Work in Pairs**

Skeletal muscles contract and move bones at a joint. The origin of a muscle is on the stationary bone, and the insertion of a muscle is on the bone that moves. Most muscles have antagonists that bring about movement in the opposite direction.

**19.4 Mechanism of Muscle Fiber Contraction**

Skeletal muscle tissue has alternating light and dark bands due to the arrangement of myofilaments in the muscle fiber.

**Muscle Fiber**

The components of muscle fibers often have names beginning with the prefix “sarco-.”

**Myofibrils and Sarcomeres**

Myofibrils are cylindrical in shape and run the length of the muscle fiber. The striations of skeletal muscle fibers are formed by the placement of myofilaments within units of myofibrils called sarcomeres. A sarcomere contains two types of protein myofilaments: myosin and actin.
Myofilaments

**Thick Filaments**
A thick filament is composed of myosin, which is shaped like a golf club.

**Thin Filaments**
A thin filament consists of two intertwining strands of actin.

**Sliding Filaments**
When a sarcomere shortens, the actin filaments slide past the myosin filaments and approach one another.

Skeletal Muscle Contraction
Muscle fibers are stimulated to contract by motor neurons whose axons are in nerves. A branch of an axon ends in an axon terminal that lies close proximity to the sarcolemma of a muscle fiber. The region where axon terminal synapse with muscle fiber is called neuromuscular junction.

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**CHAPTER 20: ENDOCRINE SYSTEM**

20.1 Endocrine Glands and Hormones
The endocrine system consists of glands and tissues that secrete hormones. Hormones are chemicals that affect the behavior of other glands or tissues. Endocrine glands have no ducts. They secrete their hormones into tissue fluid. Exocrine glands release their secretions into ducts. Pancreas serves as both endocrine and exocrine gland.

**Hormones and Homeostasis**
Homeostasis requires close cooperation between the endocrine and nervous systems. The endocrine system works by eliciting a slower but more prolonged response than the nervous system. Sometimes the distinction between endocrine and nervous system is blurred e.g. Some neuronal cells called neurosecretory cells can secrete hormones and some neurotransmitters can work to transmit nerve impulse and also work as hormones. The production of hormones is usually controlled by negative feedback and by the action of other hormones.

**The Action of Hormones**
Hormones fall into two basic chemical classes: 1) peptide hormones are either peptides, proteins, glycoproteins, or modified amino acids; and 2) steroid hormones always have the same complex of four carbon rings but with different side chains.

20.2 Hypothalamus and Pituitary Gland
The hypothalamus helps regulate the internal environment through the autonomic system and through the glandular secretions of the pituitary gland.

**Posterior Pituitary**
Neurons in the hypothalamus produce the hormones antidiuretic hormone and oxytocin that pass through axons of neurosecretory cells into the posterior pituitary where they are stored in axon terminals.

**Anterior Pituitary**
The hypothalamus controls the anterior pituitary by producing hypothalamic-releasing and hypothalamic-inhibiting hormones. These stimulate the anterior pituitary to secrete hormones such as thyroid-stimulating hormone, adrenocorticotropic hormone, gonadotropic hormones, prolactin, melanocyte-stimulating hormone, and growth hormone.

20.3 Thyroid and Parathyroid Glands
The thyroid gland is located in the neck. The parathyroid glands are embedded in the posterior surface of the thyroid gland.

**Thyroid Gland**
The thyroid gland produces hormones that increase the metabolic rate and control the blood calcium levels.

**Parathyroid Gland**
Parathyroid hormone causes the blood phosphate level to decrease and the blood calcium level to increase.

20.4 Adrenal Glands
The adrenal glands sit atop the kidneys.

**Adrenal Medulla**

The adrenal medulla produces epinephrine and norepinephrine. These provide a short-term response to stress.

**Adrenal Cortex**

The hormones produced by the adrenal cortex provide a longer-term response to stress. These include the mineralocorticoids and the glucocorticoids.

**Glucocorticoids**

Cortisol is a glucocorticoid. Cortisol raises the blood glucose level and counteracts the inflammatory response that leads to the pain and swelling of joints.

**Mineralocorticoids**

Aldosterone is the most important of the mineralocorticoids. It targets the kidney where it helps regulate blood volume and blood pressure.

**20.5 Pancreas**

The pancreatic islets produce and secrete insulin and glucagon that help regulate the blood glucose level. Insulin reduces blood glucose while glucagon increases it.

**20.6 Other Endocrine Glands**

**Testes and Ovaries**

The testes produce androgens, which are the male sex hormones. The female sex hormones, estrogen and progesterone, are produced by the ovaries.