Systemic 3[A]

Chapter 20: NERVOUS CO-ORDINATION

Learning Objectives: Upon completion of this chapter, students should be able to:

- Explain the components and organization of the nervous system.
- Describe the structure and function of the central nervous system (spinal cord, brain).
- Outline the structure and function of the peripheral nervous system (somatic and autonomic nervous systems).
- Detail the structure of a neuron (nerve cell) and its types.
- Explain the transmission of nerve impulses along nerve fibres.
- Describe the structure and function of synapses.
- Differentiate between actions and reflexes.
- Distinguish between voluntary actions, instinctive behaviour, and learned behaviour.

20.1 Components and Organization of the Nervous System

The nervous system is a complex network of nerves and cells that carry messages to and from the brain and spinal cord to various parts of the body. Its primary role is to coordinate and control body functions.

- **Main Divisions:**
    1. **Central Nervous System (CNS):** Consists of the Brain and Spinal Cord. It is the main processing center for information.
    2. **Peripheral Nervous System (PNS):** Consists of all the nerves extending from the CNS to the rest of the body, including muscles, organs, and sensory receptors.

20.2 Central Nervous System (CNS)

- **A. Spinal Cord:**
    - **Structure:** A long, thin, tubular bundle of nervous tissue and support cells that extends from the brainstem to the lower back. Protected by vertebrae (backbone).
    - **Functions:**
        - **Relay Station:** Transmits nerve impulses between the brain and the rest of the body.
        - **Reflex Centre:** Acts as a coordinating centre for many reflexes without involving the brain.

- **B. Brain:**
  - **Structure:** The main control centre of the nervous system, located in the skull. It is highly convoluted (folded) to increase surface area.
  - **Main Parts and Functions:**
    - **Cerebrum:** The largest part, divided into two hemispheres.
      - **Functions:** Controls voluntary actions, thought, memory, language, intelligence, perception, and reasoning. Different lobes specialize in different functions (e.g., frontal lobe for planning, occipital for vision).
    - **Cerebellum:** Located at the back of the brain, below the cerebrum.
      - **Functions:** Coordinates muscle movements, maintains balance and posture, fine motor control.
    - **Medulla Oblongata (Brainstem):** Connects the brain to the spinal cord.
      - **Functions:** Controls involuntary vital functions such as breathing, heart rate, blood pressure, swallowing, and coughing.

20.3 Peripheral Nervous System (PNS)

The PNS carries information between the CNS and the rest of the body.

- **A. Somatic Nervous System:**
  - **Function:** Controls voluntary movements of skeletal muscles.
  - **Components:** Contains sensory neurons (carrying information from senses to CNS) and motor neurons (carrying commands from CNS to skeletal muscles).
- **B. Autonomic Nervous System (ANS):**
  - **Function:** Controls involuntary (automatic) actions of internal organs and glands (e.g., heart rate, digestion, breathing, blood pressure).
  - **Divisions:**
    - **Sympathetic Nervous System:** Prepares the body for "fight-or-flight" responses (e.g., increases heart rate, dilates pupils, inhibits digestion).
    - **Parasympathetic Nervous System:** Promotes "rest and digest" activities (e.g., slows heart rate, constricts pupils, stimulates digestion). These two divisions often have antagonistic (opposite) effects.

20.4 Neurones (Nerve Cells): Structure and Transmission of Impulses

- **Structure of a Neurone:** The basic functional unit of the nervous system.
  - **Cell Body (Soma):** Contains the nucleus and most organelles; integrates incoming signals.
  - **Dendrites:** Short, branched extensions that receive incoming nerve impulses from other neurons or sensory receptors and transmit them towards the cell body.
  - **Axon:** A long, slender projection that transmits nerve impulses *away* from the cell body to other neurons, muscles, or glands.
    - **Myelin Sheath:** A fatty insulating layer that covers many axons, produced by Schwann cells. Increases the speed of nerve impulse transmission (saltatory conduction).
    - **Nodes of Ranvier:** Gaps in the myelin sheath, where the action potential "jumps" from node to node.
    - **Axon Terminals (Synaptic Knobs):** Swellings at the end of the axon that transmit signals across a synapse.

- **Types of Neurones:**
  - **Sensory Neurones (Afferent Neurones):** Transmit impulses from sensory receptors to the CNS.
  - **Motor Neurones (Efferent Neurones):** Transmit impulses from the CNS to effectors (muscles or glands).
  - **Relay Neurones (Interneurons):** Found within the CNS, connect sensory and motor neurons.
- **Transmission of Nerve Impulses Along Nerve Fibres (Action Potential):**
  - Nerve impulses are electrochemical signals.
  - **Resting Potential:** When a neuron is not transmitting a signal, the outside of the membrane is positively charged, and the inside is negatively charged, due to the uneven distribution of ions (mainly Na^+ and K^+) maintained by the sodium-potassium pump.
  - **Depolarization (Action Potential):** When a stimulus reaches a certain threshold, sodium ion channels open, and Na^+ ions rush into the cell, making the inside temporarily positive. This creates an electrical impulse.
  - **Repolarization:** Potassium ion channels open, and K^+ ions rush out, restoring the negative charge inside.
  - **Propagation:** The action potential propagates along the axon, like a wave of depolarization. Myelin sheath speeds up this process.

20.5 Synapses: Structure and Function

- **Definition:** A synapse is the junction between two neurons, or between a neuron and an effector cell (e.g., muscle cell or gland cell), where a nerve impulse is transmitted. There is a small gap called the **synaptic cleft**.
- **Structure:**
  - **Presynaptic Terminal:** The end of the axon of the transmitting neuron. Contains neurotransmitter vesicles.
  - **Synaptic Cleft:** The tiny gap between the presynaptic and postsynaptic membranes.
  - **Postsynaptic Membrane:** The membrane of the receiving neuron or effector cell, containing receptors for neurotransmitters.
- **Transmission Across Synapses:**
  1. When a nerve impulse (action potential) reaches the presynaptic terminal, it triggers the release of chemical messengers called **neurotransmitters** (e.g., acetylcholine, dopamine) from vesicles into the synaptic cleft.
  2. Neurotransmitters diffuse across the synaptic cleft and bind to specific **receptors** on the postsynaptic membrane.
  3. This binding causes ion channels on the postsynaptic membrane to open, generating a new electrical impulse (or inhibiting one) in the postsynaptic neuron or causing a response in the effector cell.
  4. Neurotransmitters are quickly broken down by enzymes or reabsorbed by the presynaptic neuron to clear the synapse and allow for subsequent signals.
- **Importance:** Ensure unidirectional (one-way) flow of impulses; allow for integration and processing of information; enable complex responses and learning.

20.6 Actions and Reflexes

- **Action:** A general term for any response of an organism to a stimulus.
- **Reflex (Reflex Action):**
    - **Definition:** A rapid, involuntary, automatic response to a specific stimulus, involving a neural pathway called a **reflex arc**.
    - **Characteristics:**
        - **Involuntary:** Occurs without conscious thought or control.
        - **Rapid:** Quick response, often for protection.
        - **Automatic:** Predictable response to a given stimulus.
    - **Reflex Arc Components:**
        1. **Receptor:** Detects the stimulus (e.g., pain receptors in skin).
        2. **Sensory Neuron:** Transmits impulse from receptor to CNS.
        3. **Relay Neuron (Interneuron):** In the CNS (spinal cord for most reflexes), connects sensory to motor neuron.
        4. **Motor Neuron:** Transmits impulse from CNS to effector.
        5. **Effector:** Muscle or gland that carries out the response.
    - *Example:* Withdrawal reflex (touching a hot object and immediately pulling hand away).

20.7 Voluntary Actions, Instinctive Behaviour, and Learned Behaviour

- **A. Voluntary Actions:**
    - **Definition:** Actions that are initiated consciously and are under the control of the cerebrum (brain). They require thought and decision-making.
    - *Examples:* Kicking a ball, writing notes, deciding to speak.
- **B. Instinctive Behaviour (Innate Behaviour):**
    - **Definition:** Complex, unlearned, and genetically programmed patterns of behaviour that are characteristic of a species. They are performed without prior experience or learning.
    - *Examples:* A spider spinning a web, a baby sucking reflex, bird migration, salmon swimming upstream to spawn.
- **C. Learned Behaviour:**
    - **Definition:** Behaviour that is modified or acquired as a result of experience. It is flexible and adaptable.
    - **Types of Learning:**
        - **Habituation:** Decreased response to a repeated, irrelevant stimulus (e.g., getting used to a continuous background noise).
        - **Conditioning:**
            - **Classical Conditioning:** Learning to associate an unconditioned stimulus with a new (conditioned) stimulus (e.g., Pavlov's dogs associating bell with food).
            - **Operant Conditioning:** Learning through rewards and punishments (e.g., a dog learning to sit for a treat).
        - **Imprinting:** Rapid learning during a critical period in early life (e.g., goslings following the first large moving object they see).

        - **Trial and Error:** Learning by trying different actions until a successful one is found (e.g., a rat finding its way through a maze).
        - **Insight Learning (Reasoning):** Solving problems by understanding relationships, often without prior experience (e.g., a chimpanzee stacking boxes to reach a banana).
    - **Importance:** Allows organisms to adapt to changing environments and improve their chances of survival and reproduction.