NERVOUS SYSTEM OF MAN

Students' learning outcomes
After studying this chapter, students will be able to:

1. [B-12-G-01] Recognize receptors as transducers sensitive to various stimuli.
2. [B-12-G-02] Trace the path of a message transmitted to the CNS (central nervous system) for processing.
3. [B-12-G-03] Identify the three neurons (sensory, intermediate, motor) involved in nervous transmission.
4. [B-12-G-04] Identify muscles and glands as the effectors.
5. [B-12-G-05] Annotate the detailed structure of a sensory neuron, associative and motor neuron.
6. [B-12-G-06] Relate the structure of neurons with functions.
7. [B-12-G-07] Differentiate between myelinated and non-myelinated neurons.
8. [B-12-G-08] Explain the function of the three types of neurons with the help of a reflex arc.
9. [B-12-G-09] Define nerve impulse
10. [B-12-G-10] Describe the generation and transmission of nerve impulse.
11. [B-12-G-11] Name the factors responsible for the resting membrane potential of neuron.
12. [B-12-G-12] Evaluate from a graph the phenomena of polarization, depolarization and hyperpolarization of membrane.
13. [B-12-G-13] Compare the velocities of nerve impulse in the axon membrane and in the synaptic cleft.

14. [B-12-G-14] Describe the role of local circuits in saltatory conduction of nerve impulse.
15. [B-12-G-15] Outline the structure of synapse.
16. [B-12-G-16] Explain synaptic transmission of nerve impulse.
17. [B-12-G-17] Classify neurotransmitters as inhibitory and excitatory and list some common examples.
18. [B-12-G-18] Identify the main components of the nervous system.
19. [B-12-G-19] Explain briefly the major parts, functions of major divisions of the brain and its functions of brain.
20. [B-12-G-20] Describe the architecture of human brain.
21. [B-12-G-21] Describe cranial and spinal nerves in man.
22. [B-12-G-22] Explain the structure types and functions of the autonomic nervous system.
23. [B-12-G-29] Explain the structure and functioning of the receptors for smell, taste, and touch/pain.
24. [B-12-G-30] Define narcotic drugs as agents that interact with normal nervous activity.
25. [B-12-G-31] Compare the use and abuse of drugs with respect to heroine, *Cannabis*, nicotine, alcohol and inhalants like nail polish remover and glue.
26. [B-12-G-32] Explain the terms drug addiction and drug tolerance with reference to caffeine and nicotine and their adverse effects.
27. [B-12-G-33] Associate the effects of drug addiction and tolerance with the functioning of the nervous system.
28. [B-12-G-34] Describe the way how pain medicines can reduce or numb pain in the human body.
29. [B-12-G-35] Discuss that certain pain medications are addictive.
30. [B-12-G-36] Classify nervous disorders into vascular, infectious, structural, functional and degenerative disorders.
31. [B-12-G-37] Describe the causes, symptoms and treatment of one type of each category of disorders outlined above (e.g., stroke as vascular, meningitis as infectious, brain tumor as structural, headache as functional, and Alzheimer disease as degenerative disorder).
32. [B-12-G-38] Explain the principles of important diagnostic tests for nervous disorders i.e., EEG, CT scan and MRI.

The body of an animal is frequently exposed to variety of stimuli in its daily life. For an appropriate response to a particular stimulus, usually more than one body parts are involved, their activities are coordinated either by nervous system or endocrine system or both. The system of the body that provides coordination through electric signals among different body parts for the response to a particular stimulus is called **nervous system**. Human nervous system is the most evolved among all the animals. The study of the structure and functions of the nervous system is called **neurology**. The term neurology comes from a combination of two words, "neuron" meaning nerve and "logia" meaning "the study of". Nervous coordination in higher animals consists of three basic steps i.e., reception of stimulus, processing/analysis of information and response to stimulus.

5.1 RECEPTORS ARE TRANSDUCERS

A transducer is an electronic device that converts energy from one form to another. A cell that responds to a stimulus is called a **receptor cell**. Receptor cells are **transducers**. They convert energy from one form such as light, heat or sound into energy in an electrical impulse (electrochemical energy) within a sensory neuron. So receptors are transducers sensitive to various stimuli.

Receptors are biological transducers that convert energy from both external and internal environments into electrical impulses. They may be massed together to form a sense organ, such as the eye or ear, or they may be scattered, as are those of the skin and viscera.

5.2 PATH OF A MESSAGE TRANSMITTED TO THE CENTRAL NERVOUS SYSTEM

Sensory information travels from the body to the spinal cord before reaching the brain.

First order neuron(sensory neuron): The first-order neuron is the initial neuron in a sensory pathway that transmits sensory information from the periphery (like skin, muscles, or organs) to the central nervous system (CNS). The primary role of first order neuron is to detect stimuli (e.g., touch, pain, temperature) and relay that information to the second-order neuron, usually located in the spinal cord or brainstem.

Second-order neuron (interneuron): It receives input from the first-order neuron and typically transmits the information to higher brain centers (such as the thalamus). It is usually located in the spinal cord or brainstem, depending on the specific sensory pathway. The second-order neuron processes the information received from the first-order neuron and may integrate it with other sensory inputs before relaying it to the third-order neuron or directly to the brain regions involved in perception. In the pain pathway, the second-order neuron may be located in the dorsal horn of the spinal cord, where it receives signals from the first-order neurons and then projects to the thalamus.

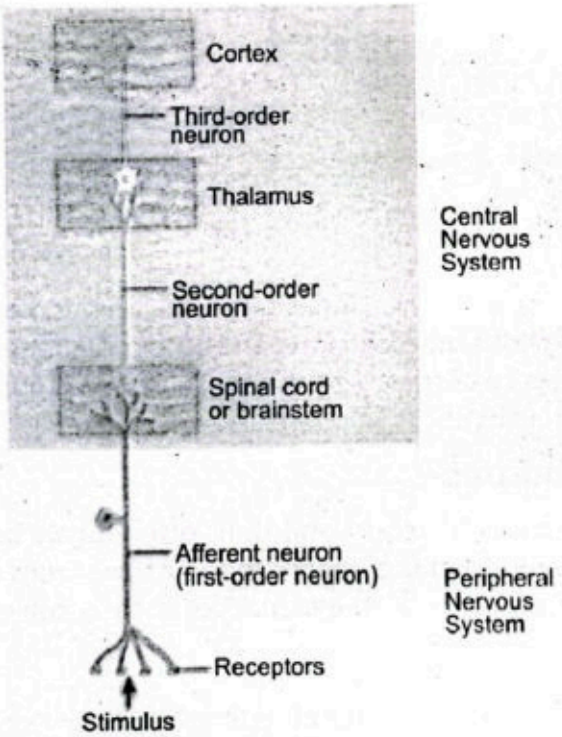

Fig. 5.1: Pathway of message transmitted to the CNS

Third order neuron: The third-order neuron picks up these impulses from the thalamus and relay them to the somatosensory portion of the cerebrum. Somatosensory sensations are pressure, pain, temperature and the body's senses.

5.3 NEURON

Nervous coordination mainly comprises highly specialized cells called **neurons** (new-ronz). Neurons are the basic structural and functional unit of the nervous system.

5.3.1 Structure of Neuron

Although neurons vary considerably in size and shape, they all have three basic components: a cell body, dendrites and an axon.

Cell body

The cell body is the main part of a neuron. It contains a mass of granular cytoplasm and cell

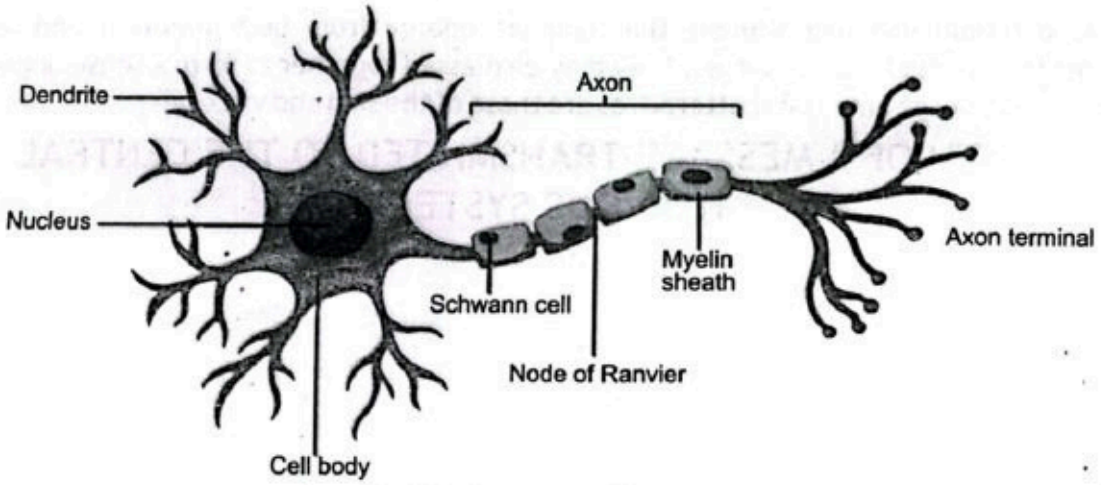

Fig. 5.2: Structure of neuron

membrane. The single large nucleus is centrally placed with a prominent nucleolus. Golgi apparatus, mitochondria and other organelles are present. The cytoplasm is characterised by the presence of **Nissl's granules**. These are group of ribosomes and rough ER associated with protein synthesis.

Dendrites

Dendrites are short and thin, often highly branched cytoplasmic extensions that are gradually tapered from their bases to their tips. Axons of other neurons form synapses with the dendrites. The function of the dendrite is to receive stimuli and conduct impulses to the cell body.

Axon

An axon is comparatively a long and thick nerve fibre which has a constant diameter and can vary in size from a few mm to more than a metre length. It may be branched or un-branched. Axons terminate by branching to form small extensions with enlarged ends called **presynaptic terminals**. Functionally, axons conduct action potentials from the neuron cell body to the presynaptic terminals, i.e., conduct signal (information) away from the cell body.

5.3.2 Types of neuron

All neurons vary somewhat in size, shape and characteristics depending on the function and role of the neuron. Based upon the function there are three types of neurons.

Sensory Neurons: The sensory neurons convert signals received from the environment into corresponding stimuli. The sensory inputs activate the sensory neurons and carry sensory information to the brain and spinal cord. They are pseudo-unipolar in structure.

Motor Neurons: These are multipolar and are located in the central nervous system extending their axons outside the central nervous system .This is the most common type of neuron and transmits information from the brain to the effector (muscles or gland) of the body.

Interneurons: They are multipolar in structure. Their axons connect only to the nearby sensory and motor neurons. They help in passing signals between two neurons.

Do you know?

Interneurons are also called, relay neurons, association neurons, connector neurons, intermediate neurons or local circuit neurons.

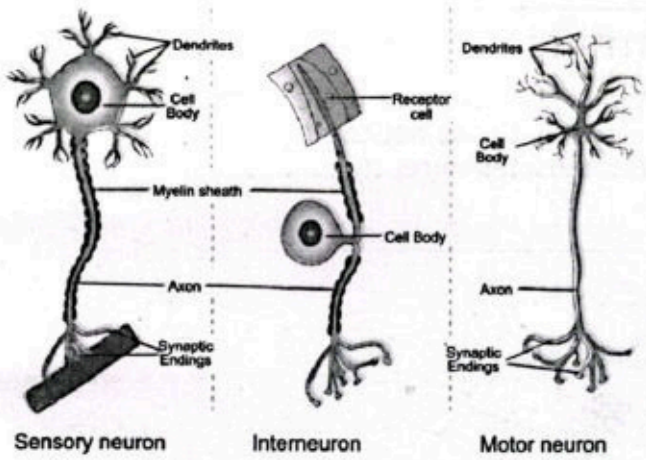

Fig. 5.3: Types of neuron based on function

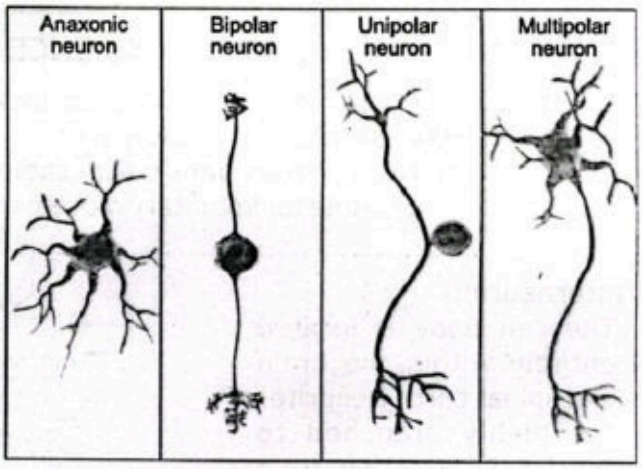

Fig. 5.4: Types of neuron based on structure

5.3.3 Effectors

The two examples of effectors are muscles and glands. The nervous system responds by sending signals to muscles and glands. The signals cause muscles to contract. The signals cause glands to produce secretions. Muscles and glands are called effectors because they cause an effect in response to directions from the nervous system.

5.3.4 Detailed structure of a sensory neuron, associative and motor neuron

a. Sensory neurons (Afferent neurons)

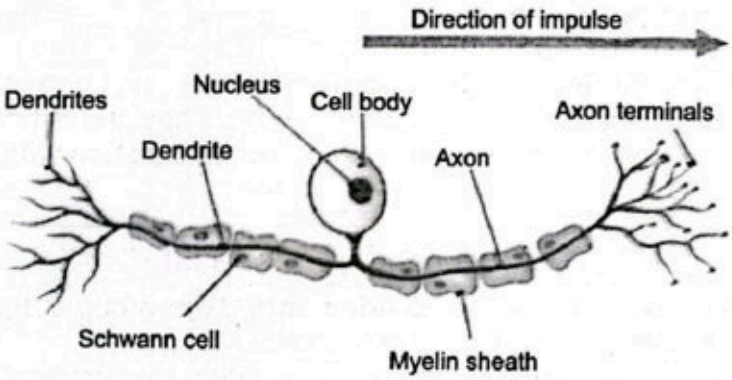

Fig. 5.5: Sensory neuron

The **cell body** or soma is located in the dorsal root ganglion outside the CNS. Sensory neurons have often their cell bodies close to the spinal cord. **Dendrites** are specialized extensions receive signals from sensory receptors. They are often long in peripheral sensory neurons. The **axon** extends from the sensory receptors to the CNS. In some cases they may be myelinated to speed up the signal transmission. Most sensory neurons are unipolar, having a single elevated process that branches into two. One branch connects to the sensory receptors and the other branch connects to the CNS. The signal pathway starts from the sensory receptor, moves along the axon and reaches the spinal cord or brain where further processing occurs.

b. Motor neurons (Efferent neurons)

The **cell body** is located in the spinal cord (for lower motor neurons) or in the brain's cortex (for upper motor neurons). Motor neurons have many **dendrites** that receive inputs from interneuron and other neurons. The **axon** is long and often myelinated to allow rapid signal transmission from CNS to the muscles or glands. Most motor neurons are multipolar. Motor neurons transmit signals from CNS to muscles and glands, allowing for movement and glandular response.

SCIENCE TITBITS

The upper motor neurons are located in the cortex of brain. They send signals to the lower motor neurons in the spinal cord. Lower motor neurons innervate skeletal muscles directly and are responsible for voluntary movement.

c. Interneurons

The cell body is located entirely within the brain and spinal cord. Dendrites are highly branched to receive information from multiple neurons making them important for processing complex information. Their axons are generally short and unmyelinated, as they primarily transmit signals locally within CNS. Interneuron is often multipolar, which allows them to communicate simultaneously. Interneuron serves as connectors between sensory and motor neuron. They are critical in reflexes, neural processing and communication with the CNS.

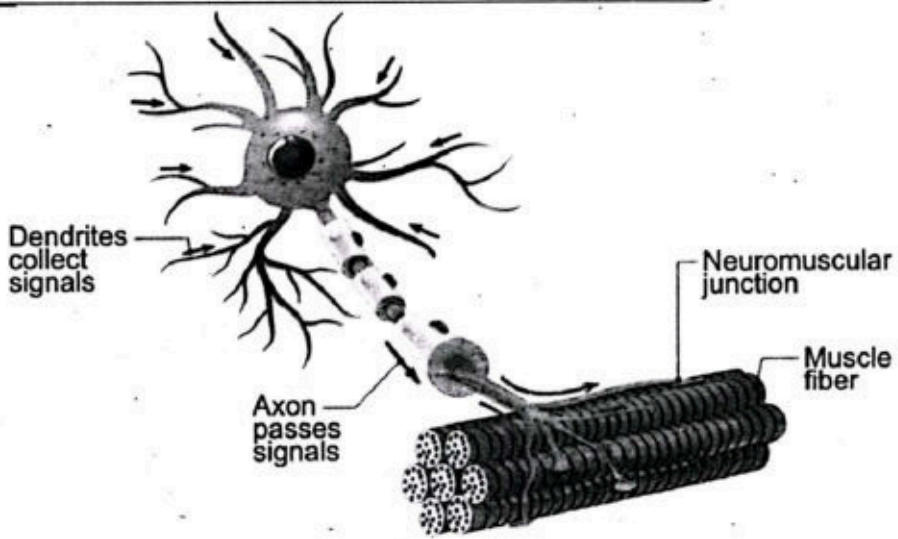

Fig. 5.6: Motor neuron

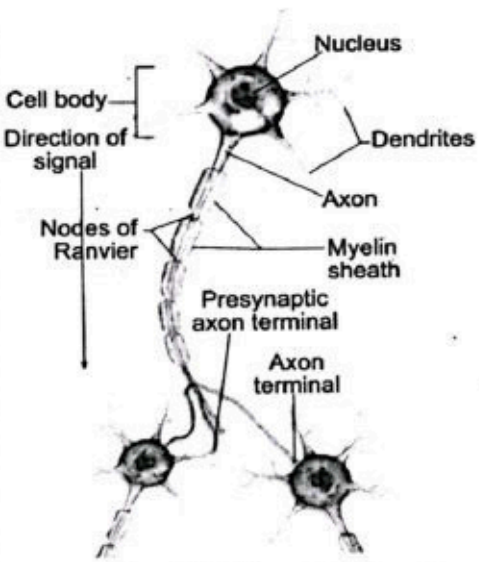

Fig. 5.7: Interneuron

Extra reading material

Interneuron can be divided into two groups: local interneuron and relay interneuron.

Local interneuron has short axons and form circuits with nearby neurons to analyze small pieces of information.

Relay interneurons have long axons and connect circuits of neurons in one region of the brain with those in other regions. The interaction between interneurons allows the brain to perform complex functions such as learning, and decision-making. Interneurons are multipolar nerve cells, meaning that they have more than one dendrite.

5.3.5 Relate the structure of neurons with functions

The structure of each type of neuron is intricately designed to support its specific function within the nervous system, ensuring efficient communication and response mechanisms

To understand how the structure of each type of neuron relates to its function in the nervous system, we can describe the characteristics of motor neurons, sensory neurons, and interneurons as follows:

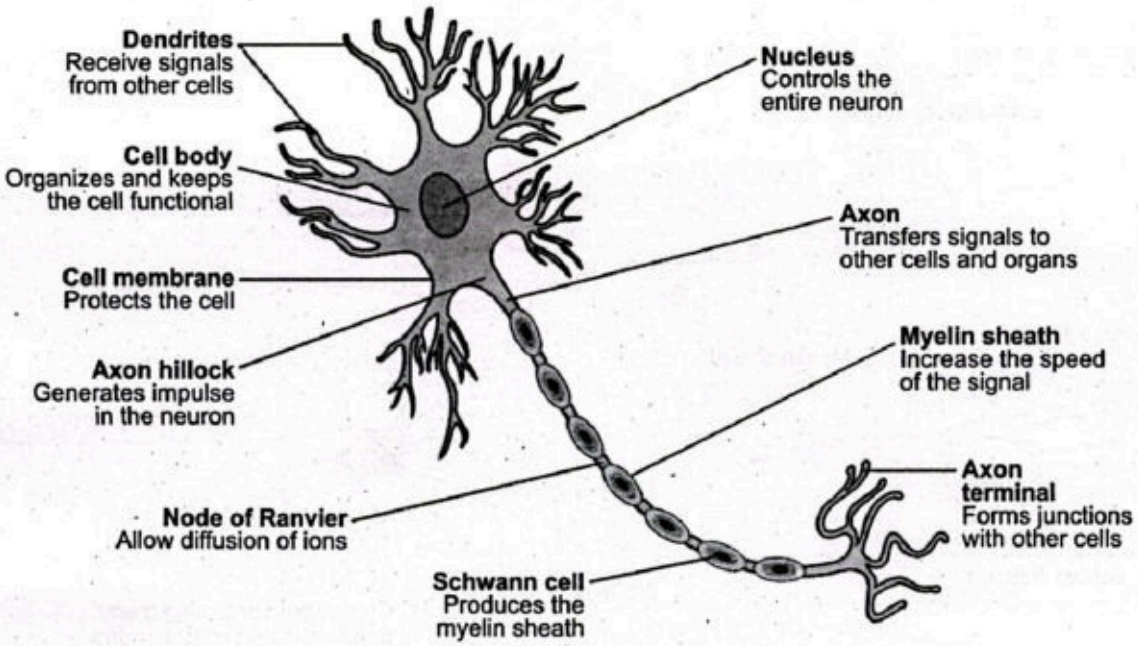

Fig. 5.8: Parts of a neuron with functions

Motor Neurons: These neurons have long axons, which are essential for covering the considerable distances between the central nervous system and target muscles or organs. The axons are myelinated, which enhances the speed of signal transmission, allowing for rapid communication necessary for quick muscle responses

Sensory Neurons: They possess long dendrites and axons, which are vital for receiving signals from sensory receptors and transmitting them over distances to the central nervous system. Sensory neurons are myelinated and often located in ganglia, which are clusters of neuron cell bodies. This arrangement aids in processing sensory information and contributes to reflex actions

Interneurons: They are generally shorter than both motor and sensory neurons, which are suitable for their role in local processing .Interneurons, have numerous branches of axons and dendrites, allowing them to form multiple connections with other neurons. Their partial myelination and clustering in large groups help to enhance the speed of signal transmission despite their shorter length.

Table 5.1 Comparison between three types of neuron

Neuron type	Function	Structure	Location
Sensory neuron	Transmit sensory information to CNS	Unipolar, with long axon, cell body in dorsal root ganglia.	Sensory organs to CNS.
Motor neuron	Transmit motor commands from CNS to muscles.	Multipolar, long, neuron, neuromuscular junction. junction	CNS to muscles/ glands
Interneuron	Relay signals between sensory and motor neuron; involved in processing information	Multipolar short axon, highly branched dendrites.	CNS (brain and spinal cord)

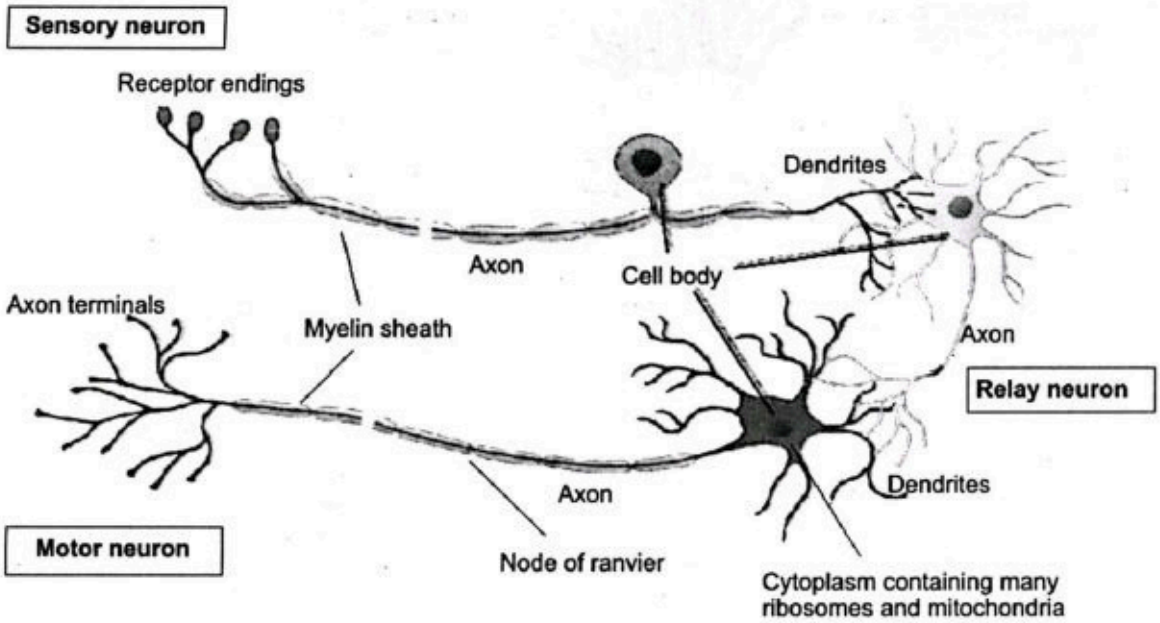

Fig. 5.9: Relationship between three types of neuron

5.3.6 Differences between myelinated and non-myelinated neurons

The axons may be categorized into myelinated (with sheath) and non-myelinated (without sheath). The myelinated fibers are present in the white part of the brain and also in the spinal cord, while the non-myelinated nerve fiber is present in the autonomic nervous system. Myllinated axons tend to be larger in diameter than the non-mylinated axons.

Table 5.2 Difference between myelinated and non myelinated neuron

Myelinated neuron	Non myelinated neuron
They possess myelin sheath.	These do not possess myelin sheath.
The Schwann cells shows wrapping around the nerve axon.	The Schwann cells do not show wrapping but are only present in the groove.
This shows two sheaths in the axis of the cylinder.	This shows only one sheath in the axis of the cylinder.
These transfer nerves impulses very fast.	These transfer nerve impulses very slow.
These appear white in their fresh form.	These appear grey in their fresh form.
They possess nodes and internodes.	These do not possess nodes and internodes.
Nodes of Ranvier are known to present in these neurons.	Nodes of Ranvier are not present in these.
Collateral fibres are produced.	Collateral fibres are not produced.

5.4 REFLEX ARC

Reflex action is an immediate, automatic and involuntary response to external and internal environmental changes. The path of the nerve impulse during reflex action is called reflex arc.

Example

A typical reflex arc includes five fundamental parts: receptors, sensory neurons, interneuron, motor neuron and effectors. For example if one unexpectedly touches a hot object, the hand is rapidly removed from the source of heat. **Receptors** in the skin of the hand are activated by the heat of the object. The receptors stimulate a **sensory neuron** leading to the spinal cord via a spinal nerve. The cell body of the sensory neuron is outside the cord. The sensory neuron enters a **dorsal nerve root** of the spinal cord. The impulse then crosses a synapse to an **interneuron** which lies completely within the cord.

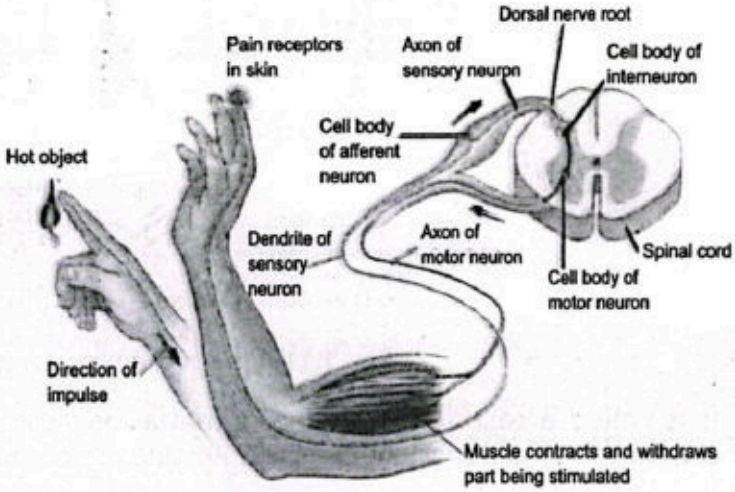

Fig. 5.10: A reflex arc

The impulse travels along the interneuron and then passes across a synapse to the dendrites and the cell body of a **motor neuron** which lies within the spinal cord. The motor neuron eventually branches to form synapses with several muscle cells i.e., an effector. The nerve impulses then move along the motor neuron to the muscles, which cause them to contract.

5.5 NERVE IMPULSE

Nerve impulse is information or signal about a stimulus that is transmitted from receptors to the CNS and from CNS to the effectors. In technical terms a nerve impulse can be defined as a wave of electrochemical changes that travel along the length of neuron, from one end to the other.

5.5.1 Generation and Transmission of Nerve Impulse

Here, word "electrochemical" refers to the electrical potential (a capacity to do electrical work) that exists on neuron membrane. In case of neuron the electrical potential is termed as membrane potential which is exhibited in two different forms i.e., Resting Membrane Potential (RMP) and Active Membrane Potential (AMP).

5.5.2 Resting membrane potential

It is characterized by more positive outer surface of neuron membrane than inner surface. This state is also referred as **polarized** state and the neuron is supposed to be at rest. This means that there is an unequal distribution of ions on the two sides of the nerve cell membrane. This potential generally measures about 70 mV (with the inside of the membrane negative with respect to the outside). So, the resting membrane potential is expressed as -70 mV, and the minus sign indicates that the inside is negative relative to (or compared to) the outside.

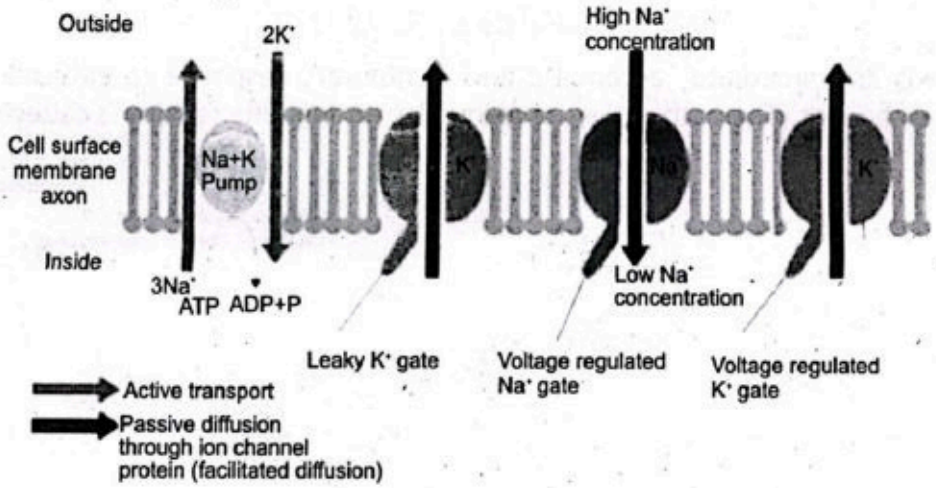

Fig. 5.11: Ionic movement across neuron membrane

It is called a resting membrane potential because it occurs when a membrane is not being stimulated or conducting impulses. Resting membrane potential is established by the following factors:

Distribution and active movement of Na^+ and K^+ ions

The concentration of potassium (K^+) is 30 times greater in the fluid inside the neuron cell than outside and the concentration of sodium ions (Na^+) is nearly 10 times greater in the fluid outside the cell than inside. These ions are continuously moved against their concentration gradient through sodium-potassium pumps by the expenditure of energy. For every two K^+ that are actively transported inward, three Na^+ are pumped out. So inside becomes more negative than outside of the neuron membrane.

Negative organic ions

There are many types of organic compounds in the neuron cytoplasm that also have negative charges. These ions include some amino acids, many proteins and RNA. Presence of these ions in the neuron cytoplasm makes inside of neuron more negative than outside.

Leakage of K^+ ions

Cell membrane of neuron also has many channel proteins called **gates**. K^+ ions leak continuously through leaky K^+ gates. This also makes more positive outside of neuron than inside.
Overall there are more positive charges on the outside than on the inside. This is known as **resting membrane potential**. This potential will be maintained until the membrane is disturbed or stimulated by a sufficiently strong **stimulus** (threshold), then action potential will be produced.

5.5.3 Active membrane potential

Active membrane potential (also called action potential) is characterized by more positive inside of neuron than outside (depolarized state). This happens when positive charges tend to move inside of neuron on receiving a particular stimulus. This electrochemical change appears on a short region of neuron for a brief period of time followed by the recovery of **polarized state.** In this way a wave of action potential begins to move towards other end of neuron. Action potential is established by the following factors.

Threshold stimulus

If a stimulus is capable to produce action potential in neuron, it is called **threshold stimulus**. If stimulus is not capable to excite or fails to arise any response, it is called **sub threshold stimulus**.

Influx of Na^+ ions

When a neuron fibre is stimulated by threshold stimulus, it causes the opening of voltage regulated Na^+ gates. As a result Na gates permit the influx of Na^+ ions by diffusion. Since there are more Na+ ions entering than leaving, the electrical potential of the membrane changes from –70 mV towards zero and then reaches to the 50 mV. This reversal of polarity across two sides of membrane is called **depolarization**. This electropositivity inside and electronegativity outside lasts for about one millisecond till the Na+ gates are not closed.

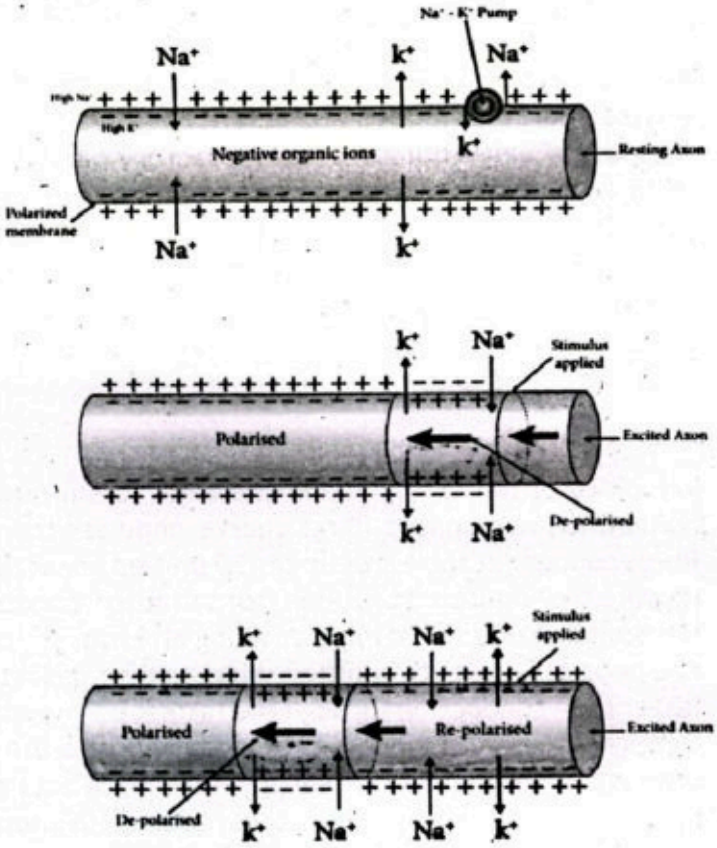

Fig. 5.12: Conduction of nerve impulse

Repolarization of neuron fibre

A fraction of second after the sodium gates open, depolarization of the axon membrane causes potassium gates to open. Potassium therefore diffuses out of the cell. Since the potassium is positively charged, this makes the inside of the cell more negative and starts the process of **repolarization**.

Hyper-polarization (More K^+ ions are on the outside than Na^+ ions on the inside)

At the peak of the action potential, the sodium gates start to close again. Sodium permeability therefore declines. The sodium-potassium pump continues to work during this time, so it gradually begins to restore the original resting potential. This repolarization is shown by the falling phase of the action potential spike and results in the membrane potential returning to its original level. In fact, there is a slight overshoot into a more negative potential than the original resting potential. This is called **hyperpolarization**. It is due to the slight delay in closing all the potassium gates compared with the sodium gates. As potassium ions continue to enter the axon their positive charge restores the normal resting potential.

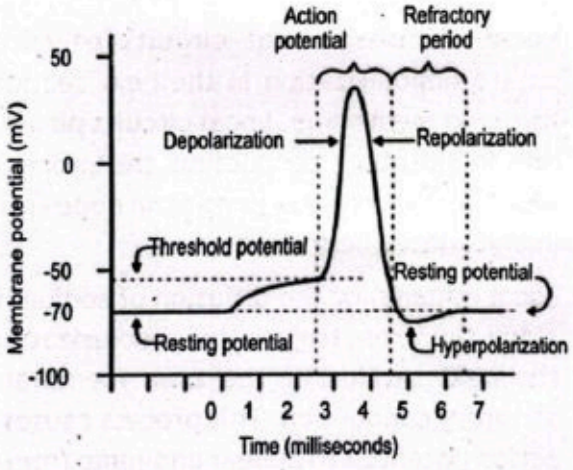

Fig. 5.13: Action potential in a neuron

Refractory period

After an action potential, nerve fibre undergoes a period of recovery in which it regains its original ionic distribution and polarity and prepares itself for the next stimulation. This period of recovery of nerve fibre is called **refractory period**. Although a repolarised neuron fibre has same polarity as that of a polarized neuron fibre but has different ionic distribution. It has more K^+ outside and more Na^+ inside. So the repolarised nerve fibre undergoes a refractory period of few milliseconds during which the original ionic distribution is restored by sodium-potassium pump which actively transports Na^+ ions out and K^+ ions in. This returns the membrane to its resting potential i.e., -70mV. Refractory period lasts for about 4 milliseconds so a neuron can conduct 250 impulses per second.

5.5.4 Velocities of Nerve Impulse

Velocities of nerve impulse in the **axon membrane** and in the **synaptic cleft** are variable. In human non myelinated fibres, nerve impulses travel at 1 to 3 metres per second. Myelinated fibres conduct at speeds of up to 120 meters per second. The velocity of nerve impulse is faster in myelinated neuron fibre due to saltatory conduction. **Saltatory conduction** is the rapid transmission of a nerve impulse along an axon, resulting from the action potential jumping from one node of Ranvier to another, skipping the myelinated regions of membrane. It is up to 50 times faster than conduction through the fastest unmyelinated axons because they don't have to travel throughout every single space before moving to the next. Another reason that myelinated fibres conduct faster impulse is that myelin sheath acts as an insulating sheath and prevents loss of energy, so myelinated neuron fibres require less energy.

Velocity of nerve impulse also depends upon diameter of neuron fibres. Thick neuron fibres conduct faster impulse than thin fibres because resistance to electrical current flow is inversely proportional to the cross sectional area of the conductor, so with the increase in thickness of neuron fibres there is decrease in resistance of fibre to nerve impulse. The short journey across the synapse takes about a millisecond, longer than a nerve impulse takes to travel the same distance. This time is therefore called **synaptic delay**.

5.5 Role of local circuits in saltatory conduction

Local circuits: Local circuits of current create depolarization in the next section of the axon membrane. Local circuits play a key role in saltatory conduction, the process by which nerve impulses jump from node to node in myelinated nerve fibers.

Local circuits, or the diffusion of sodium ions along the axon, trigger the depolarization of the next section of the axon membrane in saltatory conduction. This process causes the action potential to appear and jump from one node of Ranvier to the next.

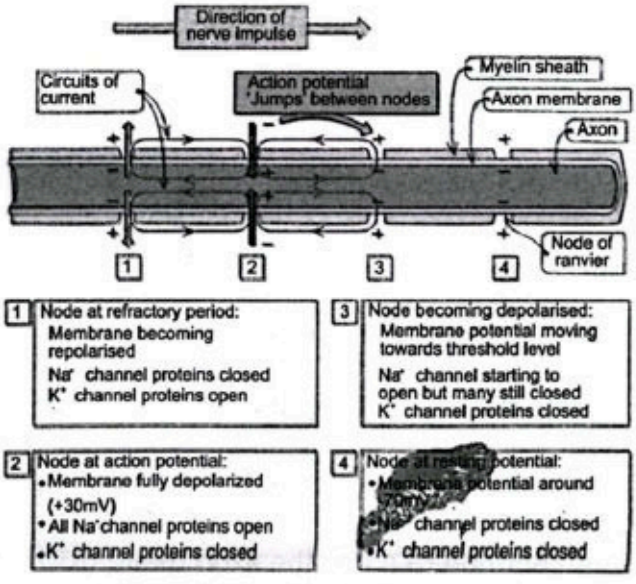

Fig. 5.14: Synaptic transmission

5.6 SYNAPSE

The junction between axon terminal of one neuron and the dendrite of another neuron, where information from one neuron is transmitted or relayed (handed over) to another neuron is called **synapse** (si-napse).

5.6.1 Structure of Synapse

The neurons are not in direct contact at a synapse. There is a gap, called a **synaptic cleft** between them. A single neuron may form synapses with many incoming fibres of different neurons. A neuron which carries an impulse toward a synapse is called **presynaptic neuron.** A neuron which receives the impulse after it crosses the synapse is a **post synaptic neuron.**

5.6.2 Mechanism of Synaptic transmission of nerve impulse

The movement of impulse across the synapse is called a **synaptic transmission.** It takes place in the formation of a message which is transmitted across the synapse in the form of chemical messenger called **neurotransmitter.** The axons usually have several rounded **synaptic knobs** at their distal ends, which dendrites lack. These knobs contain numerous membranous sacs, called **synaptic vesicles** and when a nerve impulse reaches a knob, some of the vesicles respond by releasing a neurotransmitter. Fig: 15.4 and 15.5 shows the following numbered sequence: (1) An action potential (red arrow) arrives at the synaptic knob. Calcium channels open in the presynaptic membrane. As the calcium ion concentration inside the bulb is lower than the outside, calcium ions rush in. As the calcium concentration increases, synaptic vesicles move towards the membrane. (2) The neurotransmitter vesicles fuse with the plasma membrane of the transmitting cell. (3) The fused vesicles release their neurotransmitter molecules (green) into the synaptic cleft. (4) The released neurotransmitter molecules diffuse across the cleft and bind to receptor molecules on the postsynaptic cell surface membrane. (5) Binding of neurotransmitters to the post synaptic neuron receptors opens some channels and allows Na+ ions to diffuse across the post synaptic membrane. As a result post synaptic membrane depolarizes and an action potential is generated. Since this depolarization brings the membrane potential towards threshold level, it is called **excitatory postsynaptic potential (EPSP).** (6) Once the neurotransmitters have acted on the postsynaptic membrane, they are immediately broken down by enzymes, like acetylcholine is hydrolyzed by acetylcholinesterase and adrenalin by monoamine oxidase.

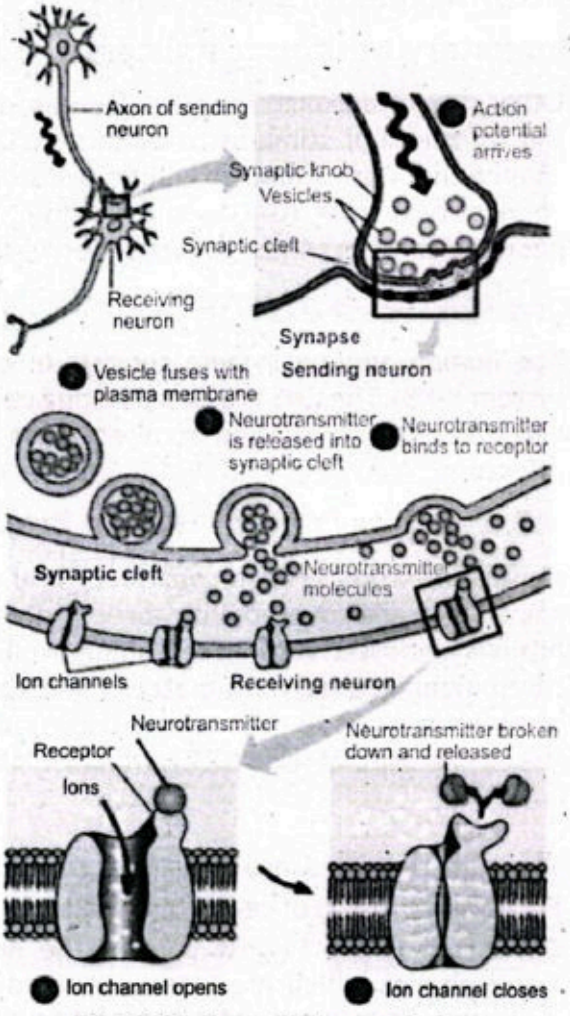

Fig. 5.15: Synaptic transmission

SCIENCE TITBITS

In electrical impulses, which are specialized for rapid signal transmission, the cells are separated by the synaptic cleft of only 0.2 nm, so that an action potential arriving at the pre-synaptic side of cleft, can sufficiently depolarize the post synaptic membrane to directly *trigger* its action potential.

5.6.3 Classifications of Neurotransmitters

Neurotransmitters are classified as excitatory and inhibitory.

Excitatory Neurotransmitters

Neurotransmitters that cause increased membrane permeability to sodium ions and, thus, trigger nerve impulses are said to be **excitatory**. **Acetylcholine** is an excitatory neurotransmitter of peripheral nervous system whereas **biogenic amines** (amino acid derivatives) are important neurotransmitters in central nervous system. They include epinephrine, norepinephrine, serotonin and dopamine, all of which also function as hormones. **Epinephrine** and **norepinephrine** increase the heartbeat rate during stress. **Serotonin** and **dopamine** affect sleep, mood, attention and learning.

Inhibitory Neurotransmitters

Other neurotransmitters cause decreased membrane permeability to sodium ions, thus causing the threshold of stimulus to be raised. This action is called **inhibitory**; because it lessens the chance that nerve impulse will be transferred to an adjoining neuron e.g., amino acids gamma-aminobutyric acid (GABA) and glycine. The **endorphins** are peptides that function as both neurotransmitters and hormones, decreasing our perception of pain.

5.7 MAIN COMPONENTS OF NERVOUS SYSTEM

The human nervous system consists of central nervous system (CNS) and peripheral nervous system (PNS). The CNS is a coordinating centre and it lies in the midline of the body, whereas, the PNS transmits information from receptors to CNS and transmits orders and commands from CNS to effectors.

5.7.1 Architecture of Human Brain and Spinal Cord and their Functions

Central nervous system consists of brain and spinal cord, and both are hollow. The brain and spinal cord are covered with three protective membranes called **meninges** (singular: meninx). Brain is enclosed within the cranium while spinal cord is enclosed within vertebral column. The three meninges are **dura matter** (next to the cranium), **arachnoid matter** (middle membrane) **pia matter** (next to the nervous tissue). Between the arachnoid and pia matter there is a fluid, the **cerebrospinal fluid** (CSF), which helps to cushion the brain from shock.

The Brain

The brain is divided into three part, forebrain, midbrain and hindbrain.

Forebrain consists of cerebrum, thalamus and limbic system.

Cerebrum is the largest part of the human brain. Cerebrum is divided into two **cerebral hemispheres** which are interconnected with each other by a band of axons, called **corpus callosum**. Each hemisphere contains four surface lobes: frontal, parietal, temporal and occipital lobe.

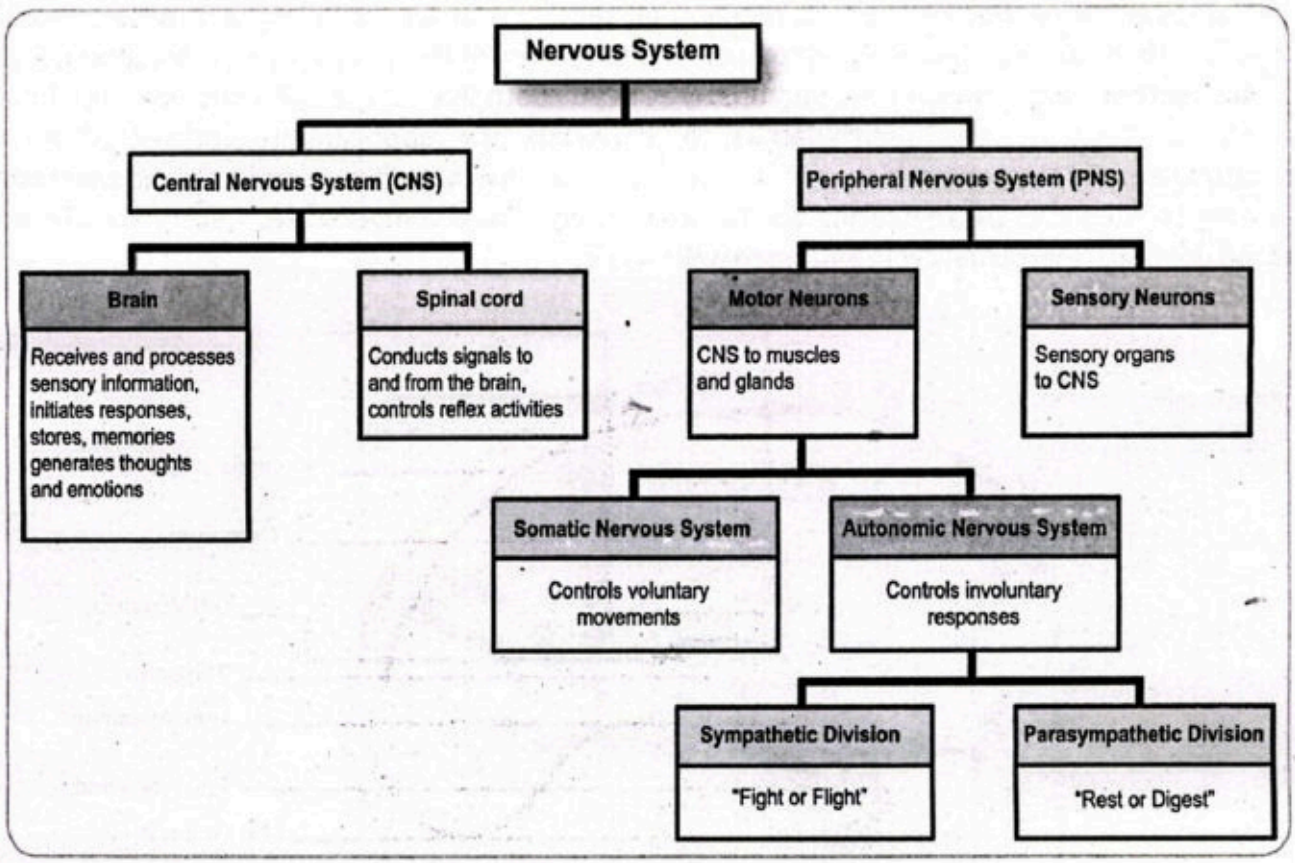

Fig. 5.16: Organization of human nervous system

SCIENCE TITBITS

The surface of the cerebrum is called cerebral cortex. Cerebral cortex has many folds or convulsions forming ridges or gyri (singular, gyrus) which are separated by grooves. A shallow groove is called a sulcus (plural, sulci) and a deep groove is called a fissure. The two hemispheres are separated by longitudinal fissure.

Each lobe further contains different functional areas e.g., auditory (hearing) visual area etc. Each functional area consists of three sub-areas i.e., sensory area, association area and motor area. **Sensory area** receives impulses from different body parts. **Association area** interprets or analyzes the incoming information. The **motor area** controls responses of the body. Cerebrum also functions in the analysis and interpretation of memory, reasoning, judgement, thoughts and dreams.

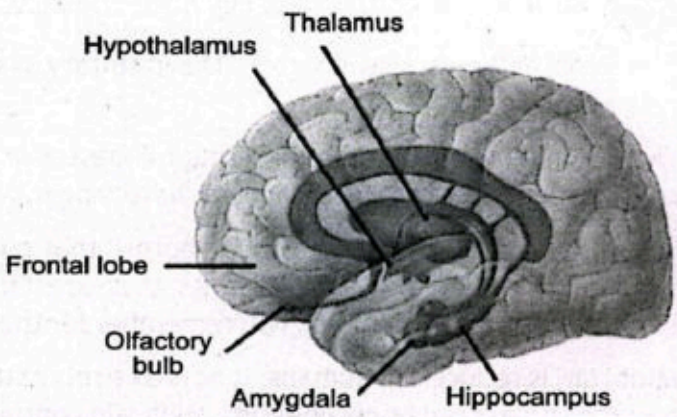

Fig. 5.17: Limbic system

Thalamus is below the cerebrum. It receives all sensory impulses (except sense of smell) and channels them to limbic system and to appropriate regions of the cortex for interpretation. The **limbic system** is a complex set of structures that lies on both sides of the thalamus, just under the cerebrum. It includes the **hypothalamus**, the **amygdala**, the **hippocampus**, and several other nearby areas. On the ventral side of the thalamus is the **hypothalamus**. It maintains homeostasis and contains centres for regulating hunger, sleep, thirst, body temperature, water balance and *blood pressure*, menstrual cycle and sleep wake cycle.

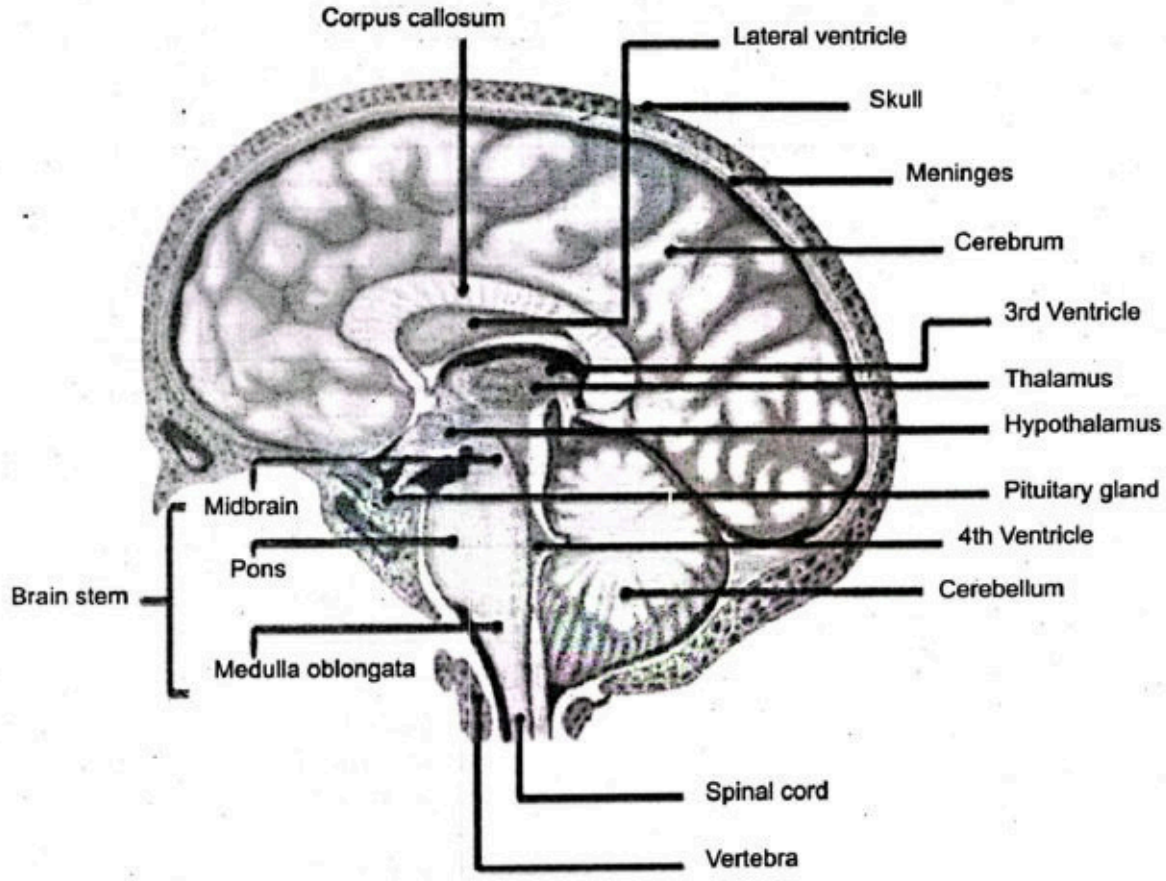

Fig. 5.18: Structure of human brain

The hypothalamus also controls the pituitary gland and thereby serves as link between the nervous and endocrine system.

The **amygdalae** are two almond-shaped masses of neurons on either side of the thalamus. They control feeling and emotions of love, hate, anger, fear, rage and sexual arousal.

The **hippocampus** consists of two "horns" that curve back from the amygdala. It appears to be very important in converting things that are "in your mind" at the moment (in short-term memory) into things that you will remember for the long run (long-term memory).

Midbrain is reduced in humans. It acts as a relay station for tracts passing between the cerebrum and the spinal cord or cerebellum. Midbrain contains reticular formation, which is a relay centre connecting hindbrain with forebrain.

Hindbrain consists of cerebellum, medulla oblongata and pons. **Cerebellum** controls equilibrium i.e., body position and coordination of the actions of individual muscles to produce complex activities such as walking, running, riding bicycles, doing delicate work with hand. The cerebellum is also involved in learning memory storage for behaviour. **Pons** acts as a bridge between the cerebellum, medulla and cerebrum. It also controls rate and pattern of heartbeat and breathing. **Medulla** controls the automatic functions of the body, such as heartbeat, blood pressure, respiration, swallowing etc.

Brain is hollow structure as it has cavities called **ventricles**. There are four ventricles in the brain.

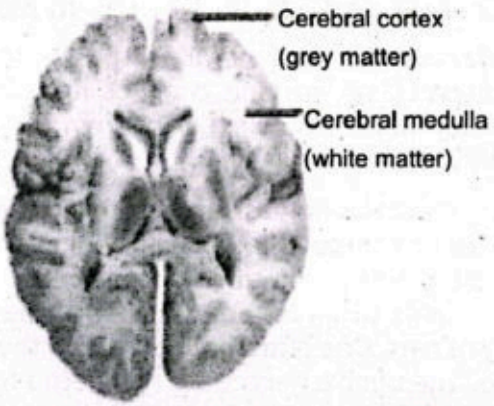

Fig. 5.19: Cross section view of brain

Spinal cord

The spinal cord is the most important structure between the body and the brain. The spinal cord extends from the medulla to the level of the lumbar vertebrae. It is a vital link between the brain and the body. A transverse section of the adult spinal cord shows white matter in the periphery, grey matter inside and a tiny central canal filled with CSF at its centre. **Grey matter** is shaped like the letter "H" or a "butterfly".

The grey matter consists of neuron cell bodies and nonmyelinated parts of the fibres. The **white matter** is made up of bundles of myelinated fibres. Several pairs of spinal nerves originate from ventral and dorsal horn of grey matter. Dorsal root of spinal nerves, also contain ganglia present just beside the spinal cord. Arrangement of grey and white matter in brain is opposite to that of spinal cord.

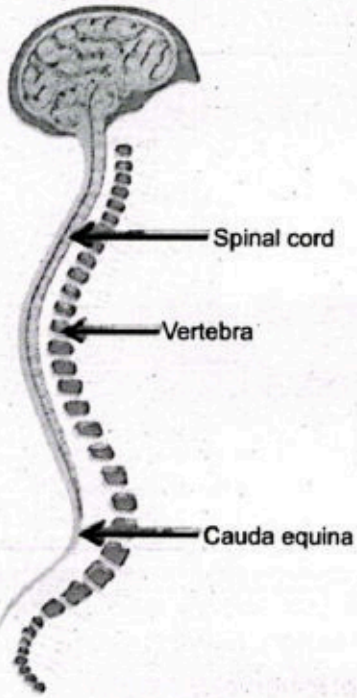

Fig. 5.20: Spinal cord elongated view

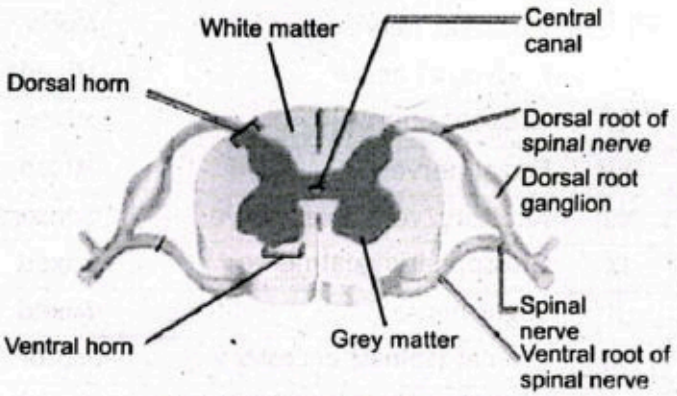

Fig. 5.21: Spinal cord anatomy

5.7.2 Cranial and Spinal Nerves in Man

Cranial Nerves: The peripheral nervous system consists of the nerves that branch out from the central nervous system and connect it to other body parts. The peripheral nervous system includes cranial nerves which arise from the brain and the spinal nerves, which arise from the spinal cord.

A number of cranial nerves send electrical signals between the brain and different parts of the **neck, head** and **torso.** These signals help us to smell, taste, hear and move our facial muscles. The cranial nerves begin toward the back of brain. There are twelve cranial nerve pairs. Each nerve pair splits to serve the two sides of the brain and body. For example, we have one pair of olfactory nerves. One olfactory nerve is on the left side of the brain and one is on the right side of the brain. The twelve nerves are numbered from I to XII using Roman numerals according to the order in which they emerge from the front of the brain to the back of the brain. The twelve cranial nerves each have a specific function. The cranial nerves have been categorized based on number and function.

Extra reading material

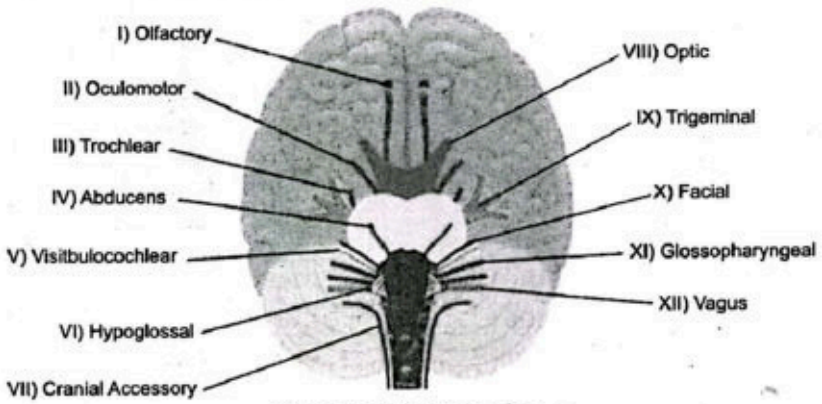

Fig. 5.22: Cranial nerves

Cranial nerves (Extra reading material)			
I	Olfactory nerve	Sensory	Sense of smell
II	Optic nerve	Sensory	Sense of sight
III	Oculomotor nerve	Motor	Movement of eyes.
IV	Trochlear nerve	Motor	Rotation of the eye ball
V	Trigeminal nerve	Mixed	Functioning of the facial parts
VI	Abducens nerve	Mixed	Rotation of the eye ball
VII	Facial nerve	Mixed	Facial expression and sense of taste
VIII	Auditory/vestibular nerve	Sensory	Sense of hearing and balance
IX	Glossopharyngeal nerve	Mixed	Ability to taste and swallow
X	Vagus nerve	Mixed	Digestion and heart rate
XI	Cranial (spinal) accessory	Motor	Shoulder and neck movement
XII	Hypoglossal nerve	Motor	Ability to move tongue

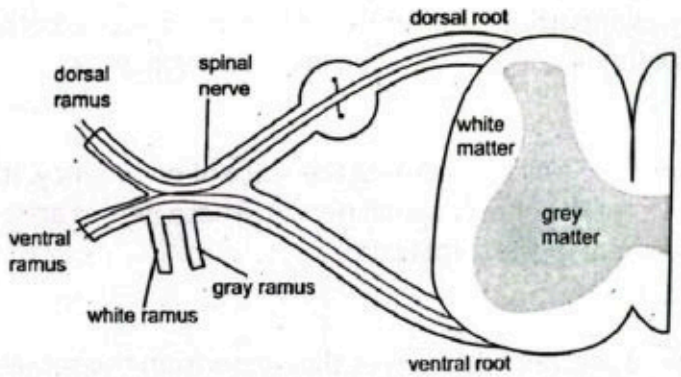

Fig. 5.23: The formation of the spinal nerve from the ventral and dorsal roots

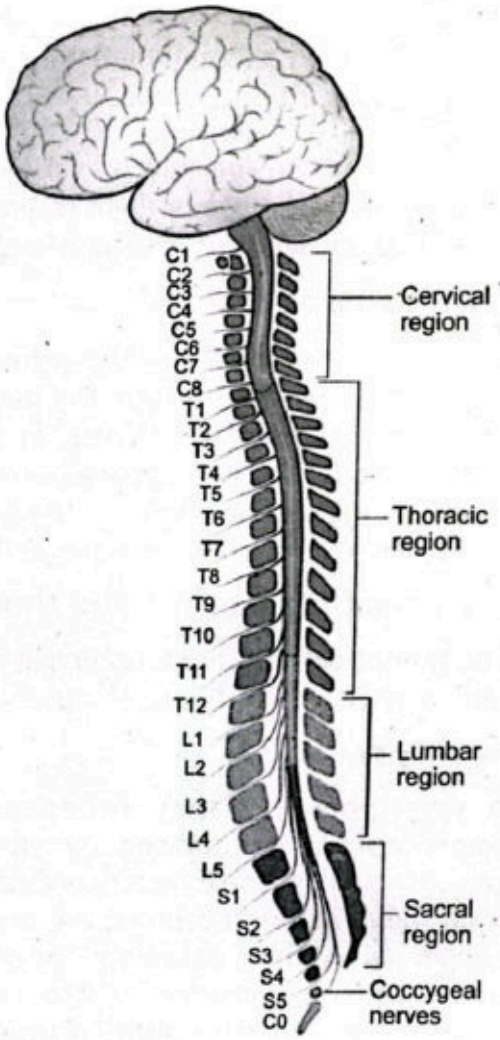

Fig. 5.24: Spinal nerves

Spinal Nerve: A **spinal nerve** carries motor, sensory and autonomic signals between spinal cord and the body. Each spinal nerve is a mixed nerve. It is formed from the combination of nerve root fibers from its dorsal and ventral roots.

There are 31 pairs of spinal nerves one on each side of the vertebral column. These include: Eight cervical nerve pairs (nerves starting in the neck and running mostly to face and head). Twelve thoracic nerve pairs (nerves in the upper body that extend to chest, upper back and abdomen).There are five lumbar nerve pairs (nerves in the low back that run to legs and feet) and five sacral nerve pairs (nerves in the low back extending into the pelvis) and one pair of coccygeal nerves. The spinal nerves are part of the peripheral nervous system.

Outside the vertebral column, the nerve divides into branches. The dorsal ramus contains nerves that serve the posterior portions of the trunk. The ventral ramus contains nerves that serve the remaining anterior parts of the trunk and the upper and lower limbs.

5.7.3 Peripheral Nervous System

The **peripheral nervous system** can also be subdivided into the somatic and autonomic nervous systems.

Somatic nervous system

Generally, the **somatic nervous system** consists of the cranial and spinal nerve fibres that connect the CNS to the skin and skeletal muscles; it is involved in conscious activities.

Autonomic nervous system

The **autonomic nervous system** includes those fibres that connect the CNS to the visceral organs, such as the heart, stomach, intestines and various glands. It is concerned with unconscious

activities. The autonomic system is divided into sympathetic and parasympathetic system. Both of these systems function automatically and usually subconsciously in an involuntary manner.

Sympathetic division

The sympathetic division controls various autonomic functions during the state of emergency. It prepares the body for fight or flight response. It consists of only spinal nerves. These nerves arise from first thoracic segment to second lumber segment of the spinal cord.

Parasympathetic division

A few cranial nerves, including the **vagus nerve**, together with nerves that arise from the sacral portion of the spinal cord, form the **parasympathetic division.** It controls various autonomic functions during the state of rest. In short, the parasympathetic system returns the body functions to normal after they have been altered by sympathetic stimulation. In times of danger, the sympathetic system prepares the body for violent activity. The parasympathetic system reverses these changes when the danger is over.

5.7.4 Sensory Receptors and their Working

The body must detect what is occurring inside and outside the body and is performed by sensory receptors. Here we will discuss receptors for smell, tastes, touch and pain.

Olfactory receptors

The smell or olfactory receptors are chemoreceptors, stimulated by chemicals dissolved in liquids. The olfactory organs, which contain the olfactory receptors, are present in the upper part of the nasal cavity. The olfactory receptor cells are neurons. These cells are surrounded by columnar epithelial cells having cilia at the distal ends. Chemicals that stimulate the olfactory receptors enter the nasal cavity as gases. They must dissolve at least partially in the watery fluids that surround the cilia before they can be detected.

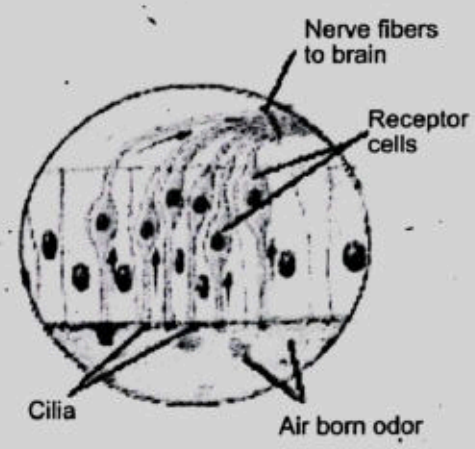

Fig. 5.25: Olfactory receptors in nasal epithelium

Taste receptors

Taste buds occur primarily on the surface of the tongue and are associated with tiny elevations called **papillae**. Each taste bud includes a group of modified epithelial cells, the **taste cells,** which function as receptors. The taste bud has an opening, the **taste pore** on its surface. Tiny projections, called **taste hairs,** protrude from outer ends of taste cells and just protrude through the taste pore. There are four primary taste sensations i.e., sweet, sour, salty and bitter, which are situated at various regions on the tongue. All the four regions overlap at certain places.

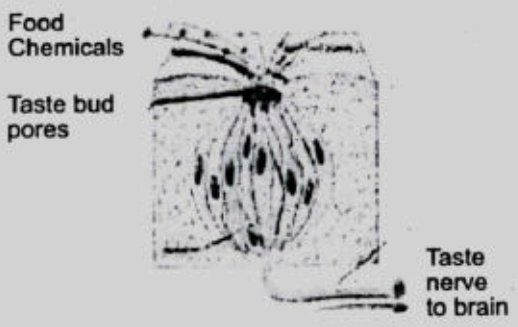

Fig. 5.26: Taste buds on tongue

Sensory receptors in human skin

The dermis of the skin contains receptors for touch, pressure, temperature and pain. **Meissner's corpuscles** and **Merkel disks** are touch receptors. These consist of small, oval masses of flattened connective tissue cells. Two or more sensory nerve fibres branch into each corpuscle. Meissner's corpuscles are especially numerous in the lips, fingertips, palm, and soles. **Paccinian's corpuscles** are also encapsulated nerve endings present in the fatty layer deep into the skin. They are concerned with sensation of pressure. Receptors for touch and pressure are also called **mechanoreceptors**. Skin also has cold and heat receptors to detect the temperature variations.

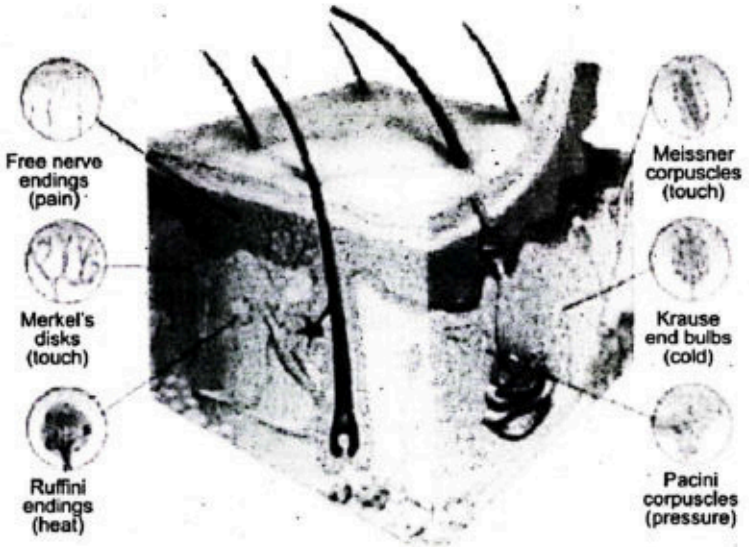

Fig. 5.27: Receptors in human skin

Pain receptors are technically called **nociceptors.** Pain receptors are located at the top of the skin in the epidermis area to detect pain. These receptors are free nerve endings that respond to chemicals released by damaged tissues or excess stimuli of heat or pressure. These receptors are widely distributed throughout the skin and inter tissues, except in the tissue of the brain.

Science, Technology and Society Connections

Ascertain the effect of nerve gas as an inhibitor of acetylcholinesterase.

Acetylcholine and the enzyme, acetyl cholinesterase, enable muscles to contract and relax. Normally, acetylcholine, a neurotransmitter, when released into the synapse of a muscle elicits the contraction of a muscle and is subsequently broken down by the enzyme, acetylcholinesterase, and relaxation of the muscle can occur. However, sarin, a nerve gas, irreversibly binds to acetylcholinesterase blocking it from breaking down the acetylcholine, thereby causing muscles to remain contracted. There exists a structural similarity between the active sites of the acetylcholine and the sarin molecule that enables the sarin molecule to fit into the acetylcholinesterase molecule. If the muscle is the diaphragm, it would remain contracted and the person would not be able to breathe. Nerve gases are extremely toxic; a small droplet can kill a person. They exist in both liquid and gaseous forms.

5.8 EFFECTS OF DRUGS ON NERVOUS COORDINATION

A narcotic is a group of substances when administered diminish the perception of pain. Narcotics bind to certain painkilling sites in the brain. With constant use, they build up in the brain and block the production of **endorphins**, the brain's natural painkilling chemicals. Their side effects are inhibition of the endocrine and autonomous nervous system etc. The narcotics are the drugs that act as agents which interact with the normal nervous activity.

5.8.1 Narcotic Drugs

Common narcotic drugs are heroin, *Cannabis*, nicotine and alcohol etc.

Heroin

Heroin gives a feeling of euphoria along with relief of pain. Side effects can include nausea, vomiting, respiratory and circulatory depression leading to death.

Cannabis

It is the dried flowering tops, leaves and stem of Indian hemp plant *Cannabis sativa*. It includes marijuana and hashish. Usually the users report a mild euphoria, along with alterations in vision and judgement. Intoxication is recognised by the presence of hallucinations, anxiety and depression.

Nicotine

It is an alkaloid derived from tobacco. When smoking a cigarette, nicotine is quickly distributed to all body organs. In peripheral nervous system, nicotine stimulates postsynaptic receptors (like acetylcholine) and leads to increased skeletal muscular activity. It also increases heartbeat rate and blood pressure.

Alcohol

Alcohol act as depressant and slows down the nervous communication. Its short term effects are impairment of vision, judgment and alertness. Long term chronic drinking can damage nervous system, liver and pancreas.

Withdrawal symptoms of alcohol

Individuals who eliminate addictive substances from their lives often feel withdrawal symptoms. Alcohol withdrawal refers to a group of symptoms that may occur from suddenly stopping the use of alcohol. The symptoms are: feeling of anxiety, irritability, depression, headache and hallucinations.

Inhalants

These are volatile organic chemicals, commonly referred to as "glue sniffing". Inhalant abuse now includes aerosols e.g., hair spray and anaesthetics e.g., ether etc. Inhalants rapidly start euphoria followed by central nervous system depression. Deep breathing of the toxic vapours may result in hallucinations or even death.

5.8.2 Drug Addiction and Drug Tolerance

Drug addiction: Drug addiction is a dependence on an illegal drug or a medication. You may want to quit, but most people find they can't do it on their own.

Drug tolerance: Drug tolerance is a person's diminished response to a drug, which occurs when the drug is used repeatedly and the body adapts to the continued presence of the drug e.g. caffeine and nicotine.

CRITICAL THINKING

What measures can be taken to eradicate drug addiction from the society?

a. Caffeine

Caffeine is a drug, and individuals can develop both tolerance and a form of dependence

Caffeine tolerance: Tolerance to caffeine means that the body becomes accustomed to its effects, requiring higher doses to achieve the same level of alertness or stimulation.

Caffeine addiction: It does not cause classic addiction the way some drugs do.

Harmful effects of caffeine: These include insomnia, rapid heart rate, anxiety, frequent urination, digestive issues, fatigue, high blood pressure and irritability tremors

b. Nicotine

Nicotine is the chemical in tobacco that makes it hard to quit.

Nicotine tolerance: It occurs when the body requires increasing amounts of nicotine to achieve the same effects initially felt with lower doses

Nicotine addiction: Nicotine produces pleasing effects in your brain, but these effects are temporary. So you reach for another cigarette. The more you smoke the more nicotine you need to feel good.

Harmful effects of nicotine: These include cancer, nausea, dizziness, emphysema, infertility, insomnia, cardiovascular diseases, headache and mouth ulcer.

Do you know?

Caffeine and nicotine both cause the brain to release dopamine, but the release from caffeine is much smaller. Nicotine changes how the brain works, making it one of the most addictive substances in the world.

5.8.3 Effects of drug addiction and tolerance on the central nervous system

Drugs are chemicals that interfere with the way neurons normally send, receive, and process information. Some drugs can activate neurons because their chemical structure mimics that of a natural neurotransmitter. Drugs interact with the brain and body to alter moods, emotions, and behaviors by changing brain chemistry. Regions of the brain affected by drug abuse are the brain stem, limbic system, and cerebral cortex.

All depressants work by slowing down the functioning of the central nervous system, while stimulants can produce a number of effects on the body such as increased heart rate, improved concentration, increased respiratory rate etc.

5.9 PAIN MEDICINES REDUCE OR NUMB PAIN IN HUMAN BODY

Analgesics are also called painkillers. These medicines reduce or numb pain in the body through various mechanisms that affect the nervous system. There are different types of pain medications and each works in a unique ways to interfere with pain signals. We will discuss here the main categories of pain medications and how they function.

a. Non-Steroid Anti-inflammatory Drugs (NSAIDs): These medicines works by inhibiting the activity of an enzyme called cyclooxygenase (COX), which plays a key role of in the production of prostaglandins. Prostaglandins are chemicals released at the site of injury or inflammation that cause pain, swelling and fever. By reducing the production of prostaglandins, NSAIDs help to reduce inflammation and numb pain.

b. Acetaminophen (Paracetamol): It is believed that it works by acting on brain's pain center. It likely inhibits COX enzymes in the brain, which reduces the perception of pain without the anti-inflammatory effect.

c. Opioids: These are also called narcotics. Opioids bind to opioid receptors in the brain, spinal cord and other parts of the nervous system. These receptors are involved in the transmission and perception of pain. When opioids binds to these receptors they block pain signals from being transmitted to the brain and increase the brain's and increase the brain's threshold for pain, essentially dulling or eliminating the sensation of pain.

d. Local Anesthetics: These work by blocking sodium channels in nerve cells. Sodium channels are essential for the transmission of electric signals along nerves. By blocking these channels, local anesthetics prevent pain signals from travelling from the site of injury to the brain. These are commonly used for procedures where localized numbing is required, such as dental work or minor surgeries.

e. Antidepressants and anticonvulsants: These medicines are used to treat chronic pain, particularly nerve pain. They work by modulating the neurotransmitters involved in pain perception. Such as serotonin and norepinephrine.

f. Corticosteroids: They reduce swelling and inflammation, which in turn reduces pain. They work by inhibiting the production of inflammatory chemicals and suppressing the immune response.

g. Other medicines: These numb localized area. Some are used to relax muscles.

5.9.1 Certain Pain Medications are Addictive

Physicians typically prescribe opioids to manage moderate to severe pain. However, opioids can become addictive because they not only dull pain, but also produce a sense of euphoria (intense happiness). This, combined with tolerance build (needing to increase doses to produce the same effect) can lead to opioid use disorder.

Opioids also cause neurons that produce dopamine the neurotransmitter, which plays a role in how we feel pleasure, or strong reactions to something. This creates feelings of euphoria Physicians reduce the length and strength of opioids to try to prevent addiction.

5.10 DISORDERS OF THE NERVOUS SYSTEM

The disorders of the nervous system may be classified as vascular, infectious, structural, functional and degenerative. While classifying the site of involvement is also considered. We will discuss here causes, symptoms and treatment of few diseases of the major categories.

5.10.1 Vascular Disorders of the CNS

Any disorder of nervous system which occurs due to abnormality in blood circulation is called vascular disorder of the nervous system e.g., strokes, brain haemorrhage.

Stroke

It occurs due to rupture of small cerebral arteries. **Cause:** The cause and risk factors for stroke include hypertension, cigarette smoking, diabetes mellitus, high alcohol intake, thrombosis, blood disorders, blood embolism and cocaine abuse. **Symptoms:** These include sudden loss of function in one region of brain. Weakness and heaviness occur in arm, leg or face. Paralysis occurs on the side of the body opposite the cerebral infarction (a portion of the tissue that is dying because of blood supply to it has been cut off). Aphasia (inability to express through words) may be present. **Treatment:** Medical treatment is aimed at preventing further attacks and stroke.

Anticoagulants and platelet aggregation inhibitor (such as aspirin) is given. Blood pressure management and nursing care is essential.

5.10.2 Infectious Disorders of the CNS

Infections of the central nervous system can be caused by almost any infectious agent, including viruses, bacteria, fungi, protozoa and Platyhelminthes.

Meningitis

It is an inflammation of the meninges. **Cause:** Bacterial or viral infection of meninges. **Symptoms:** usually include stiffness in the neck, headache and fever. In severe cases, meningitis may also cause paralysis, coma or death. **Treatment:** For viral meningitis, there is no specific treatment. Bacterial meningitis is treated with antibiotics and steroids.

5.10.3 Structural Disorders of the CNS

Several disorders disturb the structure of brain are referred as structural disorders, such as tumours.

Tumour

Tumour (tumor) is an abnormal mass of neuroglial cells produced as a result of uncontrolled cell division. **Cause:** It is caused by mutation which may occur at any age in brain and spinal cord. **Symptoms:** These vary widely, depending on the location of the tumour but may include headaches, severe nerve pain, paralysis, seizures, coma and death. **Treatment:** Surgical removal of tumour.

5.10.4 Functional Disorders of the CNS

Headache

Headache is the pain anywhere in the region of the head or neck. It can be a symptom of a number of different conditions of the head and neck. The brain tissue itself is not sensitive to pain because it lacks pain receptors. Rather, the pain is caused by disturbance of the pain-sensitive structures around the brain. There are two major categories of headaches i.e., **primary headaches** (due to the headache condition itself and not due to another cause) e.g., migraine, tension headache; and **secondary headaches** (due to an underlying structural problem in the head or neck such as bleeding in the brain, tumour, meningitis etc. Several analgesic drugs are available for **treatment** of any kind of headache.

5.10.5 Degenerative Disorders of the CNS

Many diseases cause degeneration in different part of the nervous system without an identifiable external cause. Genetic factors are known to be involved. Example of such diseases is Alzheimer's disease.

Alzheimer's disease

Alzheimer's disease is a slowly progressive disease of the brain that is characterized by impairment of memory and eventually by disturbances in reasoning, planning, language, and perception. Although onset of this disease occurs in aged peoples but it is not particularly associated with aging. **Cause:** There is genetic predisposition, so tends to run in families. **Symptoms:** Most prominent symptom is short-term memory loss. **Treatment:** There is no effective treatment for this disease.

5.11 PRINCIPLES OF DIAGNOSTIC TESTS FOR NERVOUS DISORDERS

These days number of diagnostic tests have been developed for nervous disorders. The principle of EEG, CT scan and MRI are discussed here.

Electroencephalography (EEG)

Neurons within the cerebral cortex continuously generate electrical activity. This activity can be recorded by electrodes attached to precise locations on the scalp, producing **electroencephalogram** and this technique is called **electroencephalography (EEG).** An EEG pattern is commonly called **brain waves.**

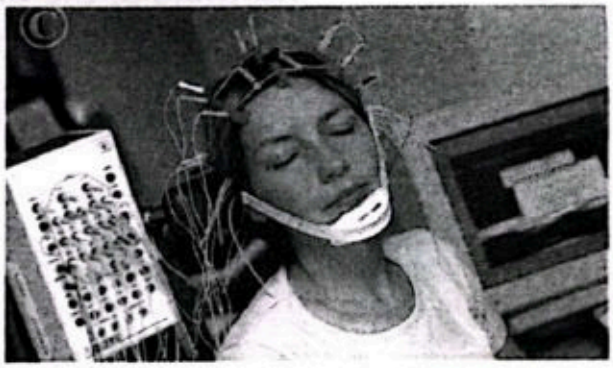

Fig. 5.28: Receptors in human skin

Computed Tomography Scan (CT Scan)

Computerized tomography is more commonly known by its abbreviated names, CT scan. It is an X-ray procedure that combines many X-ray images with the aid of a computer to generate cross-sectional views and, if needed, three-dimensional images of the internal organs and structures of the body. A CT scan is used to define normal and abnormal structures in the body and/or assist in procedures by helping to accurately guide the placement of instruments or treatments.

CT scanners give doctors a 3-D view of the body. The images are exquisitely detailed but require a dose of radiation that can be 100 times that of standard X-ray.

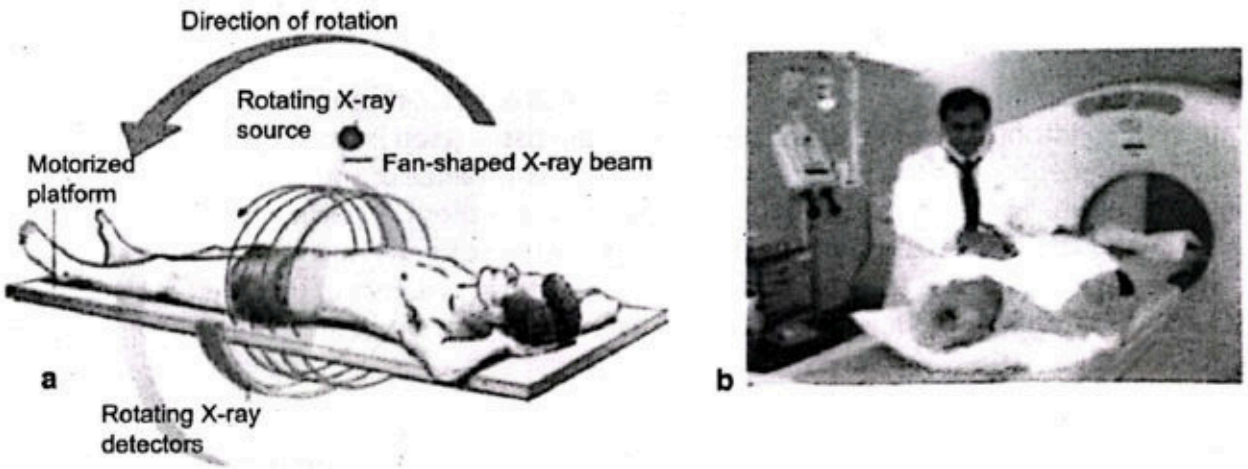

Fig. 5.29: (a) Principle of CT Scan (b) CT Scan

Do you know?

In CT Scan a large donut-shaped X-ray machine or scanner called tomograph takes X-ray images at many different angles around the body. These images are processed by a computer to produce cross-sectional pictures of the body. In each of these pictures the body is seen as an X-ray "slice" of the body, which is recorded on a film. This recorded image is called a tomogram.

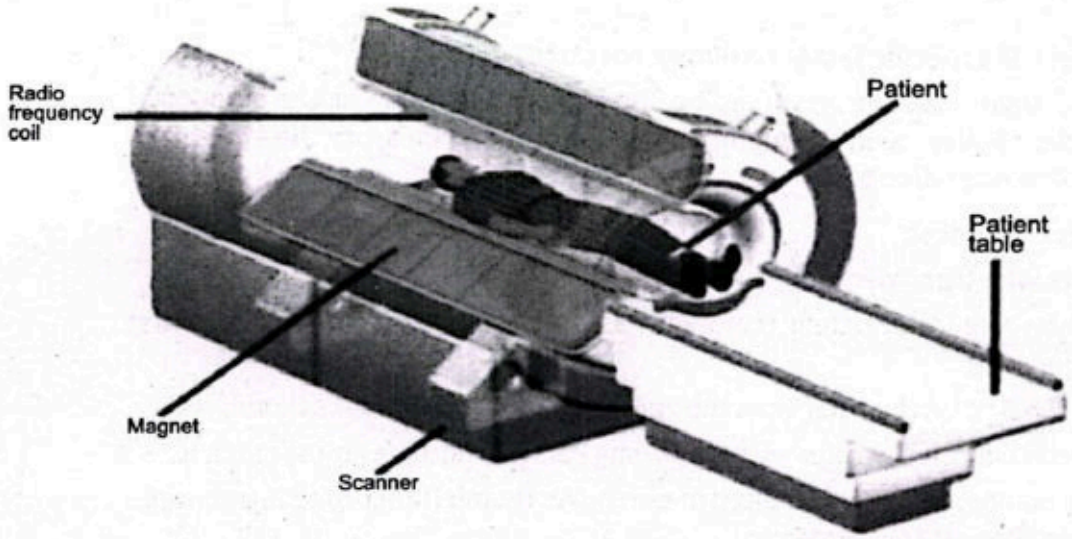

Fig. 5.30: MRI scanner

Magnetic Resonance Imaging

Magnetic Resonance Imaging **(MRI)** scan is a radiology technique that uses magnetism, radio waves, and a computer to produce images of body structures. The MRI scanner is a tube surrounded by a giant circular magnet. The patient is placed on a moveable bed that is inserted into the magnet. The patient is exposed to strong magnetic field and beam of radio waves. The receiver information is processed by a computer, and an image is produced. The image and resolution produced by MRI is quite detailed and can detect tiny changes of structures within the body.

Skills: Interpreting and Communication

• **Conceptualize the activity of brain as an electrical activity, which can be recorded using magnet and tomography.**

Scientists have attempted to conceptualize electrical activity of the brain as a reflection of mental processes. Due to recent advances in computer software and hardware it is now possible to sample more electrical information from the brain by using different radiologic imaging technique such as CT scan, MRI Scan and EEG. Therefore, these techniques have become very useful for the diagnosis of brain disorders.

• **Compare EEG of the brain of a sleeping human with that of a fully awake individual.**

During wakefulness, alpha and beta activities are experienced in the human brain. Alpha activities consist of medium frequency waves. Beta activities consist of irregular low amplitude waves which are present when the individual is very alert and attentive. As the individual gets drowsy, brain experiences theta activities. This is the transition stage between wakefulness and sleep. Sleeping stage contains irregular theta activities where sleep spindles (short bursts of waves of 12-14 Hz) and K complexes (sudden sharp wave forms) are present. Then the next stage of sleep contains high-amplitude delta activities 20 to 50 percent of the time.

STEAM ACTIVITY 5.1

Investigating reflex actions

Researchers can carry out a number of investigations to determine the effect of a specific factor on human reaction times.

A suitable investigation could be the effect of caffeine or the amount of background noise in the room. A simple method to measure the effect is to use the ruler drop test.

Ruler drop test

Work with a partner.

Person A holds out their hand with a gap between their thumb and first finger.

Person B holds the ruler with the zero at the top of person A's thumb

Person B drops the ruler without telling Person A and they must catch it.

The number level with the top of person A's thumb is recorded in a suitable table. Repeat this ten times.

Swap places, and record another ten attempts.

You can use the conversion table to help convert your ruler measurements into reaction time or just record the catch distance in cm.

Catch distance (cm)	Reaction time (ms)
1	50
5	90
10	140
15	170
20	200
25	230
30	250

Example results

	Attempt	Distance on ruler (cm)
	With noise	Without noise
1	25	18
2	38	15
3	36	22
4	31	24
5	38	13

Important: 1 millisecond (ms) is one thousandth of a second. (1/1000 s)

EXERCISE

Section I: Multiple Choice Questions
Select the correct answer:

1. The cell transmits impulses from the
   A. effector organ to the spinal cord
   B. receptor cells to the effector organ
   C. receptor cells to the spinal cord
   D. spinal cord to the effector organ

2. Depolarization of an axon is produced by the movement of:
   A. Na^+ into the axon and K^+ out of the axon
   B. Na^+ into the axon to bond with K^+
   C. K^+ into the axon and Na^+ out of the axon
   D. Na^+ and K^+ within the axon towards the axon terminal

3. What will happen if the receptor sites on the post-synaptic membrane are blocked by a drug at the neuromuscular junction?
   A. inhibition of acetylcholine
   B. inhibition of cholinesterase
   C. muscle contraction
   D. muscle paralysis

4. Which of these are the first and last elements in a spinal reflex?
   A. axon and dendrite
   B. sense organ and muscle effector
   C. ventral horn and dorsal horn
   D. motor neuron and sensory neuron

5. Impulses travel very rapidly along nerves to the leg of a man. Which fact accounts for the speed at which they travel?
   A. a nerve impulse is an all or none phenomenon
   B. the nerves contain myelinated fibres
   C. there is a high concentration of Na+ ions inside the axons
   D. there is a potential difference across the axon membranes

6. Where are neurotransmitter receptors located?
   A. on the nuclear membrane
   B. at nodes of Ranvier
   C. on the postsynaptic membrane
   D. in the myelin sheath

7. The human nervous system is capable of a wide range of functions. What is the basic unit of the nervous system?
   A. glial cell
   B. meninges
   C. neuron
   D. cerebrospinal fluid

8. Which of the following is the correct order of meninges from the inner side?
   A. Pia mater - arachnoid mater - durometer
   B. Pericardium - myocardium - endocardium
   C. Durometer - pia mater - arachnoid mater
   D. Durometer - arachnoid mater - pia mater

9. Which of the following structure at a synapse has the neurotransmitter?
   A. schwan cells
   B. synaptic cleft
   C. synaptic knobs
   D. synaptic vesicles

9. The action potential while the propagation of a nerve impulse is due to the movement of_____.
   A. K^+ ions from intracellular to extracellular fluid
   B. K^+ ions from extracellular to intracellular fluid
   C. Na^+ ions from intracellular to extracellular fluid
   D. Na^+ ions from extracellular to intracellular fluid
10. Which one is the ability of neurons to initiate nerve impulses?
   A. myelination B. conductivity C. irritability D. neurotransmission
11. Which of the following is one of the parts of the hindbrain?
   A. hypothalamus B. cerebellum C. corpus callosum D. spinal cord
12. If there is an injury in the hypothalamus region of the brain, it is most likely to affect
   A. regulation of body temperature B. decision making
   C. co-ordination during locomotion D. short-term memory
13. Afferent neurons carry nerve impulses from
   A. CNS to muscles B. CNS to receptors
   C. receptors to CNS D. effector organs to CNS
14. The cranial nerve that regulates the heartbeat
   A. VII B. VIII C. IX D. X
15. Nissl's granules present in the neurons are made up of
   A. protein B. ribosome C. RNA D. DNA
16. A neuron that carries information from the peripheral nervous system to the central nervous system is
   A. afferent neuron B. efferent neuron C. both D. none
17. Which of the following parts of the brain controls the body temperature and urge of eating?
   A. thalamus B. cerebellum C. pons D. hypothalamus
18. The central nervous system consists of the
   A. brain and spinal cord
   B. spinal nerves only
   C. cerebrum and the spinal column
   D. brain stem and the cerebéllum
19. Which one of the following controls involuntary activities such as coughing and sneezing?
   A) medulla B) cerebrum C) pons D) cerebellum
20. Spinal cord and brain are wrapped in protective membranes known as _____
   A) nodes of ranvier B) meninges C) axomembranes D) myelin sheath

Section II: Short Answer Questions

1 Why is neuron co-ordination important?
2. Describe the receptors as transducers sensitive to various stimuli.
3. Name the five fundamental parts of human reflex arc.

4. What is the function of neurotransmitter?
5. What characteristics do the brain and spinal cord have in common?
6. What is limbic system?
7. Name the sensory receptors of human skin.
8. How narcotic drugs interact with the normal nervous activity.
9. Find out some of the common withdrawal symptoms of alcohol.
10. Write the differences between:
    (a) thermoreceptors and nociceptors
    (b) axoplasm and axolemma
    (c) neuroglial cells and Schwann cells
    (d) sensory neuron and motor neuron
    (e) reflex action and reflex arc
    (f) resting membrane potential and active membrane potential
    (g) depolarization and repolarization
    (h) repolarization and hyperpolarization
    (i) refractory period and absolute refractory period
    (j) presynaptic neuron and postsynaptic neuron
    (k) axon and dendndrite
    (l) synaptic knob and synaptic vesicles
    (m) pons and medulla
    (n) white matter and grey matter
    (o) myelinated and nonmyelinated nerve fibres
    (p) cranial nerves and spinal nerves
    (q) drug addiction and drug tolerance
    (r) somatic and autonomic nerves system

Section III: Extensive Answer Questions

1. What is the basic organization of a nervous system?
2. Describe the structure of a neuron.
3. Describe the three types of neurons and write their functions.
4. Describe the mechanism of synaptic transmission.
5. Write the classification of neurotransmitters.
6. Describe the human brain.
7. Describe the structure of spinal cord with diagram.
8. Describe the somatic and autonomic nervous system.
9. Give an account of narcotic drugs.
10. Describe the cause, symptoms and treatment of:
    a. Stroke, b. Headache, c. Meningitis, d. Tumour, e. Alzheimer disease
11. Explain the principles of the following diagnostic tests of nervous disorders:
    a. EEG
    b. CT scan
    c. MRI
12. Describe the way how pain medicines can reduce or numb pain in the human body.