

NEURAL CONTROL AND COORDINATION

CHAPTER 18



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I. Introduction

- Coordination is essential for maintaining homeostasis in the body.
- It involves the interaction and complementation of functions among various organs and systems.
- During physical exercises, energy demand and oxygen supply increase, necessitating coordinated responses from different organ systems.

II. Coordinated Functions During Physical Exercise A. Increased Muscular Activity

- Muscles require more energy during exercise.

B. Increased Oxygen Supply

- Enhanced oxygen demand necessitates adjustments in other systems.

C. Respiratory System

- The rate of respiration increases to provide more oxygen to the muscles.

D. Cardiovascular System

- Heart rate increases to pump oxygenated blood to muscles.
- Blood vessels dilate to accommodate increased blood flow.

E. Nervous System

- Nervous system controls muscle contractions and motor function.

F. Renal System (Kidneys)

- Adjusts blood filtration and fluid balance as needed during exercise.

III. Return to Normal Conditions

- When exercise stops, organs gradually return to their normal functions.

IV. Coordination by Neural and Endocrine Systems A. Neural System

- Provides point-to-point connections for rapid coordination.
- Controls voluntary and involuntary muscle movements.

B. Endocrine System

- Uses hormones for chemical integration and coordination.
- Regulates various physiological processes, such as metabolism, growth, and stress responses.

V. Mechanisms of Neural Coordination A. Transmission of Nerve Impulse

- Nerve impulses carry information between neurons.

B. Impulse Conduction Across a Synapse

- Synapses allow communication between neurons.
- Neurotransmitters transmit signals from one neuron to another.

VI. Conclusion

- The coordinated efforts of the neural and endocrine systems are crucial for maintaining homeostasis and synchronizing the functions of various organs and systems in the human body.
- Understanding these mechanisms is essential for comprehending how our body responds to various stimuli and maintains its balance.

A. NEURAL SYSTEM

I. Introduction

- The neural system in animals is composed of specialized cells known as neurons.
- Neurons can detect, receive, and transmit various stimuli.
- The complexity of the neural system varies among different animal groups.

II. Neural Organization in Lower Invertebrates

- In lower invertebrates like Hydra, the neural system is relatively simple.
- It consists of a network of neurons that coordinate basic responses to stimuli.

III. Neural Organization in Insects

- Insects exhibit a more advanced neural organization.
- They have a brain, as well as multiple ganglia and neural tissues.
- This allows for more complex sensory processing and responses to stimuli.

IV. Neural System in Vertebrates

- Vertebrates, including humans, possess a highly developed neural system.
- It is characterized by advanced brain structures and intricate neural networks.

V. Conclusion

- The neural system varies in complexity across the animal kingdom.
- Higher vertebrates, such as humans, exhibit a sophisticated neural system that enables complex sensory perception, motor control, and cognitive functions.
- Understanding these differences in neural organization is crucial for comprehending the range of sensory and motor capabilities across the animal kingdom.

B. HUMAN NEURAL SYSTEM

I. Introduction

- The human neural system is divided into two main parts: the central neural system (CNS) and the peripheral neural system (PNS).
- The CNS processes information and controls bodily functions.
- The PNS consists of all the nerves associated with the CNS.

II. Components of the Central Neural System (CNS)

A. The Brain

- The central processing unit for sensory information, motor control, and higher cognitive functions.

B. The Spinal Cord

- Transmits signals between the brain and the rest of the body.

III. Components of the Peripheral Neural System (PNS)

- The PNS includes all nerves in the body that connect to the CNS.

A. Afferent Nerve Fibres

- Transmit sensory impulses from tissues and organs to the CNS.

B. Efferent Nerve Fibres

- Transmit regulatory impulses from the CNS to peripheral tissues and organs.

IV. Divisions of the Peripheral Neural System (PNS)

A. Somatic Neural System

- Relays impulses from the CNS to skeletal muscles, allowing voluntary motor control.

B. Autonomic Neural System

- Transmits impulses from the CNS to involuntary organs and smooth muscles of the body.

V. Subdivisions of the Autonomic Neural System

A. Sympathetic Neural System

- Responsible for "fight or flight" responses, preparing the body for action during stress or emergencies.

B. Parasympathetic Neural System

- Promotes relaxation, energy conservation, and recovery after stress.

VI. Visceral Nervous System

- A component of the PNS that encompasses a network of nerves, fibers, ganglia, and plexuses.
- It facilitates the transmission of impulses between the CNS and visceral organs and back, regulating functions of the internal organs.

VII. Conclusion

- The human neural system is a complex network of structures that allows for sensory perception, motor control, and coordination of bodily functions.
- The division of the neural system into the CNS and PNS, along with the subcategories, enables efficient communication and regulation of various physiological processes in the body.

C. NEURON AS STRUCTURAL AND FUNCTIONAL UNIT OF NEURAL SYSTEM

I. Introduction

- Neurons are the fundamental building blocks of the neural system.
- They are responsible for transmitting and processing electrical and chemical signals within the nervous system.

II. Structure of a Neuron

A. Cell Body (Soma)

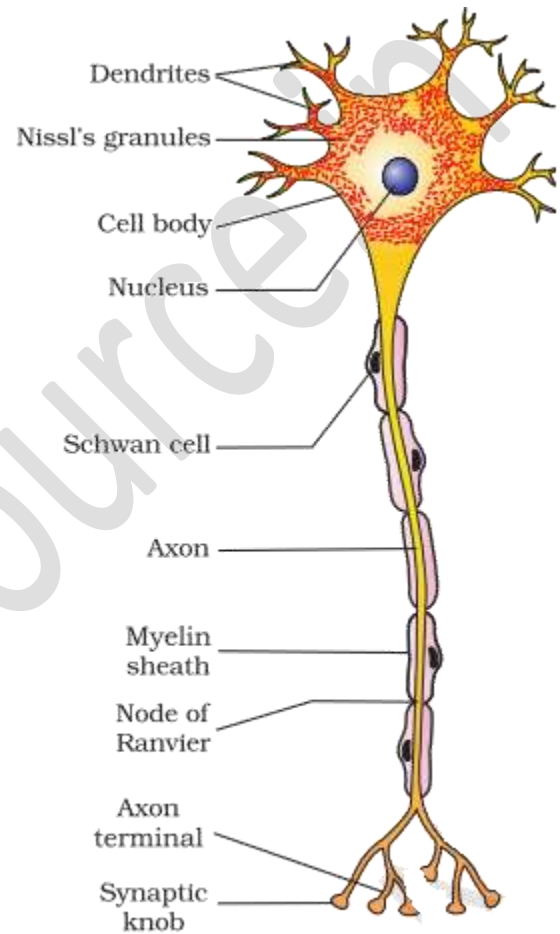
- Contains cytoplasm with typical cell organelles.
- Contains Nissl's granules, which are involved in protein synthesis.

B. Dendrites

- Short, branched fibers that extend from the cell body.
- Contain Nissl's granules and transmit impulses towards the cell body.
- Receive incoming signals from other neurons or sensory receptors.

C. Axon

- A long, single fiber extending from the cell body.
- Ends in bulb-like structures called synaptic knobs, which contain synaptic vesicles with neurotransmitters.
- Transmits nerve impulses away from the cell body to synapses or neuro-muscular junctions.



Structure of a neuron

III. Types of Neurons Based on Axon and Dendrite Arrangement

A. Multipolar Neurons

- Have one axon and two or more dendrites.
- Commonly found in the cerebral cortex of the brain.

B. Bipolar Neurons

- Possess one axon and one dendrite.
- Typically found in the retina of the eye.

C. Unipolar Neurons

- Have a cell body with a single axon only.
- Commonly found in the embryonic stage.

IV. Types of Axons

A. Myelinated Axons

- Enveloped by Schwann cells, forming a myelin sheath around the axon.

- Nodes of Ranvier are gaps between adjacent myelin sheaths.
- Found in spinal and cranial nerves, allowing for rapid signal transmission.

B. Unmyelinated Axons

- Enclosed by Schwann cells but lack a myelin sheath.
- Commonly found in the autonomous and somatic neural systems.

V. Conclusion

- Neurons are the structural and functional units of the neural system.
- Their unique structure, with dendrites for receiving signals and axons for transmitting signals, allows for the complex communication and processing of information within the nervous system.
- The presence or absence of myelin on axons influences the speed of signal transmission and is tailored to the specific needs of different neural pathways.

(a) Generation and Conduction of Nerve Impulse

I. Introduction

- Neurons are excitable cells with polarized membranes.
- This polarity is due to the selective permeability of ion channels and the active transport of ions across the neural membrane.

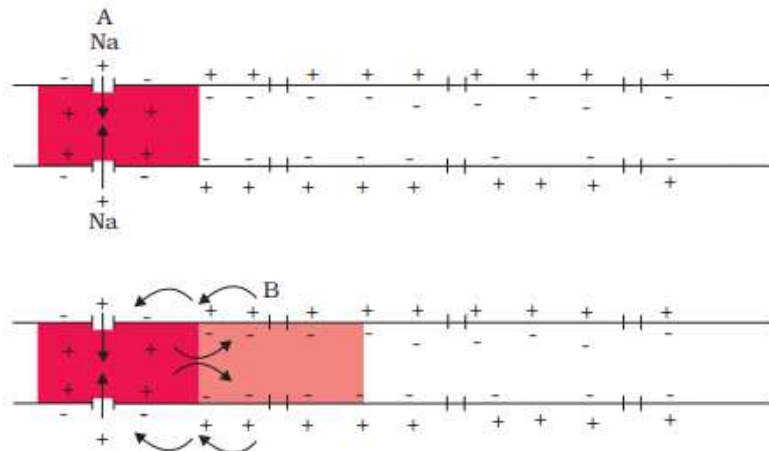
II. Membrane Polarization at Rest

- When a neuron is at rest, the axonal membrane is more permeable to potassium ions (K^+) and nearly impermeable to sodium ions (Na^+).
- The membrane is impermeable to negatively charged proteins in the axoplasm.
- This results in a concentration gradient with high K^+ and negatively charged proteins inside the axon and low K^+ and high Na^+ outside.
- The sodium-potassium pump actively maintains these ionic gradients by pumping 3 Na^+ out for 2 K^+ into the cell.
- The inner surface of the axonal membrane becomes negatively charged, and the outer surface becomes positively charged, creating a resting potential.

III. Generation of Nerve Impulse (Action Potential)

- When a stimulus is applied to a specific site on the polarized membrane (e.g., point A), the membrane becomes permeable to Na^+ .
- This leads to a rapid influx of Na^+ at site A, reversing the polarity: the outer surface becomes negatively charged, and the inner surface becomes positively charged (depolarization).

- The change in electrical potential at site A is known as the action potential or nerve impulse.
- Current flows on the inner surface from site A to site B, and on the outer surface from site B to site A, completing the circuit.
- The impulse generated at site A arrives at site B, and this sequence repeats along the length of the axon, allowing the impulse to be conducted.



Diagrammatic representation of impulse conduction through an axon (at points A and B)

IV. Restoration of Resting Potential

- The increased permeability to Na⁺ is short-lived and quickly followed by increased permeability to K⁺.
- K⁺ diffuses out of the membrane, restoring the resting potential at the site of excitation.
- The fiber becomes responsive to further stimulation.

V. Conclusion

- Neurons maintain a resting potential due to the selective permeability of ion channels and the active transport of ions by the sodium-potassium pump.
- The generation and conduction of a nerve impulse involve depolarization, action potential, and restoration of resting potential, enabling the transmission of signals along the length of the axon.

(b) Transmission of Impulses

I. Introduction

- Nerve impulses are transmitted from one neuron to another through specialized junctions called synapses.
- **Two main types of synapses exist:** electrical synapses and chemical synapses.

II. Electrical Synapses

- At electrical synapses, the membranes of pre-synaptic and post-synaptic neurons are in close proximity.
- Electrical current can flow directly from one neuron to another.

- Impulse transmission at electrical synapses is rapid and similar to the conduction along a single axon.
- However, electrical synapses are rare in the human nervous system.

III. Chemical Synapses

- Chemical synapses have a synaptic cleft, a fluid-filled gap, between the pre-synaptic and post-synaptic neuron's membranes.
- Neurotransmitters play a crucial role in transmitting impulses at chemical synapses.

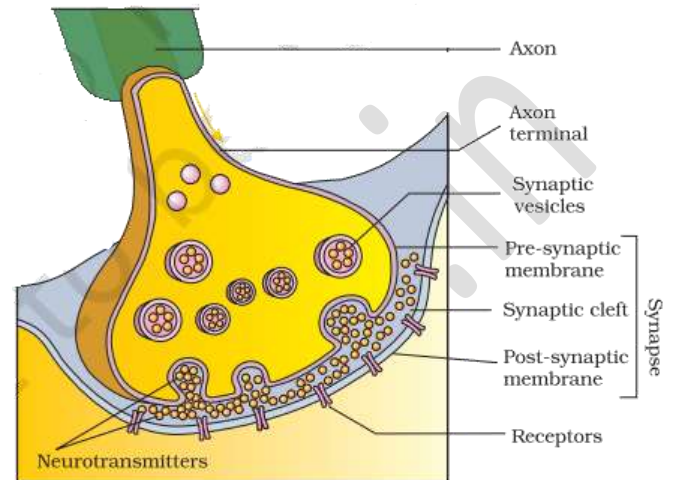


Diagram showing axon terminal and synapse

IV. Transmission at Chemical Synapses

A. Axon Terminals

- Axon terminals contain vesicles filled with neurotransmitters.

B. Arrival of Impulse (Action Potential)

- When an impulse (action potential) reaches the axon terminal, it stimulates the movement of synaptic vesicles toward the membrane.

C. Release of Neurotransmitters

- The vesicles fuse with the plasma membrane and release their neurotransmitters into the synaptic cleft.

D. Interaction at the Post-Synaptic Neuron

- Neurotransmitters bind to their specific receptors on the post-synaptic membrane.
- This binding opens ion channels, allowing ions to enter the post-synaptic neuron.

E. Generation of a New Potential

- The entry of ions can generate a new potential in the post-synaptic neuron.
- The new potential may be either excitatory (depolarizing) or inhibitory (hyperpolarizing).

V. Conclusion

- Chemical synapses are the predominant means of transmitting nerve impulses in the human nervous system.
- Neurotransmitters play a key role in signal transmission, allowing for precise and specific communication between neurons.
- The effects of neurotransmitters can be excitatory or inhibitory, influencing whether the post-synaptic neuron will generate an action potential.

D. CENTRAL NEURAL SYSTEM

I. Introduction

- The brain serves as the central information processing organ of the human body, functioning as the "command and control system."
- It controls various essential functions, including voluntary movements, vital involuntary organs, thermoregulation, hunger, thirst, circadian rhythms, endocrine gland activities, and human behavior.
- Additionally, the brain is responsible for processing sensory information, memory, intelligence, emotions, thoughts, and various cognitive functions.

II. Protection of the Brain

- The brain is well-protected within the skull.
- It is covered by cranial meninges, including the dura mater (outer layer), arachnoid (middle layer), and pia mater (inner layer in contact with brain tissue).

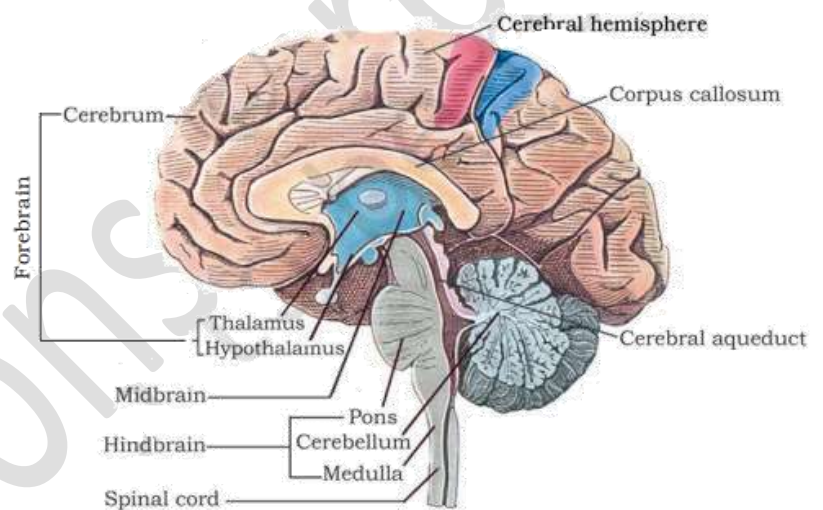


Diagram showing sagittal section of the human brain

III. Major Divisions of the Brain

A. Forebrain

- The forebrain is the largest and most complex part of the brain.
- It plays a vital role in higher cognitive functions, including reasoning, problem-solving, and conscious thought.
- Subdivisions of the forebrain include the cerebral cortex, thalamus, hypothalamus, and limbic system.

B. Midbrain

- The midbrain is a smaller region that serves as a relay center for sensory and motor pathways.
- It plays a role in controlling certain involuntary responses and is involved in the processing of auditory and visual information.

C. Hindbrain

- The hindbrain is located at the base of the brain and is responsible for fundamental bodily functions.
- It consists of the medulla oblongata, pons, and cerebellum.
- The medulla oblongata controls vital functions like breathing and heart rate.

- The pons helps coordinate breathing and contains neural pathways.
- The cerebellum is essential for motor control, balance, and coordination.

IV. Conclusion

- The human brain is a highly complex and vital organ responsible for a wide range of functions, including those related to cognition, behavior, and the regulation of essential bodily processes.
- The brain's three major parts—the forebrain, midbrain, and hindbrain—each have distinct roles and contribute to the overall functioning of the central neural system.

(a) Forebrain

I. Introduction

- The forebrain is a major division of the human brain and plays a crucial role in various complex functions.
- It consists of the cerebrum, thalamus, and hypothalamus.

II. Cerebrum

A. Left and Right Cerebral Hemispheres

- The cerebrum is the largest part of the human brain.
- It is divided longitudinally into two halves, the left and right cerebral hemispheres.
- These hemispheres are connected by the corpus callosum, a tract of nerve fibers.

B. Cerebral Cortex (Grey Matter)

- The cerebral cortex covers the cerebral hemispheres and is characterized by its greyish appearance.
- It contains neuron cell bodies, giving it its color.
- The cortex is highly folded, forming prominent folds.
- It houses motor areas, sensory areas, and association areas responsible for complex functions like memory, communication, and intersensory associations.

C. White Matter

- The inner part of the cerebral hemisphere is composed of white matter.
- It consists of myelinated nerve fibers that appear opaque white.
- White matter connects different regions of the brain and facilitates communication.

III. Thalamus

- The thalamus is a major coordinating center for sensory and motor signaling.
- It serves as a relay station for sensory information on its way to the cerebral cortex.
- The thalamus helps process and filter sensory input before it reaches the cerebral cortex.

IV. Hypothalamus

- The hypothalamus is located at the base of the thalamus and plays a vital role in regulating various bodily functions.

A. Temperature Regulation

- The hypothalamus controls body temperature, helping maintain homeostasis.

B. Appetite and Thirst

- It regulates the urge for eating and drinking.

C. Neurosecretory Cells

- The hypothalamus contains neurosecretory cells that secrete hormones known as hypothalamic hormones.

V. Limbic System

- The limbic system is a complex structure comprising the inner parts of cerebral hemispheres and deep structures like the amygdala and hippocampus.
- It is involved in regulating sexual behavior, emotional reactions (e.g., excitement, pleasure, rage, and fear), and motivation.
- The limbic system, in coordination with the hypothalamus, plays a crucial role in various emotional and behavioral responses.

VI. Conclusion

- The forebrain, consisting of the cerebrum, thalamus, and hypothalamus, is responsible for a wide range of complex functions, including sensory processing, motor coordination, temperature regulation, and emotional and motivational responses.
- The limbic system, within the forebrain, plays a central role in emotional and behavioral regulation.

(b) Midbrain

I. Introduction

- The midbrain is a region of the brain located between the thalamus/hypothalamus of the forebrain and the pons of the hindbrain.
- It plays a critical role in sensory and motor functions.

II. Anatomy of the Midbrain A. Cerebral Aqueduct

- The midbrain contains a canal known as the cerebral aqueduct, which allows for the passage of cerebrospinal fluid.

B. Corpora Quadrigemina

- The dorsal portion of the midbrain is characterized by four round swellings known as corpora quadrigemina.

- The corpora quadrigemina are further divided into two pairs of lobes: the superior colliculi (upper pair) and the inferior colliculi (lower pair).

III. Functions of the Midbrain A. Sensory Processing

- The superior colliculi play a crucial role in visual processing, particularly in the coordination of eye movements and visual reflexes.
- The inferior colliculi are involved in auditory processing, including the relay of auditory information to the thalamus and cortex.

B. Motor Functions

- The midbrain is involved in motor coordination, particularly in initiating and controlling movements related to posture and balance.

C. Relay Center

- It serves as a relay center for transmitting sensory information to higher brain regions.
- The midbrain helps integrate sensory input from various modalities, including vision and hearing.

IV. Conclusion

- The midbrain is a vital component of the brain, situated between the forebrain and hindbrain.
- Its anatomical features, such as the corpora quadrigemina, house sensory processing centers for vision and audition.
- Additionally, the midbrain contributes to motor coordination, posture control, and the integration of sensory information from different modalities.

(c) Hindbrain

I. Introduction

- The hindbrain is a critical region of the brain located at its posterior part, responsible for various vital functions.
- It includes the pons, cerebellum, and medulla, with each region serving specific roles.

II. Pons

- The pons contains fiber tracts that connect different regions of the brain.
- It serves as a bridge between various parts of the brain and plays a role in transmitting information.
- The pons is involved in functions like controlling respiration and various reflexes.

III. Cerebellum

- The cerebellum is known for its highly convoluted surface, which provides extra space for a vast number of neurons.
- It plays a critical role in motor coordination, balance, and fine-tuning of movements.

- The cerebellum ensures precise muscle coordination and contributes to motor learning and cognitive functions.

IV. Medulla (Medulla Oblongata)

- The medulla is the region of the brainstem that connects to the spinal cord.
- It contains centers responsible for essential functions, including: A. Respiration: It controls breathing and respiratory reflexes. B. Cardiovascular Reflexes: The medulla regulates heart rate, blood pressure, and various cardiovascular functions. C. Gastric Secretions: It influences the secretion of digestive enzymes and controls functions related to the gastrointestinal system.

V. Brain Stem

- The brain stem is composed of three major regions: midbrain, pons, and medulla oblongata.
- It serves as a vital connection between the brain and the spinal cord, allowing for the relay of sensory and motor information.

VI. Conclusion

- The hindbrain, consisting of the pons, cerebellum, and medulla, plays a crucial role in maintaining essential bodily functions.
- The pons serves as a bridge between different brain regions, while the cerebellum is responsible for motor coordination and balance.
- The medulla controls respiration, cardiovascular reflexes, and gastric secretions, making it a central region for regulating vital physiological processes.