UNIT 5: HUMAN BODY SYSTEME

5.1 The Nervous System

The nervous system is a complex network responsible for receiving, processing, and responding to sensory information. It consists of two major divisions:

1. **Central Nervous System (CNS)**: Includes the brain and spinal cord.
2. **Peripheral Nervous System (PNS)**: Comprises all nerves outside the CNS.

Functions of the Nervous System

1. **Receiving Sensory Input**: Sensory receptors in the skin and organs detect stimuli (such as touch, heat, and light) and generate nerve signals. These signals travel through the PNS to the CNS.
2. **Processing Information**: The CNS processes and integrates sensory information received from throughout the body.
3. **Generating Motor Output**: The CNS sends nerve signals through the PNS to muscles, glands, and organs, initiating appropriate responses.

5.1.1 Neurons and Their Functions

The nervous system is composed of two main types of cells:

1. **Neurons**: The fundamental units of the nervous system. Neurons are specialized for:
    - Responding to physical and chemical stimuli.
    - Conducting electrochemical impulses.
    - Releasing chemical regulators.

    Neurons have three main parts:

    - **Cell Body (Soma)**: Contains the nucleus and other organelles. It maintains the neuron's structure and provides energy. In the CNS, neuron cell bodies form the grey matter. In the PNS, cell bodies are grouped into structures called ganglia.
    - **Axon**: A single long extension that conducts impulses away from the cell body. Axons may be insulated with a fatty substance called the myelin sheath, which speeds up impulse transmission. The axon ends in many branches called axon terminals, which connect with other neurons, glands, or muscles.

    - **Dendrites**: Short, branching extensions that receive signals from sensory receptors or other neurons. They conduct incoming signals towards the cell body.
2. **Supporting Cells (Glial Cells)**: Provide support and nourishment to neurons. They are about five times more numerous than neurons and include:
    - **Neuroglia (CNS)**: Supporting cells in the central nervous system.
    - **Schwann Cells (PNS)**: Form the myelin sheath around axons in the peripheral nervous system.

5.1.2 The Nerve Impulse and Transmission

Nerve impulses are electrical signals that travel along neurons. They involve changes in charge across the neuron's membrane. Key processes include:

1. **Resting Potential**:
    - When a neuron is not transmitting an impulse, its membrane is polarized, with a negative charge inside and a positive charge outside (about -65 mV). This state is called the resting potential.
2. **Action Potential**:
    - **Depolarization**: Triggered by a stimulus, sodium (Na^+) channels open, allowing Na^+ ions to flood into the neuron, reversing the charge (positive inside, negative outside). This change in charge is known as depolarization.
    - **Repolarization**: Following depolarization, potassium (K^+) channels open, allowing K^+ ions to exit the neuron, restoring the negative charge inside (and positive charge outside). This process is called repolarization.
3. **Synaptic Transmission**:
    - The gap between two neurons is called the synapse. The axon terminal of the presynaptic neuron releases neurotransmitters into the synaptic cleft, where they bind to receptors on the postsynaptic neuron, continuing the signal.
    - Synaptic transmission involves the release of neurotransmitters from vesicles in the presynaptic neuron, which then diffuse across the synaptic cleft and bind to receptors on the postsynaptic neuron.

5.1.3 Neurotransmitters

Neurotransmitters are the chemical messengers that transmit signals across a synapse from one neuron to another target neuron, muscle, or gland. They play a crucial role in the functioning of the nervous system by facilitating communication between neurons and other cells.

Types of Neurotransmitters

1. **Excitatory Neurotransmitters**:
    - **Function**: Promote the generation of an action potential in the receiving neuron. They increase the likelihood that the neuron will fire and transmit the signal further.
    - **Example**: **Acetylcholine (ACh)** is a common excitatory neurotransmitter found in both the central nervous system (CNS) and the peripheral nervous system (PNS). It is involved in muscle activation and various brain functions including memory and learning.
2. **Inhibitory Neurotransmitters**:
    - **Function**: Prevent the generation of an action potential in the receiving neuron. They decrease the likelihood that the neuron will fire, thereby dampening or inhibiting neural transmission.
    - **Example**: **Gamma-Aminobutyric Acid (GABA)** is a well-known inhibitory neurotransmitter in the brain. It helps to regulate anxiety, muscle relaxation, and sleep.

How Neurotransmitters Work

- **Release**: When an action potential reaches the axon terminal of a neuron, neurotransmitters are released into the synaptic cleft (the gap between neurons).
- **Binding**: The neurotransmitters cross the synaptic cleft and bind to specific receptors on the postsynaptic neuron (the neuron receiving the signal).
- **Response**: Depending on whether the neurotransmitter is excitatory or inhibitory, it will either stimulate or inhibit the generation of a new action potential in the postsynaptic neuron.
- **Reuptake/Degradation**: After the signal is transmitted, neurotransmitters are either reabsorbed by the presynaptic neuron for reuse or broken down by enzymes.

Understanding neurotransmitters helps us grasp how brain functions and mental health conditions are managed and treated.

5.1.4 Types of the Nervous System

The human nervous system is divided into two main parts: the Central Nervous System (CNS) and the Peripheral Nervous System (PNS). Each has distinct functions and components.

1. Central Nervous System (CNS)

- **Components**: The CNS includes the brain and spinal cord.
- **Functions**:
  - **Brain**: The brain is responsible for processing sensory information, decision-making, emotions, and controlling voluntary actions. It is protected by the skull and surrounded by three protective membranes called the meninges (dura mater, arachnoid mater, pia mater).
    - **Cerebrum**: The largest part of the brain, responsible for higher functions such as touch, vision, hearing, speech, reasoning, emotions, and fine motor control.
    - **Hypothalamus**: Regulates body temperature, hunger, thirst, and emotional responses. It also interacts with the pituitary gland.
    - **Thalamus**: Acts as a relay station for sensory information.
    - **Cerebellum**: Coordinates movement, balance, and posture.
    - **Brainstem**: Includes the medulla oblongata, pons, and midbrain. It controls basic life functions such as heart rate, breathing, and reflexes.
  - **Spinal Cord**: Extends from the brainstem down the back and is responsible for transmitting information between the brain and the rest of the body. It is protected by the vertebral column and has both gray matter (neuron cell bodies) and white matter (bundled axons).

2. Peripheral Nervous System (PNS)

- **Components**: Includes all nerves outside the CNS.
- **Divisions**:
  - **Afferent Division**: Carries sensory information from receptors to the CNS.
  - **Efferent Division**: Transmits motor commands from the CNS to muscles and glands.
    - **Somatic Nervous System**: Controls voluntary movements and transmits sensory information.
    - **Autonomic Nervous System**: Regulates involuntary functions such as heart rate and digestion. It has two branches:
      - **Sympathetic System**: Activates the "fight-or-flight" response, increasing heart rate and energy expenditure.
      - **Parasympathetic System**: Promotes the "rest-and-digest" response, conserving energy and maintaining normal bodily functions.

Together, the CNS and PNS coordinate all body functions, from sensory perception to motor activity, ensuring the body's response to internal and external stimuli.

5.1.6 Reflex Action

Definition: A reflex action is an involuntary and automatic response to a stimulus that occurs without conscious thought. This rapid reaction helps protect the body from potential harm and allows for quick adjustments to external conditions.

Why Reflexes Happen Quickly: Reflexes are fast because they bypass the brain's higher processing centers. Instead, the spinal cord handles the reflex arc, enabling an immediate response. This speed is crucial for minimizing injury and reacting to sudden threats.

The Reflex Arc: The reflex arc is the pathway that nerve impulses travel along during a reflex action. It consists of five main parts:

1. **Receptors:** Detect the stimulus and generate an impulse.
2. **Sensory Neurons:** Transmit the impulse from the receptors to the Central Nervous System (CNS).
3. **Central Nervous System (CNS):** Processes the impulse and contains one or more synapses, which may involve interneurons.
4. **Motor Neurons:** Carry the impulse from the CNS to the effector.
5. **Effector:** Executes the response, such as a muscle contraction or gland secretion.

Example - Patellar (Knee-Jerk) Reflex:

1. **Stimulus:** A tap on the patellar tendon below the kneecap.
2. **Response:** The lower leg extends.

Pathway:

1. Sensory receptors in the skin detect the tap and send an impulse through a sensory neuron to the spinal cord.
2. The impulse travels through a relay neuron in the spinal cord.
3. The relay neuron sends an impulse through a motor neuron to the quadriceps muscle.
4. The muscle contracts, causing the leg to kick.

Importance: Reflex actions are crucial for protecting the body and maintaining balance. For example, the knee-jerk reflex helps keep the body upright by adjusting the position of the leg.

5.1.7 Drug Abuse

Definition: Drug abuse refers to the excessive or improper use of substances that alter a person's mental or physical state. This can lead to dependence and serious health issues.

Types of Drugs:

1. **Legal Drugs:** Used for medical purposes or mild pleasure (e.g., caffeine, alcohol).
2. **Illegal Drugs:** Prohibited substances that can cause significant harm (e.g., heroin, cocaine).

Drug Abuse and Addiction:

- **Drug Abuse:** Using drugs in a manner that causes harm or dependence.
- **Addiction:** A chronic condition characterized by a strong, often uncontrollable desire to use a substance despite its harmful effects.

Common Drugs and Their Effects:

1. **Nicotine:** Found in cigarettes, nicotine is highly addictive. It releases dopamine in the brain, creating a feeling of pleasure. Over time, this leads to increased dependency.
2. **Alcohol:** Commonly used but can lead to addiction, impaired judgment, and health problems. It affects the brain's ability to control behavior and emotions.
3. **Khat (Catha edulis):** Chewing khat leaves produces a stimulant effect similar to amphetamines. It can lead to tolerance, dependence, and addiction.
4. **Cannabis (Marijuana):** Contains cannabinoids like THC that affect brain function. It can cause euphoria but may also lead to addiction and varying psychological effects.

Effects on Health:

- **Nicotine:** Causes cardiovascular issues, lung diseases, and addiction.

- **Alcohol:** Leads to liver disease, addiction, and impaired cognitive functions.
- **Khat:** Can cause dependence, psychological effects, and social issues.
- **Cannabis:** Affects mental health, can lead to addiction, and impair cognitive and motor functions.

5.2 Sense Organs

5.2.1 Skin

The skin is the largest organ in the human body, covering approximately 20 square feet. It is vital for various functions:

- **Protection**: The skin acts as a barrier against pathogens, UV light, and water loss. It forms a waterproof layer that prevents water loss through evaporation and protects against gaining excess water by osmosis.
- **Temperature Regulation**: It plays a crucial role in maintaining body temperature through sweat production and blood flow adjustments.
- **Sensation**: It contains a variety of sensory receptors that detect touch, temperature, pressure, and pain.

Basic Components:

1. **Epidermis**: The outermost layer, made up of dead cells that provide a waterproof barrier and skin tone.
2. **Dermis**: Beneath the epidermis, it contains connective tissue, hair follicles, sweat glands, blood vessels, and sensory receptors. It helps with temperature control and touch sensation.
3. **Hypodermis**: The deepest layer, composed of fat and connective tissue that provides insulation and energy storage.

Cells:

- **Keratinocytes**: Produce keratin, which is important for the skin's strength and resilience.
- **Melanocytes**: Produce melanin, which gives skin its color and protects against UV radiation.
- **Langerhans Cells**: Involved in immune responses and protection against pathogens.

Skin Types:

- **Thin Skin**: Covers most of the body and varies in thinness, with the thinnest skin on the eyelids.

- **Thick Skin**: Found on the soles of the feet and palms of the hands, lacks hair follicles and sebaceous glands.

5.2.2 The Tongue

The tongue is a muscular organ in the mouth covered with a moist tissue called mucosa. It has tiny bumps called papillae, which house thousands of taste buds.

Functions:

- **Taste**: Taste buds detect five basic tastes: sweet, sour, bitter, salty, and umami (savory). These receptors are spread across the tongue, although concentrations may vary.
- **Chewing and Swallowing**: The tongue aids in moving food around the mouth and pushing it towards the throat for swallowing.
- **Speech**: It is essential for articulation and pronunciation.

Structure:

- **Papillae**: Bumps on the tongue that contain taste buds.
- **Frenum**: Tissue that anchors the tongue to the mouth.

5.2.3 The Nose

The nose is the organ responsible for the sense of smell, or olfaction. It plays a role in identifying food, mates, and potential dangers.

Functions:

- **Smell**: Olfactory receptors in the nasal passages detect and identify odors. Smell molecules bind to these receptors, sending signals to the brain.
- **Air Conditioning**: The nose warms and moistens inhaled air and filters out large particles.

Anatomy:

- **Nasal Passages**: Allow air to flow and are lined with cilia and mucus to trap particles.
- **Olfactory Epithelium**: Contains receptor cells that detect smells.
- **Turbinates**: Bones that divide the nasal airway into passages, enhancing air filtration and conditioning.

5.2.4 The Eye

The eye is responsible for vision and is protected by the bony orbit and a cushion of fat.

External Structures:

- **Eyebrows**: Prevent sweat from entering the eyes and provide shade.
- **Eyelids**: Protect the eye, distribute tears, and filter dust.
- **Conjunctiva**: A transparent membrane covering the eye and lining the eyelids.

Internal Structures:

- **Cornea**: The transparent front part of the eye that refracts light.
- **Iris**: The colored part of the eye that controls the size of the pupil.
- **Pupil**: The aperture that allows light to enter the eye.

Retina:

- **Rods**: Sensitive to light and responsible for black-and-white vision.
- **Cones**: Sensitive to color and function in bright light.
- **Fovea Centralis**: Area of highest visual resolution and color vision.

Lens:

- Biconvex and transparent, it focuses light onto the retina.

5.2.5 The Ear

The ear is responsible for hearing and balance.

External Ear:

- **Auricle (Pinna)**: The visible part of the ear that collects sound waves.
- **Ear Canal**: Transmits sound waves to the eardrum.

Middle Ear:

- **Eardrum (Tympanic Membrane)**: Vibrates in response to sound waves.
- **Ossicles**: Three tiny bones (malleus, incus, stapes) that transmit vibrations from the eardrum to the inner ear.

Inner Ear:

- **Cochlea**: A spiral-shaped organ that converts sound vibrations into electrical signals sent to the brain.
- **Semicircular Canals**: Help maintain balance by detecting head movements.

Function:

- **Hearing**: Sound waves are collected by the auricle, transmitted through the ear canal, and cause vibrations in the eardrum, which are then amplified by the ossicles and converted into electrical signals by the cochlea.
- **Balance**: The semicircular canals and the vestibule detect changes in head position and motion, helping to maintain balance.

5.2.6 The Endocrine System

1. Definition of Glands and Hormones

- **Glands:** Structures in the body that produce and secrete substances. There are two main types of glands: endocrine and exocrine.
- **Hormones:** Chemical messengers secreted into the bloodstream by endocrine glands. They travel through the blood to regulate various physiological processes by targeting specific organs or tissues.

2. Principal Endocrine Glands and Their Functions

- **Pituitary Gland:** Located in the brain, it is often called the "master gland" because it controls other endocrine glands. It has two parts:
    - **Anterior Pituitary:** Secretes hormones like Growth Hormone (GH) for growth, Adrenocorticotropic Hormone (ACTH) for adrenal gland function, Thyroid-Stimulating Hormone (TSH) for thyroid function, Prolactin (PRL) for milk production, and Gonadotropic Hormones (FSH and LH) for reproductive function.
    - **Posterior Pituitary:** Stores and releases hormones produced by the hypothalamus, including Antidiuretic Hormone (ADH) which regulates water balance, and Oxytocin which facilitates childbirth and milk release.

- **Thyroid Gland:** Located in the neck, it produces Thyroxine (T4) and Triiodothyronine (T3) which regulate metabolism. It also secretes Calcitonin to lower blood calcium levels.
- **Parathyroid Glands:** Four small glands located on the back of the thyroid gland. They secrete Parathyroid Hormone (PTH) which regulates calcium levels in the blood by increasing calcium release from bones and absorption in the intestines.
- **Adrenal Glands:** Located on top of the kidneys, composed of:
    - **Adrenal Cortex:** Produces steroid hormones such as Aldosterone (regulates sodium and potassium levels), Cortisol (affects metabolism and stress response), and Androgens (sex hormones).
    - **Adrenal Medulla:** Produces adrenaline (epinephrine) and norepinephrine, which prepare the body for 'fight or flight' responses.
- **Pancreas:** Located below the stomach, it has both endocrine and exocrine functions. The endocrine part includes:
    - **Islets of Langerhans:** Groups of cells that secrete insulin (lowers blood glucose levels) and glucagon (raises blood glucose levels).

3. Comparison of Exocrine and Endocrine Glands

- **Exocrine Glands:** Have ducts and secrete substances (e.g., sweat, saliva) directly to the surface or into body cavities. Examples include sweat glands and salivary glands.
- **Endocrine Glands:** Ductless and secrete hormones directly into the bloodstream. Examples include the thyroid, pituitary, and adrenal glands.

4. Function of Glands and Hormones

- **Glands** secrete hormones that regulate numerous body functions such as growth, metabolism, stress response, and reproductive processes.
- **Hormones** travel through the bloodstream to target organs, where they influence various physiological processes such as maintaining metabolism, regulating blood sugar levels, and controlling growth and development.

Understanding the roles of these glands and hormones helps in comprehending how the endocrine system maintains homeostasis and coordinates complex body functions.

5.3 Homeostasis in the Human Body

5.3.1 The Structure and Function of the Human Kidney

Introduction: The kidneys are vital organs in the human body responsible for maintaining homeostasis by regulating various aspects of blood composition and volume. Here's a detailed overview of their structure and function.

Structure of the Kidney:

- **Shape and Location:** The kidneys are bean-shaped organs located just above the waist, one on each side of the spine.
- **Regions of the Kidney:**
  - **Renal Cortex:** The outer layer of the kidney that contains the nephron units.
  - **Renal Medulla:** The middle region of the kidney, containing the renal pyramids and collecting ducts.
  - **Renal Pelvis:** The expanded end of the ureter where urine collects before being transported to the bladder.

Function of the Kidney:

- **Filtering Blood:** Blood enters the kidneys through the renal arteries. In the kidneys, blood is filtered to remove waste products and excess substances. This filtration occurs in the nephrons, the functional units of the kidney.
- **Reabsorption:** After filtration, essential substances like glucose, salts, and some water are reabsorbed back into the bloodstream. The reabsorption process adjusts based on the body's needs.
- **Urine Production:** The remaining fluid, now called urine, contains waste products such as urea and excess ions. This fluid exits the kidneys through the ureters and is stored in the urinary bladder.

Detailed Structure and Function of Kidney Tubules:

- **Bowman's Capsule:**
  - **Function:** Site of ultrafiltration where blood pressure forces water, salts, glucose, and urea from the blood into the tubule.
  - **Structure:** The capsule surrounds a cluster of capillaries called the glomerulus. Blood pressure in the glomerulus causes filtration.
- **Glomerulus:**
  - **Function:** A network of capillaries where ultrafiltration occurs. The pressure in the glomerulus forces fluid into Bowman's Capsule.
- **First Coiled (Convoluted) Tubule:**

    - **Function:** Reabsorbs essential substances from the filtrate. About 67% of sodium ions and 80% of water are reabsorbed here. Glucose is actively reabsorbed.
    - **Structure:** Lined with microvilli to increase surface area for absorption.
- **Loop of Henle:**
    - **Function:** Concentrates urine and conserves water. The structure of the loop helps in creating a concentration gradient in the medulla.
- **Second Coiled (Convoluted) Tubule:**
    - **Function:** Fine-tunes water reabsorption based on the body's needs, under the influence of anti-diuretic hormone (ADH). This section also secretes additional waste products.
    - **Regulation:** ADH increases the permeability of the tubule to water, leading to more reabsorption when the body is dehydrated.
- **Collecting Duct:**
    - **Function:** Collects urine from multiple nephrons and continues the reabsorption of water, depending on the body's hydration levels. Urine exits the kidney here and flows to the bladder.
    - **Composition:** The final urine is concentrated and contains urea at higher concentrations compared to blood.

Regulation of Water Balance:

- **ADH Role:** When blood water levels are low, the brain's osmoreceptors detect this and stimulate the pituitary gland to release ADH. ADH makes the kidney tubules more permeable to water, increasing reabsorption and reducing urine volume.
- **Feedback Mechanism:** This is an example of negative feedback. High blood water content reduces ADH release, causing less water reabsorption and a larger volume of dilute urine.

Summary: The kidneys play a crucial role in maintaining homeostasis by filtering blood, reabsorbing essential substances, and excreting waste as urine. The structure of the kidneys and their tubules allows for efficient regulation of blood composition and fluid balance.