Unit 5
Human body system

5. Human body system

Body Coordination

- There are two main forms of coordination in animals as a whole.
- These are nervous and hormonal coordination.
- Thus, the nervous system and the endocrine system are the two important systems that are responsible for body coordination.
- The nervous system uses nerve cells to pass electrical impulses along their length.
- They stimulate their target cells by secreting chemicals, known as neurotransmitters, directly on to them.
- On the other hand, the endocrine system produces chemicals (hormones) that are transported in the blood plasma to their target cells.
- The target cells have specific receptors on their cell-surface membranes and the change in the concentration of hormones stimulates them.

Table 5.1 Nervous system versus endocrine system

	Nervous system	Endocrine system
Speed of action	Seconds	Minutes to hours (even days)
Duration of action	Seconds to minutes	Minutes to days
Method of transmitting messages	Electrical	Chemical
Transport method	Neurones	Hormones

5.1. The Nervous System: Definition of the nervous system

- The **nervous system** is responsible for the reception and processing of sensory information from both the external and internal environments.
- The nervous system has two major divisions.
- The **central nervous system (CNS)** consists of the **brain and spinal cord.**
- The **peripheral nervous system (PNS)** consists of **nerves** outside the CNS.
- The nervous system has three specific functions:

1. The nervous system receives sensory input. Sensory receptors in skin and other organs respond to external and internal stimuli by generating nerve signals that travel by way of the PNS to the CNS.
2. The CNS performs information processing and integration, summing up the input it receives from all over the body.

3. The CNS generates motor output. Nerve signals from the CNS go by way of the PNS to the muscles, glands, and organs.

5.1.1 Neurons and their functions

- The nervous system is composed of only two principal types of cells - neurons and supporting cells (glial cells).
- **Neurons** are the basic structural and functional units of the nervous system.
- They are specialized to respond to physical and chemical stimuli, conduct electrochemical impulses, and release chemical regulators.
- Through these activities, neurons enable the perception of sensory stimuli, learning, memory, and the control of muscles and glands.
- **Supporting cells** aid the functions of neurons and are about five times more abundant than neurons. In the CNS, supporting cells are collectively called **neuroglia,** or simply **glial cells** (from the Middle Greek *glia* = glue).
- **Neuroglia** serves as supporting cells, providing support and nourishment to the neurons.
- The basic unit of communication in the nervous system is the nerve cell **(neuron).** All neurons consist of: **(1) a cell body, (2) dendrites, and (3) an axon**.
- Dendrites and axons can be referred to generically as processes or extensions from the cell body.

1. Cell body:

- The cell body contains the nucleus, as well as other organelles.
- Also known as a soma, the cell body is the neuron's core.
- The cell body consists of nucleus that carries genetic information, maintains the neuron's structure, and provides energy to drive activities.
- Most of the neuron cell bodies are located inside the central nervous system and form the grey matter.
- The Cell bodies that are located in the peripheral nervous system are called **ganglia.**

2) Axon:

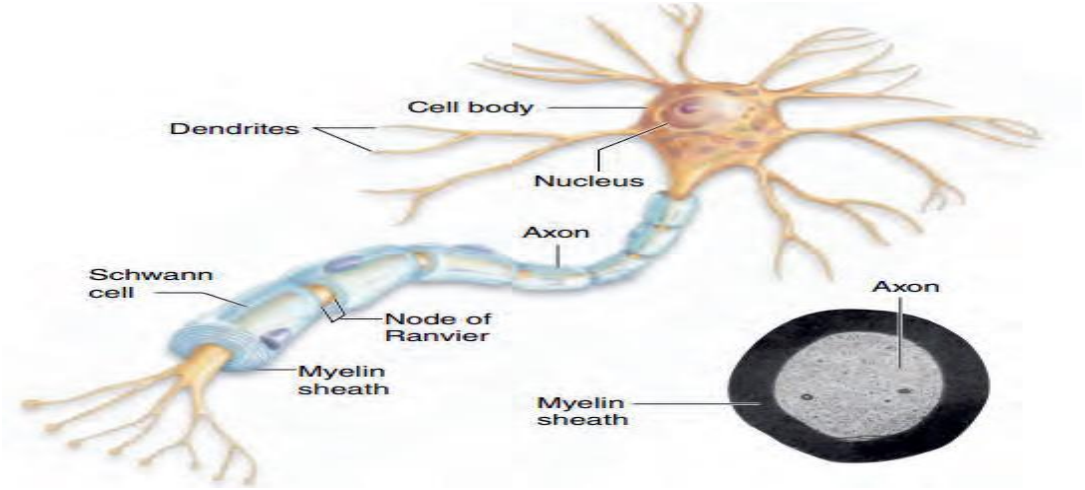
- Each neurone has only one axon that conducts information away from the cell body.
- The axon will also branch at its terminal into many axon terminals.
- The axon delivers the impulse to another neurone or a gland or a muscle.
- Individual axons are termed nerve fibers, and collectively they form a nerve.
- Many axons are insulated with a fatty substance called myelin sheath.

3). Dendrites:

- Dendrites are short extensions that receive signals from sensory receptors or other neurons.
- Incoming signals from dendrites can result in nerve signals that are then conducted by an axon.
- Neurons can have more than one set of dendrites, known as dendritic trees.
- The number of dendritic tree neurons have generally depends on their role.

Myelin sheath:

- Myelin is a fatty substance whose purpose is to protect the neurone and to electrically insulate it, speeding up impulse transmission.
- The axons of peripheral nerves and long or large axons are covered by a myelin sheath.
- Within the peripheral nervous system Schwann cells wrapped in layers around the neurone form the myelin sheath.
- The gaps where there is no myelin sheath are called nodes of Ranvier. Some nerve fibres are unmyelinated, and this makes nerve impulse transmission significantly slower.



Types of neurons

- Neurons vary in structure and function. In terms of function, scientists classify neurons into three broad types: **sensory, motor,** and **interneurons.**

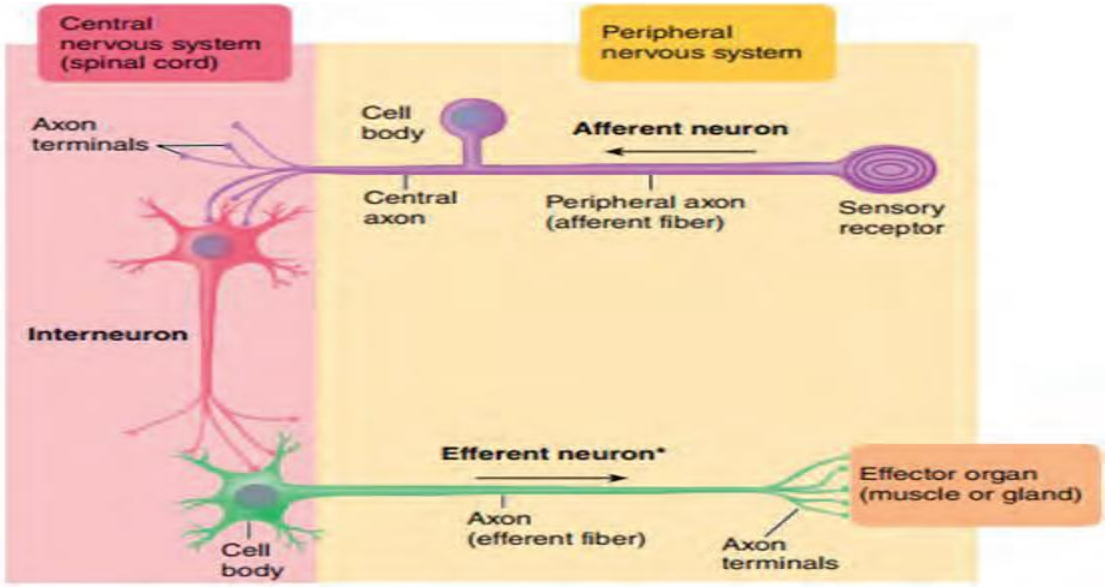
1. Sensory (affector/ afferent) neurons:

- Sensory neurons carrymessages from sensory receptors to the central nervous system.
- They have typically a long dendrite and short axon.
- Sensory neurons are triggered by the physical and chemical inputs from environment (stimuli) such as sound, touch, heat, and light.

2. Motor (effector/ efferent) neurons:

- Motor neurons transmit messages from the central nervous system to the effectors (muscles or glands).
- Motor neurons have a long axon and short dendrites. Motor neurons play a role in voluntary and involuntary movements.
- These neurons allow the brain and the spinal cord to communicate with muscles, organs, and glands all over the body.

4. **Interneurons (association neurons):**
   - ❖ Interneurons are found entirely within the central nervous system.
   - ❖ They pass signals from sensory to motor neurons, or to integrate these functions.



- ❖ The nervous system takes in information from our receptors.
- ❖ Once a stimulus is picked up by a receptor, the information is passed along special nerve cells, affector or afferent (sensory) neurons, to the central nervous system (CNS).
- ❖ In the CNS interneurons (associated neurons) pass signals from sensory neurons to motor neurons and other interneurons.
- ❖ Once the information has been processed in the CNS, instructions are sent out to the body along motot neurons called effector or efferent (motor) neurons.
- ❖ The summary of information flows through the nervous system in the following sequence:

- ❖ Stimulus------Reception by sensory receptor------ transmission by afferent neuron-------- integration by interneurons in CN--------transmission by efferent neuron------ action by effectors

Nerves and nerve tracts

- ❖ **A nerve** is a group of neurons (bundles of neurons) with blood vessels and connective tissue
- ❖ Sensory (afferent) nerves are made only of sensory neurons. The optic nerves for vision and olfactory nerves for smell are examples of nerves with a purely sensory function.
- ❖ Motor (efferent) nerves are made only of motor neurons; autonomic nerves are motor nerves.
- ❖ A mixed nerve contains both sensory and motor neurons. Most of our peripheral nerves, such as the sciatic nerves in the legs, are mixed nerves.
- ❖ The term nerve tract refers to groups of neurons within the central nervous system.
- ❖ All the neurons in a nerve tract are concerned with either sensory or motor activity.

- These tracts are often referred to as white matter; the myelin sheaths of the neurons give them a white color.
- The sodium channel and potassium channels on the membrane of neuron are closed.
- This state of resting neuron is called Polarized state and it is electro negatively charged.

Depolarization or Action Potential

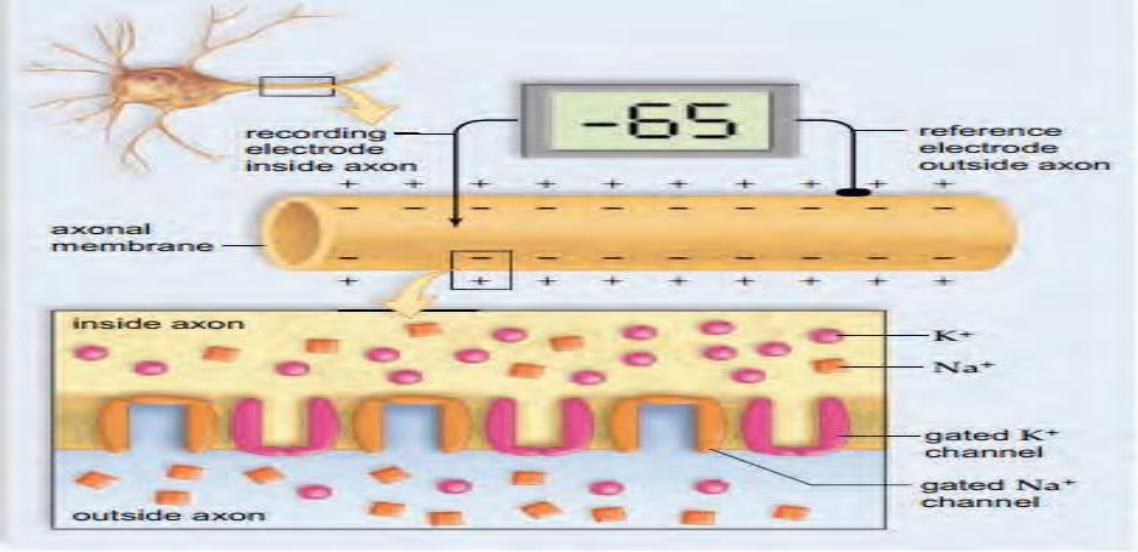
- A stimulus above the threshold which can be initiated by mechanical, chemical and physical stimulation cause the initiation of impulse

5.1.2. The Nerve Impulse and transmission

- The nervous system relies on nerve impulses travelling along a neuron.
- Each nerve impulse is a minute electrical event that works as a result of charge differences across the membrane of the axon.
- The wave of positive charge inside the axon when the neuron is stimulated is **known as the action potential.**

Resting Potential

- When an axon is resting, its membrane is polarized; that is, the outside is positive compared to the inside **(which is negative).**
- When the axon is not conducting an impulse, the voltmeter records a membrane potential equal to about -65 mV (millivolts), indicating that the inside of the neuron is more negative than the outside.
- This is called the **resting potential.** Because, the axon is **not conducting an impulse.**



Polarization

- In the resting state the inside of membrane has negative electrical potential compared to outside. This difference in potential is called **resting potential** (about -40mv to -90mv).
- The interstitial fluid has high concentration of Na+ ion which is about 16 times higher outside the neuron than inside neuron.

- Similarly, the axoplasm has high concentration of K+ ion which is about 25 times higher inside than in outer interstitial fluids.
- Due to difference in Na, K concentration, the Na+ ions diffuse inside the exoplasm and K+ ions tends to diffuse outside of it.
- The membrane of neuron at resting is more permeable to K+ ion than Na+ ion. So, K+ leaves the neuron faster than Na+ enter the neuron.
- Na+ and K+ are transported across the membrane against their concentration gradient by carrier protein, which is called Na-K pump and energy is used through ATP.
- The difference in permeability results in accumulation of high concentration of cation (+ve charged ion) outside the neuron compared to the concentration of cation inside.
- Sodium channels are opened but potassium channels are closed and Na+ ions flood in through cell membrane and create a positive charge of +40mv.
- It is a very short periods that change in potential and last for 3 milliseconds.
- When an **action potential** occurs, the axon is said to be **depolarized.**
- The depolarization of the membrane stimulates the adjacent voltage channel, so the action potential passes as a wave along the length of neuron.

Depolarization:

- This process is started by a nerve impulse. Acetylcholine released by the axon terminal makes the sarcolemma very permeable to Na+ ions, which enter the cell and cause a reversal of charges to (-ve) outside and (+ve) inside.
- The depolarization spreads along the entire sarcolemma and initiates the contraction process.
- As soon as depolarization takes place, the neuron membrane becomes very permeable to K+ ions, which rush out of the cell.
- This restores the positive charge outside and the negative charge inside, and is called **repolarization.**
- Then the sodium and potassium pumps return Na+ ions outside and K+ ions inside, and the neuron is ready to respond to another stimulus and transmit another impulse.
- An action potential in response to a stimulus takes place very rapidly and is measured in milliseconds. An individual neuron is capable of transmitting hundreds of action potentials (impulses) each second

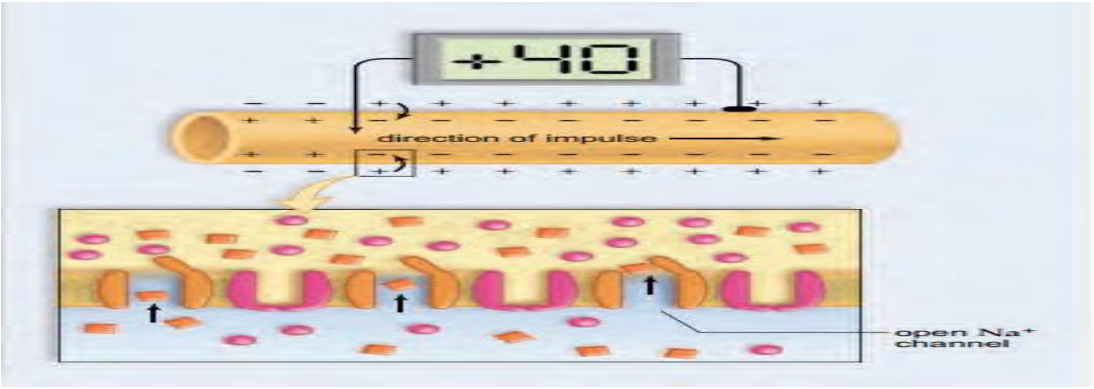
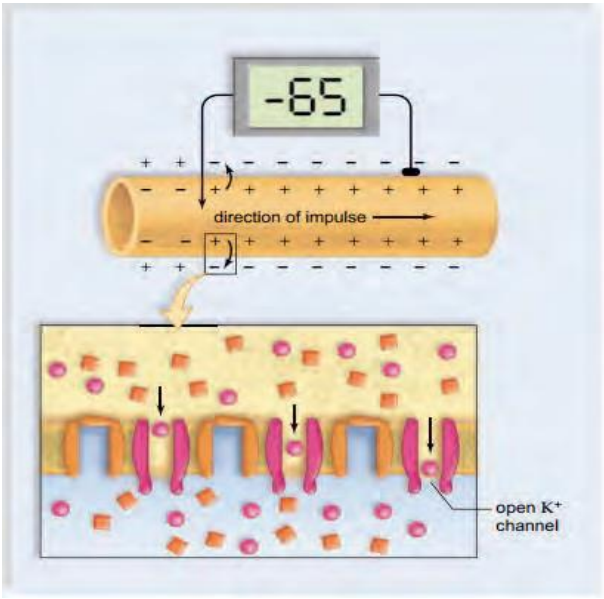


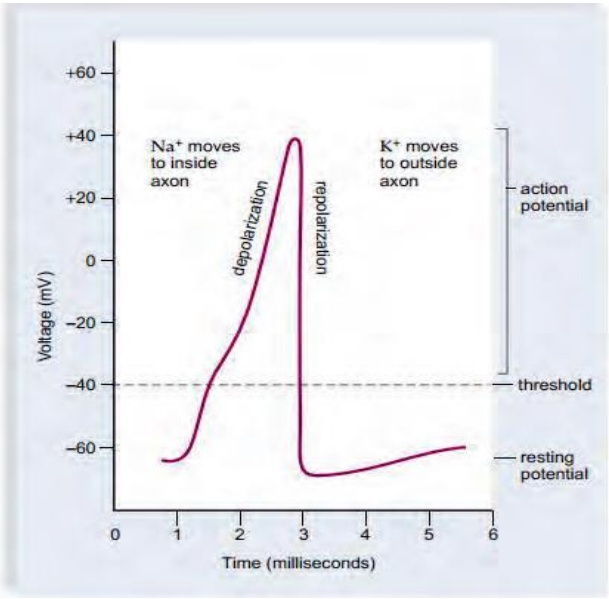
Figure: Action potential begins: depolarization occurs

Repolarization

- Sodium channels are closed potassium channel are opened and K+ ions diffuse out along their concentration gradient. This starts repolarization and resting potential going to reestablish.
- At the same time nerve become less permeable for Na+ than K+. So many K+ flow out and inside charge become more negative than that it was originally.
- Na-k pump starts and normal concentrations of Na and K ions are reestablished. Each pump actively transports two K+ ions into the cell to every three Na+ ions transported out.
- The membrane is once again at its resting potential.
- **Action Potential:** An action potential is a rapid change in polarity across a portion of an axonal membrane as the nerve impulse occurs. An action potential uses two types of gated ion channels in the axonal membrane.
- When the nerve fiber is conducting a nerve impulse (action potential), a change in polarity occurs across the axon's membrane.
- First, the inside of an axon becomes positive compared to the outside (this is called **depolarization)**, and then the inside becomes negative again (this is called **repolarization).**
- An action potential requires two types of channels in the membrane: One channel can allow Na ions to pass through the membrane, and the other can allow K ions to pass through the membrane.
- During depolarization, Na ions move to the inside of the axon, and during repolarization, K ions move to the outside.



A) Action potential ends



B) Action potential graph

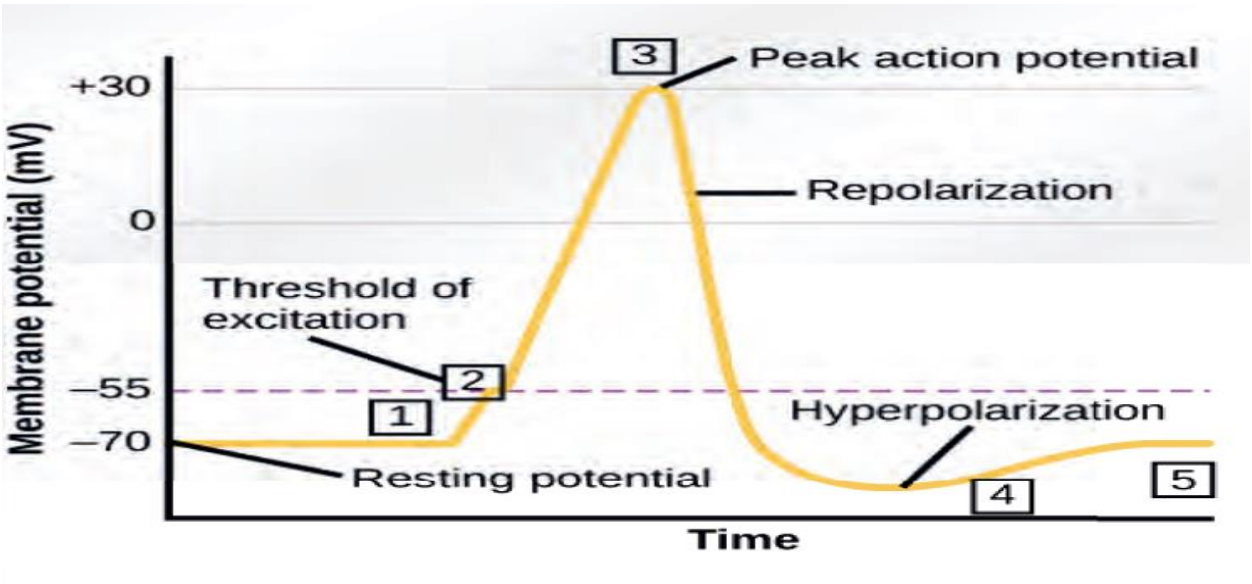


Figure: Conduction of Action Potentials

Syanapse

- Whenever one neuron ends and another begins there is a gap known as a **synapse.**
- Neuron-neuron synapses usually involve a connection between the axon of one neuron and the dendrites, cell body, or axon of a second neuron.
- The axon of the presynaptic neuron ends in slight swellings, the axon terminals, which hold the synaptic vesicles that contain neurotransmitter molecules.
- The axon terminal of the presynaptic neuron, which conducts its action potentials toward the synapse, ends in a slight swelling, **the synaptic knob**.
- The synaptic knob contains synaptic vesicles, which store a specifc chemical messenger, a **neurotransmitter** that has been synthesized and packaged by the presynaptic neuron.
- The synaptic knob comes close the to, but does not touch, the postsynaptic neuron, whose action potentials are propagated away from the synapse.
- The space between the presynaptic and postsynaptic neurons is called the **synaptic cleft.**
- The process by which the impulse in the presynaptic neuron signals the postsynaptic cell is called synaptic transmission.
- As a result of synaptic transmission, the presynaptic neuron stimulates or inhibits a postsynaptic cell. Synaptic transmission is a one-way process carried out by neurotransmitters.
- An impulse travels along the axon of the presynaptic neuron to axon terminal. Most axons have several rounded synaptic knobs at their terminals, which dendrites do not ave.
- These knobs have arrays of membranous sacs, called synaptic vesicles that contain neurotransmitter molecules.
- When an impulse reaches a synaptic knob, voltage- sensitive calcium channels open and calcium diffuses inward from the extracellular fluid.
- The increased calcium concentration inside the cell initiates a series of events that fuses the synaptic vesicles with the cell membrane, where they release their neurotransmitter by exocytosis.

5.1.3 Neurotransmitters

- Neurotransmitters are often referred to as the body's chemical messengers. They are the molecules used by the nervous system to transmit messages between neurons, or from neurons to muscles.
- Acetylcholine (ACh) is an abundant neurotransmitter in the human body. It is found in both the central nervous system (CNS) and the peripheral nervous system (PNS).
- An excitatory transmitter promotes the generation of an action potential in the receiving neuron, whereas an inhibitory transmitter prevents it. Whether a neurotransmitter is excitatory or inhibitory depends on the receptor it binds to.
- **Figure 5.7** Synapsis occurs from axon terminal one neuron to the denderities or cell body another neuron

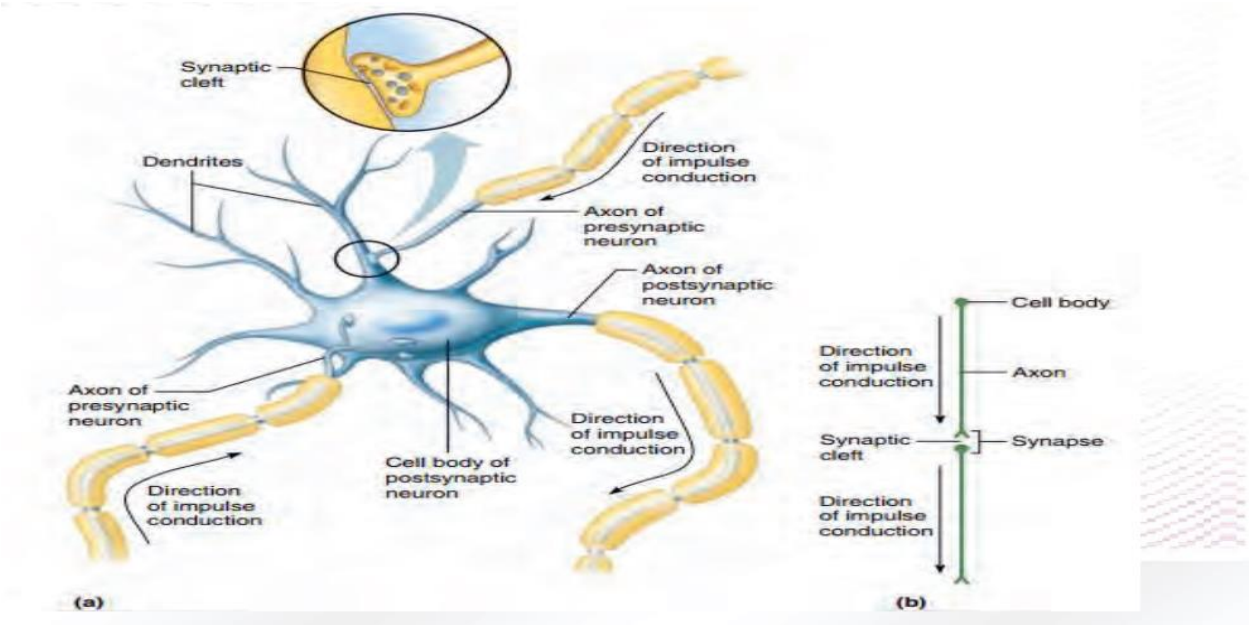


Figure: Synapsis occurs from axon terminal one neuron to the denderities or cell body another neuron

5.1.4 Types of the nervous system

- Human nervous system has two main parts. These are the central nervous system (CNS), which is made up of **brain** and **spinal cord,** and the **peripheral nervous system** which consists of the nerves that branch out from the brain and spinal cord.

A. The Central Nervous System

The Central Nervous System (CNS) consists of two main parts: - the **brain** and the **spinal cord.**

The Brain

- Central nervous tissue is delicate. Because of this characteristic, and because damaged nerve cells cannot be replaced, this fragile, irreplaceable tissue must be

well protected. Four major features help protect the CNS from injury:

1. It is enclosed by hard, bony structures. The cranium (skull) encases the brain, and the vertebral column surrounds the spinal cord.
2. Three protective and nourishing membranes, the **meninges**, lie between the bony covering and the nervous tissue.

The meninges consist of three connective tissue layers:

- **Dura mater:** this layer lies closest to the bone of the skull and is a double layer of tough, fibrous, connective tissue.
- The outer layer is called the periosteal layer (the spinal cord lacks this layer), and the meningeal layer lies closest to the brain.
- **Arachnoid mater:** between the dura mater and the arachnoid mater there is a space called the **subdural space.**
- The arachnoid mater is a delicate serous membrane. The subarachnoid space is below the arachnoid mater and above the pia mater.
- The subarachnoid space contains CSF and is also home to some of the larger blood vessels serving the brain.
- **Pia mater -** this is a delicate connective tissue layer that clings tightly to the brain.
- It contains many tiny blood vessels that serve the brain.
- The brain "floats" in a special cushioning fluid, the cerebrospinal fluid (CSF).
- It is a thin fluid similar to plasma and has several important functions:
    - It acts as a cushion, supporting the weight of the brain and protecting it from damage;
    - It helps to maintain a uniform pressure around the brain and spinal cord;
    - There is a limited exchange of nutrients and waste products between neurones and CSF.
- Protected within the skull, the brain is composed of the **cerebrum, cerebellum,** and **brainstem (Medula)**

Cerebrum

- The **cerebrum,** also called the telencephalon, is the largest portion of the brain in humans. **Cerebrum:** is the largest part of the brain and is composed of **right** and **left** hemispheres. It performs higher functions like interpreting touch, vision and hearing, as well as speech, reasoning, emotions, learning, and fine control of movement.
- The **hypothalamus** ("under the thalamus") is the center for homeostatic control of the internal environment. It receives signals about the state of the body and regulates thirst, appetite, and body temperature. It also controls sex drive and is an endocrine gland that interacts with the adjacent pituitary gland.

Thalamus

- The thalamus is superior to the hypothalamus and inferior to the cerebrum. The third ventricle is a narrow cavity that passes through both the thalamus and hypothalamus.
- Many of the functions of the thalamus are concerned with sensation.
- The **midbrain** acts as a relay station for tracts passing between the cerebrum and the spinal cord or cerebellum.
- The tracts cross in the brain stem so that the right side of the body is controlled by the left portion of the brain, and the left portion of the body is controlled by the right portion of the brain.
- The brain stem also has reflex centers for visual, auditory, and tactile responses.
- The **cerebellum** lies under the occipital lobe of the cerebrum and is separated from the brain stem by the fourth ventricle. It is the largest part of the hindbrain.
- The cerebellum receives sensory input from the eyes, ears, joints, and muscles about the present position of body parts, and it also receives motor output from the cerebral cortex about where these parts should be located.
- After integrating this information, the cerebellum sends motor impulses by way of the brain stem to the skeletal muscles. In this way, the cerebellum maintains posture and balance.
- It also ensures that all of the muscles work together to produce smooth, coordinated voluntary movements. The cerebellum assists the learning of new motor skills such as playing the piano or hitting a baseball.

Medulla (Brainstem)

- The medulla oblongata, pons, and midbrain constitute the **brainstem.**
- The brainstem connects the spinal cord to the remainder of the brain and is responsible for many essential functions.
- The word **pons** means "bridge" in Latin, and true to its name, the pons contains bundles of axons traveling between the cerebellum and commands.
- The rest of the CNS. In addition, the pons functions with the medulla oblongata to regulate breathing rate, and has reflex centers concerned with head movements in response to visual and auditory stimuli.
- The **medulla oblongata** contains a number of reflex centers for regulating heartbeat, breathing, and blood pressure. It also contains the reflex centers for vomiting, coughing, sneezing, hiccuping, and swallowing.

- The medulla oblongata lies just superior to the spinal cord, and it contains tracts that ascend or descend between the spinal cord and higher brain centers.

White and gray matter

- The brain and spinal cord contain gray matter and white matter. **Gray matter** is primarily made up of neuron cell bodies.
- **White matter** consists of bundled axons. In the spinal cord, white matter forms the outer layer, reflecting its role in linking the CNS to sensory and motor neurons of the PNS.
- In the brain, white matter is predominantly in the interior, where signaling between neurons functions in learning, feeling emotions, processing sensory information, and generating

The spinal cord

- The spinal cord has a much simpler structure than the brain.
- It is a tubular structure composed of the nervous tissue that extends from the brainstem and continues distally before tapering at the lower thoracic/upper lumbar region as the conus medullaris (the terminal end of the spinal cord).
- The spinal cord runs out from the brain down the body. The spinal cord is encased and protected by the vertebrae making up the spine.
- The majority of nerves come out of the spinal cord are known as the **spinal nerves.**
- They stretch to the arms, legs, trunk and to the rest of the body (Figure 5.4). In the spinal cord **the grey matter** is located in the middle whereas the **white matter** is found on the outside.
- At regular intervals along the spinal cord there are entrance points for **affector** nerves that bring information into the CNS and exit points for effector nerves carrying instructions from the CNS.

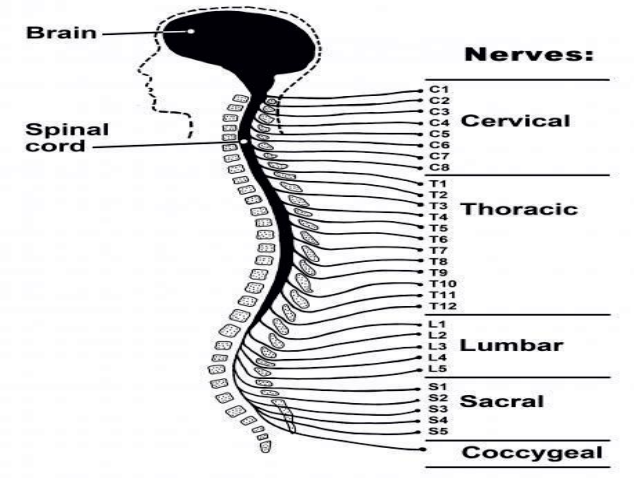


Figure: The spinal cord and spinal nerves

Dura mater: This is the thick outermost covering (meninges) of the brain and spinal cord.

- It is the layers of connective tissue that make up the meninges of the brain (dura, arachnoid, and pia).
- It is the outermost layer of the three meninges that surround and protect the brain and spinal cord

Pia mater: This is the innermost covering of the spinal cord.

- Intimately adhered to its surface, the pia mater stabilizes the spinal cord through lateral extensions of the pia called the denticulate ligaments, extending between the ventral and dorsal roots unto the dura mater.

The Peripheral Nervous System

- The Peripheral Nervous System (PNS) is the division of the nervous system that contain all the nerves that lie outside of the central nervous system.
- The peripheral nervous system is subdivided into the afferent division and the efferent division.
- The afferent division of the PNS carries signals to the CNS and includes all the neurons that transmit sensory information from their receptors.
- The efferent division of the PNS carries signals from the CNS to the muscles and glands, which act as effectors to bring about the desired response.
- In mammals, 31 pairs of spinal nerves carry signals between the spinal cord and the body trunk and limbs, and 12 pairs of cranial nerves connect the brain directly to the head, neck, and body trunk.
- The efferent division of the PNS is further subdivided into the somatic nervous system and the autonomic nervous system.

The Somatic Nervous System

- The somatic system is the part of the PNS that is responsible for carrying out sensory and motor information to and from the central nervous system.
- The somatic nervous system derives its name from the Greek word soma, which means "body."
- The somatic system is responsible for transmitting sensory information as well as for voluntary movement.

The Autonomic Nervous System

- The autonomic system is part of your PNS that is responsible for regulating involuntary body functions, such as blood flow, heartbeat, digestion, and breathing.
- In other words, it is the autonomic system that controls aspects of the body that are usually not

under voluntary control.

- This system allows these functions to take place without the need to consciously think about what is happening. The autonomic system is further divided into two branches:
- **Sympathetic system:** By regulating the 'flight-or-fight' response, the sympathetic system prepares the body to expend energy to respond to environmental threats.
- When action is needed, the sympathetic system triggers a response by accelerating heart rate and increasing breathing rate, boosting the blood flow to muscles, activating sweat secretion, and dilating the pupils.
- **Parasympathetic system:** This helps maintain the normal body functions and conserve physical resources. Once a threat is recognized, this system will slow the heart rate, slow breathing, reduce blood flow to muscles, and constrict the pupils. This allows us to return our bodies to a normal resting state.
- **Parasympathetic system:** This helps maintain the normal body functions and conserve physical resources.
- Once a threat is recognized, this system will slow the heart rate, slow breathing, reduce blood flow to muscles, and constrict the pupils. This allows us to return our bodies to a normal resting state.

5.1.6 Reflex action

- A reflex action is a sudden, automatic and uncontrolled response of parts of the body or the whole body to the external stimuli.
- They are usually involved in helping us to avoid danger or damage. When the body is in danger, it can respond to the situation, without conscious, thought.
- This causes a faster response, preventing or minimizing damage to the body. This is known as reflex action.
- A reflex action is an automatic response to a stimulus.

Reflex Arc

- The parhway of neurons involved in a reflex action is known as reflex arc. Most reflexes follow the same steps between the stimuli and the response. One of the simplest situations where impulses cross synapses to produce action is in the reflex arc.
- A reflex action is an automatic response to a stimulus. (A stimulus is a change in the external or internal environment of an organism.)
- It provides a means of rapidly integrating and co- coordinating a stimulus with the response of an effector (a muscle or a gland) without the need for thought or a decision.

- **A reflex arc** is the pathway that nerve impulses travel when a reflex is elicited, and there are five essential parts:

  1. **Receptors:-** detect a change (the stimulus) and generate impulses.
  2. **Sensory neurons:-transmit** impulses from receptors to the CNS.
  3. **Central nervous system:-**contains one or more synapses (interneurons may be part of the pathway).
  4. **Motor neurons:-transmit** impulses from the CNS to the effector.
  5. **Effector:** -performs its characteristic action.

- In this reflex, a tap on the patellar tendon just below the knee lower leg. This is a stretch reflex, which means that a muscle that is stretched will automatically contract.
- Impulses from a sensory receptor in the skin pass along an affector neuron to the central nervous system - the spinal cord.
- The neuron enters the spinal cord through the dorsal root.
- When an impulse from the affector neuron arrives in the synapse with a short relay neuron a transmitter is released, which causes an impulse to be sent along the relay neuron.
- When the impulse reaches the synapse between the relay neuron and an effector neuron returning to the arm again another transmitter chemical is released.
- This starts impulses travelling along the effector neuron to the organ (effector), which brings about change.
- The effector neuron leaves the spinal cord by the ventral root. In this example the impulses arrive in the muscles of the upper arm, causing them to contract and move your hand upwards sharp
- Some reflexes are important for avoiding injury, but the knee-jerk and ankle-jerk reflexes are important for normal physiological functions. For example, the knee-jerk reflex helps a person stand erect. If the knee begins to bend slightly when a person stands still, the quadriceps femoris is stretched, and the leg straightens.
- The spinal cord has a much simpler structure than the brain. It is a tubular structure composed of the nervous tissue that extends from the brainstem and continues distally before tapering at the lower thoracic/upper lumbar region as the conus medullaris (the terminal end of the spinal cord).
- The spinal cord runs out from the brain down the body. The spinal cord is encased and protected by the vertebrae making up the spine.
- The nerves that originate from the spinal cord are known as the **spinal nerves.** They stretch

to the arms, legs, trunk and to the rest of the body.

- In the spinal cord **the grey matter** is located in the middle whereas the **white matter** is found on the outside.
- At regular intervals along the spinal cord there are entrance points for **affector** nerves that bring information into the CNS and exit points for **effector** nerves carrying instructions from the CNS.
- The key point about a reflex action is that the messages do not reach a conscious area of your brain before instructions are sent out to take action. Many reflexes involve the spinal cord, whereas others involve the brain.
- They involve three types of neuron affector neurons, relay neurons and effector neurons.
- Relay neurons (interneurons with short axons) connect the affector and effector neurons directly in the CNS, without input from other areas. The receptors, neurons and effectors involved are referred to as a **reflex arc.**
- The brain and spinal cord act together as coordinators that process the information coming from sensory receptors and neurons and instruct effector neurons and effectors to react.