Chapter 15

HUMAN NERVOUS SYSTEM

STUDENTS'LEARNING OUTCOMES

After studying this chapter, the students will be able to:

- Recognize receptors as transducers sensitive to various stimuli.
- Trace the path of a message transmitted to the central nervous system for processing.
- Identify the three neurons (sensory, inter-, motor) involved in nervous transmission.
- Identify muscles and glands as the effectors.
- Annotate the detailed structure of a sensory neuron, associative and a motor neuron
- Relate the structure of neurons with functions.
- Differentiate between myelinated and non- myelinated neurons.
- Explain the function of the three types of neurons with the help of a reflex arc.
- Define nerve impulse.
- Describe the generation and transmission of nerve impulse.
- Name the factors responsible for the resting membrane potential of neuron.
- Evaluate from a graph the phenomena of polarization, depolarization, and hyperpolarization of membrane.
- Compare the velocities of nerve impulse in the axon membrane and in the synaptic cleft.
- Describe the role of local circuits in saltatory conduction of nerve impulse.
- Outline the structure of synapse.
- Explain synaptic transmission of nerve impulse.
- Classify neurotransmitters as inhibitory and excitatory and list some common examples.
- Identify the main components of the nervous system.
- Explain briefly the major parts functions of major divisions of the brain and their functions.
- Describe the architecture of human brain.
- Describe cranial and spinal nerves in man.
- Explain the structure, types and functions of the autonomic of autonomic nervous system.
- Explain the structure and functioning of the receptors for smell, taste and touch / pain.
- Define narcotic drugs as agents that interact with the normal nervous activity.
- Compare the use and abuse of drugs with respect to heroine, Cannabis, nicotine, alcohol and inhalants like nail polish remover and glue.
- Explain the terms; drug addiction and drug tolerance with reference to caffeine and nicotine and their adverse effects.
- Associate the effects of drug addiction and tolerance with the functioning of the nervous system.
- Describe the way how pain medicines can reduce or numb pain in the human body.
- Discuss that certain pain medications are addictive.

- Classify nervous disorders into vascular, infectious, structural, functional and degenerative disorders.
- Describe the causes, symptoms and treatment of one type of each category of disorders outlined above.
- Explain the principles of the important diagnostic tests for nervous disorders i.e., EEG, CT scan and MRI.

Tidbit
Think of your body as a large, complex city. For the city to run smoothly, the traffic lights, emergency services, and power plants must all talk to each other. This "talking" is what we call **coordination**.

To survive, every animal must stay connected to the world around it. They need to sense and respond to changes in environment. The activities of their organs and systems are also coordinated. For example; the heart rate, breathing rate, digestion, and many other functions are coordinated. Due to such coordination, every function is regulated according to the needs of the body. In humans and other complex animals, there are two types of coordination i.e.,

i- Nervous coordination controlled by the nervous system
ii- Chemical coordination controlled by the endocrine system

This chapters deals with details of the human nervous system.

15.1- Nervous Coordination

In nervous coordination, the nervous system controls coordination with external environment and among the different parts of the body. Nervous coordination is done by means of electrical signals.

15.1.1- Basic Elements of Nervous Coordination

For homeostasis, the nervous system is the most important because it regulates other systems and also maintains homeostasis by itself. You have studied the basic elements of homeostasis. Here, you will study them with reference to the nervous system.

Tidbit
Receptors act as transducers because they convert one form of energy into another form e.g., rod and cone cells in the retina of eye convert the light energy into nerve impulse (electrochemical energy).

1. **Receptors:** These are organs, tissues or cells – such as eyes, ears, or skin – that detect stimuli (the changes in the external and internal environment). They act as transducers. When they receive stimuli, they generate nerve impulses in **sensory neurons**. For processing the information, the sensory neurons carry nerve impulse to central nervous system.

2. **Central nervous system:** It is the control centre of nervous coordination. It consists of brain and spinal cord. These parts are made of **associative neurons** (also called **inter-neurons**). They receive the nerve impulses from sensory neurons and process them. After processing, they send nerve impulses to effectors via **motor neurons**.
3. **Effectors:** These are the parts which produce responses on receiving nerve impulse sent by the central nervous system via motor neurons. Muscles and glands act as effectors. Muscles produce response by contracting while glands produce secretion.

So, in nervous coordination, the path of a message (nerve impulse) consists of receptors, sensory neurons, central nervous system (inter-neurons), motor neurons, and effectors. In this pathway, the neurons act as the functional units.

15.2- Neurons

The function of the nervous system (responding to the environment and coordinating body activities) is actually carried out by specialized celled neurons (also called nerve cells). A neuron is the structural and functional unit of nervous system.

15.2.1- Structure of Neuron

There are many variations in the structure of neurons. But all neurons have the three basic components i.e., a cell body, dendrites and an axon.

The **cell body** is an enlarged region of the neuron cell. The nucleus of neuron and most of its organelles are located in cell body. The cytoplasm in cell body is characterised by the presence of **Nissl's granules**. These are group of ribosomes and rough endoplasmic reticulum.

Dendrites are membrane-bounded extensions of cell body. Dendrites receive information from other neurons or other cells. They convert the information into nerve impulses and carry it toward cell body. From cell body, the impulses are conducted away along an axon. Motor and inter-neurons receive impulses from many different sources simultaneously. That is why, they possess highly branched dendrites.

Axon is a long and membrane-bounded extension of cell body. It transmits impulses away from cell body. A neuron may have a single axon or branching axons. The end of an axon is called the **axon terminal**. It may contact and communicate with a muscle cell, a gland cell, or another neuron.

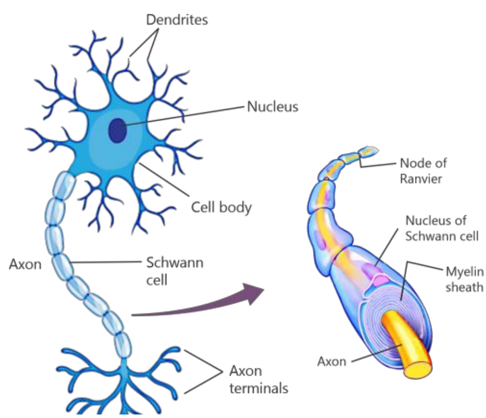


Figure 15.1: Structure of a model neuron

Tidbit
An axon can be quite long: the axons controlling the muscles in your feet are more than a meter long, and the axons that extend from the skull to the pelvis in a giraffe are about three meters long!

Supporting Cells – The Neuroglia

In the nervous system, there are special cells which support neurons. These supporting cells are called **neuroglia** or **glial cells**. They supply nutrients to neurons, remove wastes, and provide immunity. Two important glial cells are Schwann cells and oligodendrocytes. They are wrapped around the axons of many neurons. Here, they make myelin sheaths (sheaths of multiple membrane layers) around the axons. **Schwann cells** produce myelin sheaths around the axons in the peripheral nervous system. **Oligodendrocytes** produce myelin sheath in central nervous system.

Myelin sheath is an insulating covering. It helps in the fast transmission of nerve impulse along the axons. The neurons which have myelin sheaths around axons are called **myelinated**, and those that do not have such covering are called **non-myelinated**. In the CNS, myelinated axons make **white matter**, and the non-myelinated dendrites and cell bodies make **grey matter**. In the peripheral nervous system, both myelinated and non-myelinated axons are bundled together to form nerves. In myelinated neurons, the myelin sheath is interrupted at intervals of 1 to 2 mm by small gaps (non-myelinated parts). These non-myelinated interruptions are called **nodes of Ranvier**.

15.2.2- Types of Neurons

Sensory neurons conduct impulses from receptors to central nervous system. Their cell bodies are located outside of the CNS in the form of clusters called **ganglia**. Their cell body gives rise to a dendrite on one side and an axon at the other. Sensory neurons are unipolar. It means that they have only one long dendrite. The terminal end of dendrite has many smaller branches, which are connected to the receptors.

Motor neurons conduct impulses away from central nervous system. They have a cell body on one end, a long axon and many dendrites. Their cell bodies are located in the CNS. They are multipolar. It means that they have many dendrites that branch out into many smaller dendrites. Their dendrites make contact with other neurons in brain and spinal cord.

Inter-neurons (associative neurons) occur entirely within the CNS. They receive impulses from sensory neurons or other inter-neurons and transmit impulses to motor neurons or other inter-neurons. Some inter-neurons have short axons and form circuits with nearby neurons to analyse small information. Other inter-neurons have long axons and connect with other inter-neurons in different regions of the brain and spinal cord.

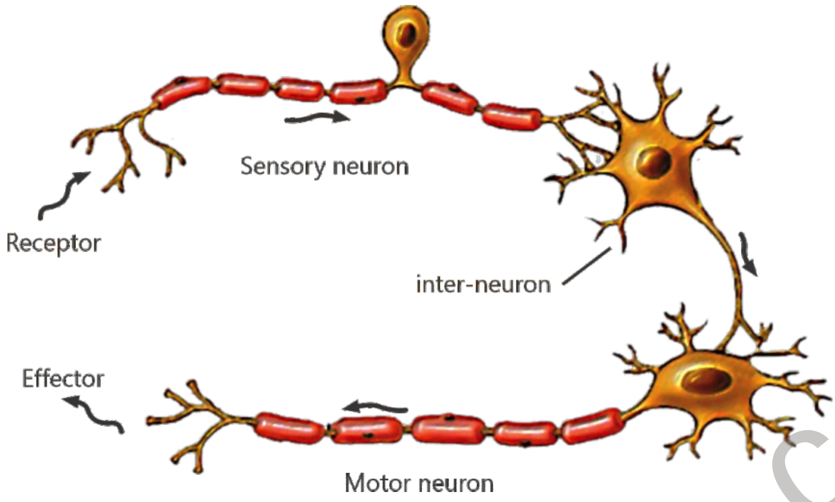


Figure 15.2: Types of neurons

15.2.3- Reflex Arc

In nervous system, neurons follow specific neural pathways (arcs) to receive, transmit and process impulses. Neural pathways may compose of only a few neurons, or may be more complex networks. The reflex arc is the simplest neural pathway. It controls reflex action i.e., immediate, automatic and involuntary responses to external and internal stimuli.

The Knee-Jerk Reflex

Knee-jerk is a reflex that occurs when someone hits the tendon below the knee (the patellar tendon) with a hammer. Tapping on that tendon acts as a stimulus. This stimulus (tapping) is sensed by a receptor present in the quadriceps muscle of thigh. The receptor generates a nerve impulse in a sensory neuron. The sensory neuron carries this impulse travels to spinal cord. Here, the sensory neuron transfers the impulse to a motor neuron without involving an inter-neuron. The motor neuron carries the impulse to the effector (quadriceps muscle) which contracts. It leads to extension of the lower leg at the knee (i.e., the lower leg kicks forward).

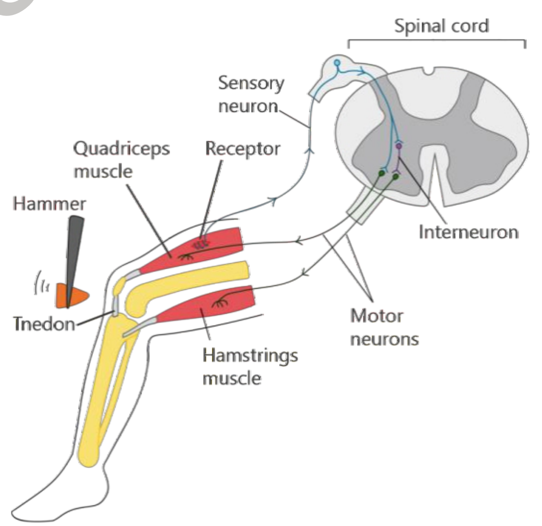


Figure 15.3: Knee-jerk reflex

In the meantime, sensory neuron also activates an inter-neuron in spinal cord. The inter-neuron releases chemicals which inhibit the motor neurons that connect to the hamstrings muscle. It results in the relaxation of hamstrings during the extension of the lower leg.

15.3- Nerve Impulse

A nerve impulse is defined as a wave of electrochemical changes that travels along the length of neuron. All cells, including neurons, have electrical charges on their inner and outer sides. The inner side of membrane (towards cytoplasm) is electrically negative while the outer side (towards extracellular fluid) is positive. This difference in the electrical charges across cell membrane is called **membrane potential**.

These membrane potentials are due to different concentrations of positive and negative ions and due to the movement of ions across cell membrane. In most cells, the inward and outward movement of ions through the membrane is constant. So, the net negative charge on the inner side remains constant. However, the cell membranes of muscle and neurons can change the rates of ions movements. So, their membrane potentials also change.

15.3.1- Generation and Transmission of Nerve Impulse

1- Before Nerve Impulse - Resting Membrane Potential

A resting neuron (not conducting a signal) is said to be **polarized**. Its inner side has negative while outside has positive charge. This membrane potential of a polarized neuron is called Resting Membrane Potential (RMP) and it is about –70 millivolts (–70 mV). The negative sign indicates that the inside of the cell is negative with respect to the outside. In resting neurons, RMP is established by the following factors:

1. Large negatively charged molecules e.g., proteins and nucleic acids are more abundant inside the cell and cannot diffuse out. These molecules are called **fixed anions**.

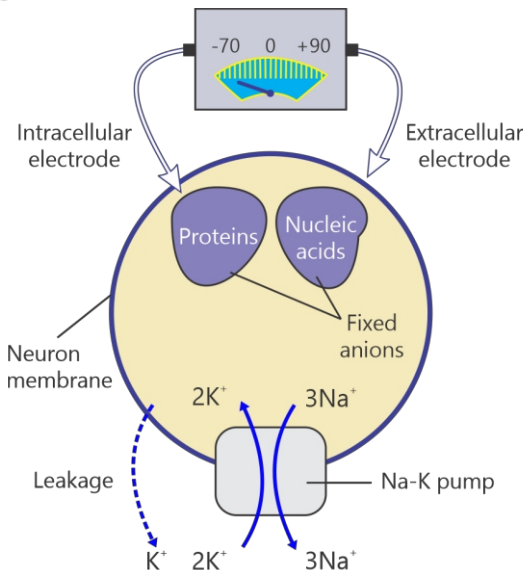


Figure 15.4: Factors responsible for RMP

2. The concentration of K^+ is 30 times greater inside the neuron than outside. While, the concentration of Na^+ is 10 times greater outside than inside the cell. Sodium-potassium pumps present in neuron membranes constantly move these ions against their concentration gradient by the expenditure of ATP. For every two K^+ that are actively transported inward, three Na^+ are pumped out. So inside becomes more negative than outside.

For Information
This exit of K^+ and the retention of negatively charged proteins are the major factors for establishing net negative charge inside and a positive charge outside i.e., RMP.

3. Some K^+ ions also leak out of the cell through K^+ gates of membrane.

2- Generation of Nerve Impulse - Active Membrane Potential

When a neuron becomes active (generates nerve impulse), the membrane potential at a region of neuron is reversed i.e., the inside becomes positive than the outside. It is called Active Membrane Potential (or action potential).

The following events happen for producing action potential.

- **Depolarization:** The Na^+ gates of membrane open and Na^+ ions rush into the cell. This sudden inward movement of Na^+ ions reduces the negative charge on the inside. The electrical potential of the membrane changes from -70 mV towards zero and then reaches to 50 mV. This reversal of polarity across two sides of membrane is called depolarization. This depolarization produces action potential on a short region of neuron for about one millisecond.
- **Repolarization**: After a short period of depolarization, Na^+ gates close and the K^+ gates open. So, more K^+ ions diffuse out. It makes the inside of cell negative again. It is called repolarization of membrane (negative inside and positive outside).
- **Hyperpolarization:** The repolarization carries the membrane potential to a value slightly more negative than the resting potential for a brief period. This is called hyperpolarization**.** It is due to the slight delay in closing all the K^+ gates. During hyperpolarization, the neuron cannot generate another action potential and period is called the **refractory period**.
- **Return to Original RMP:** After a short refractory period, original ionic distribution is restored by sodium-potassium pump and the membrane returns to its RMP i.e., -70mV. In this way, the region of neuron prepares itself for the next action potential.

Tidbit
The propagation of action potentials is similar to the action when people in a stadium perform the "wave": Individuals stay in place as they stand up (depolarize), raise their hands (action potential), and sit down again (repolarize).

3- Propagation of Action Potentials

In reality, action potentials (impulses) do not really travel along the axon. Rather, they are reproduced at adjacent regions along the axon. An action potential in a region of axon serves as a depolarization stimulus for the next region. So, the next region produces its own action potential. Meanwhile, the previous region repolarizes back to the RMP .

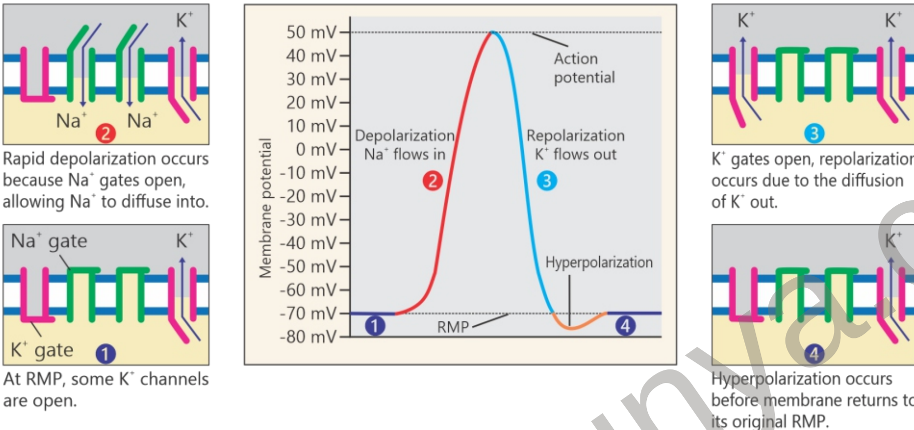


Figure 15.5: Generation of action potential

15.3.2- Velocities of Nerve Impulse

The strength (amplitude) of action potentials remains constant along the length of axon. The action potential at the end of axon is as strong as the first action potential. However, the velocity of nerve impulse i.e., speed of conduction of action potential may vary. The velocity is greater if the diameter of the axon is large or if the axon is myelinated.

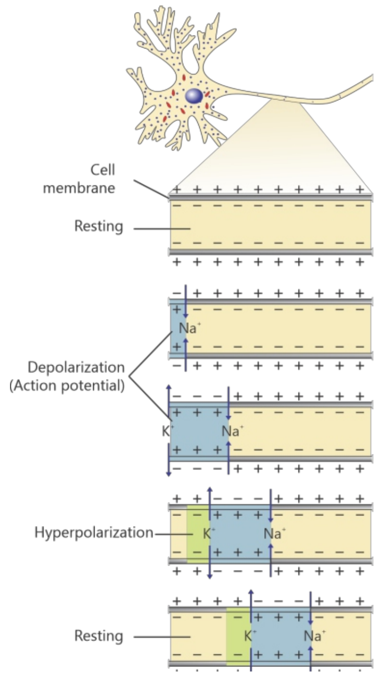


Figure 15.5: Propagation of action potential

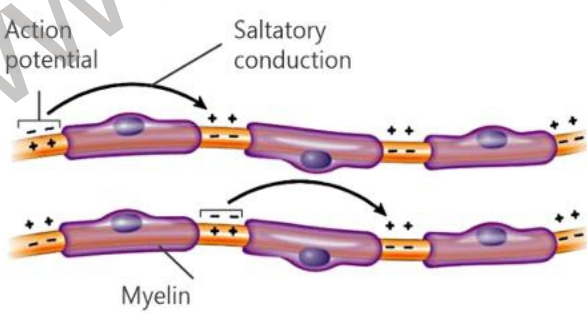


Figure 15.6: Saltatory conduction in myelinated axon

In myelinated axons, action potentials are only produced at the nodes of Ranvier. These action potential jump from one node of Ranvier to another, skipping the myelinated regions of membrane. It is called as **saltatory conduction** of nerve impulse. It is up to 50 times faster than the nerve impulse through the fastest non-myelinated axons. In human, the non-myelinated neurons conduct impulses at speed of 1 to 3 metres per second. While, the myelinated neurons conduct at speeds of up to 120 meters per second.

15.4- SYNAPSE

The junction between axon terminal of one neuron and the dendrites of other neurons, or effector cells (of muscle or gland) is called a synapse. At a synapse, the two neurons or a neuron and a cell are not in direct contact. Rather, there is a fluid-filled gap between them, called a **synaptic cleft**. The neuron whose axon transmits action potentials towards synapse is the **presynaptic** neuron. The neuron or cell on the other side of the synapse is the **postsynaptic** cell.

For Information
The synapse between a motor neuron and a muscle fibre is also called **neuro-muscular junction.**

15.4.1- Mechanism of Synaptic Transmission

The axon terminal of presynaptic neuron has several **synaptic knobs**. These knobs contain numerous **synaptic vesicles** which are packed with chemicals called **neurotransmitters**. When an action potential on a presynaptic neuron reaches a synapse, its information is transmitted to postsynaptic neuron or effector cell. The movement of action potential across synapse is called **synaptic transmission**. In happens in the following way:

1. When action potential arrives at synaptic knobs, calcium gates in presynaptic membrane open.
2. Calcium ions present in synaptic cleft diffuse rapidly into presynaptic axon.
3. Due to the diffusion of calcium ions into presynaptic axon, its synaptic vesicles fuse with its membrane. This fusion causes the release of neurotransmitters from vesicles by exocytosis.
4. The released neurotransmitters diffuse rapidly in the cleft and bind to postsynaptic membrane at receptor proteins.

For Information
The higher the frequency of action potentials in the presynaptic axon, the more neurotransmitters are released.

5. The binding of neurotransmitters acts as a massage for postsynaptic membrane. Its Na^+ gates open and an action potential is generated in postsynaptic membrane.
6. After their action, the neurotransmitters do not remain in the synaptic cleft indefinitely. At many synapses, the used neurotransmitters are reabsorbed by the presynaptic neuron. At other synapses, they are broken down by enzymes.

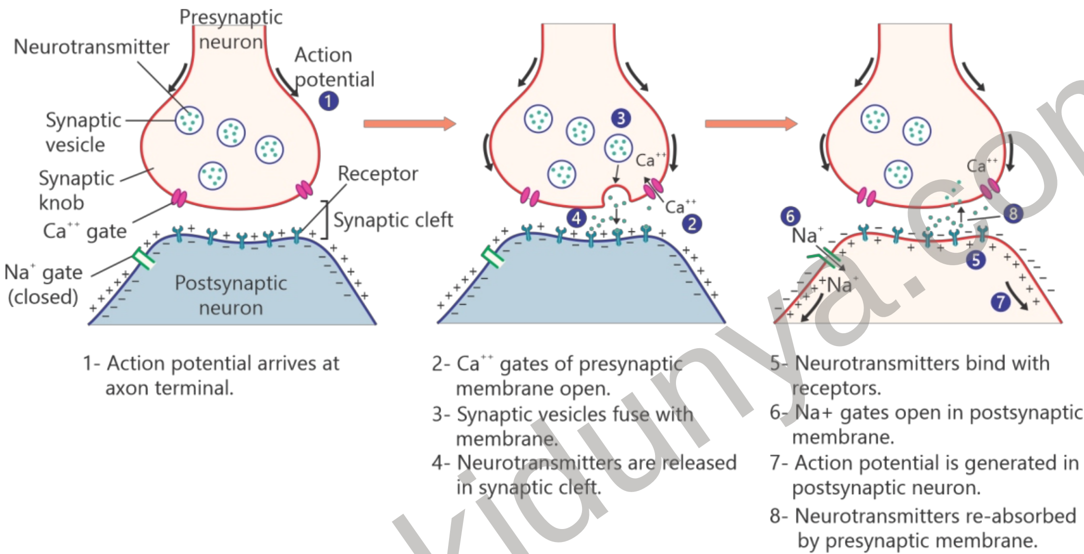


Figure 15.7: Structure of synapse and mechanism of synaptic transmission

15.4.2- Types of Neurotransmitters

i- Excitatory Neurotransmitters

Excitatory neurotransmitters generate nerve impulse (action potential) in postsynaptic neurons by increasing membrane permeability to Na^+. For example,

- **Acetylcholine** acts between motor neurons and skeletal muscle fibres, and between many neurons.
- **Glutamate** acts in the CNS.
- **Biogenic amines** are excitatory neurotransmitters. They also function as hormones. These include;
  i- **Norepinephrine** is made in CNS and sympathetic nerves. It regulates sleep patterns, focus and alertness.

For Information
Degeneration of dopamine-releasing neurons produces the muscle tremors of Parkinson's disease.
Insufficient activity of serotonin-releasing neurons may cause depression. Many antidepressant drugs block the elimination of serotonin from the synaptic cleft. So, serotonin remains in the synaptic cleft and reduces depression.

ii- **Epinephrine** is released in adrenal glands and the brainstem. It plays a role in sleep. It also enables to become and stay alert.

iii- **Dopamine** is a neurotransmitter in brain. It controls body movements, pleasures related to motivation and also emotional stimulation.

iv- **Serotonin** is produced by the neurons in intestine (approximately 90%), and CNS (10%). It regulates appetite, sleep, memory and learning, temperature, mood, behaviour, muscle contraction etc.

ii. Inhibitory Neurotransmitters

These neurotransmitters decrease the chance of transmission of nerve impulse to the postsynaptic neuron. When they bind to the receptors on postsynaptic neuron, channels for chloride ions open instead of opening sodium channels (which would excite the cell). As a result, chloride ions diffuse into neuron and make the inside of the membrane even more negative than RPM. This hyperpolarization causes inhibitory effect. Examples of inhibitory neurotransmitters include:

- **Gamma - aminobutyric acid (GABA)** is the chief inhibitory neurotransmitter in CNS. It reduces the neural excitability throughout the nervous system. It helps to control and regulate various physiological and behavioural processes. It reduces anxiety, stress, and fear, and promotes relaxation and sleep.

For Information
Many sedative drugs enhance the binding of GABA to its receptors and so increase the effectiveness of GABA at the synapse.

- **Glycine** is an inhibitory neurotransmitter especially in the spinal cord, brainstem, and retina.

Endorphins are inhibitory neurotransmitters released by neurons in brain. They reduce the release of excitatory neurotransmitters responsible for transmitting pain messages. In this way, they block the pain signals to reach the concerned part of the brain.

For Information
Opium and its derivatives, morphine and heroin, have an analgesic (pain-reducing) effect because they are similar in chemical structure to endorphins. So, they easily bind to the receptors of endorphins.

Effect of nerve gas on neurotransmitter acetylcholine
The excitatory neurotransmitter acetylcholine is released by motor neurons at neuromuscular junctions. It stimulates the skeletal muscles to contract. Then, it is broken down by acetylcholinesterase enzyme. A nerve gas (e.g., sarin, tabun, soman) is a highly toxic chemical that inhibits this enzyme. This inhibition leads to the accumulation of acetylcholine, causing overstimulation of skeletal muscle and cause muscles to remain contracted. If the diaphragm muscle remains contracted, the person is not be able to breathe. Other effects may include muscle twitching, convulsions, respiratory distress, and ultimately death.

15.5- BASIC ORGANIZATION OF HUMAN NERVOUS SYSTEM

The human nervous system consists of central nervous system (CNS) and peripheral nervous system (PNS). The **CNS** consists of brain and spinal cord. The **PNS** consists of cranial and spinal nerves which arise from brain and spinal cord respectively. The nerves make sensory and motor pathways. There are two motor pathways: (i) voluntary (somatic) nervous system which controls voluntary (skeletal) muscles, and (ii) autonomic nervous system which controls involuntary muscles and glands. The autonomic system consists of sympathetic and parasympathetic nervous systems.

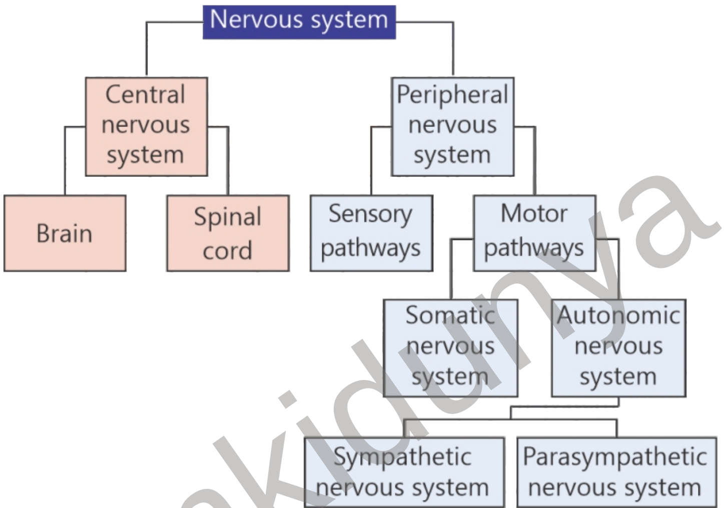


Figure 15.8: Basic organization of nervous system

15.5.1- Central Nervous System – Brain & Spinal Cord

The CNS (brain and spinal cord) is made of inter-neurons and neuroglia. Brain is enclosed within the cranium while spinal cord is enclosed within vertebral column. Both are covered with protective **meninges** which consists of three layers of membranes;

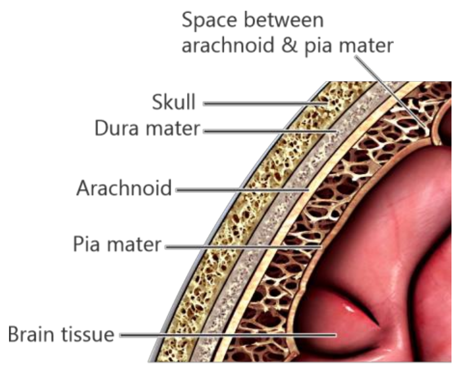


Figure 15.9: The meninges of brain

i- The outermost thick layer (below skull and vertebrae) is called **dura mater**. It contains larger blood vessels.

ii- The second layer (below dura mater) is thin and is called **arachnoid**. It acts as a barrier between the cerebrospinal fluid present below it and the blood in the dura mater.

iii- The third layer is very delicate membrane called **pia mater**. It adheres to the surfaces of brain and spinal and has blood capillaries that nourish the brain and spinal cord.

Structure of Brain

The average adult human brain weighs 1.4 kg (about 2 percent of total body weight). It contains about 100 billion inter-neurons. Each neuron has synapses with several thousand other neurons.

For Information
In Grade X, you have studied the traditional divisions of brain structure i.e., forebrain, midbrain, and hindbrain. Here, you would study the structure of brain according to the latest defined divisions.

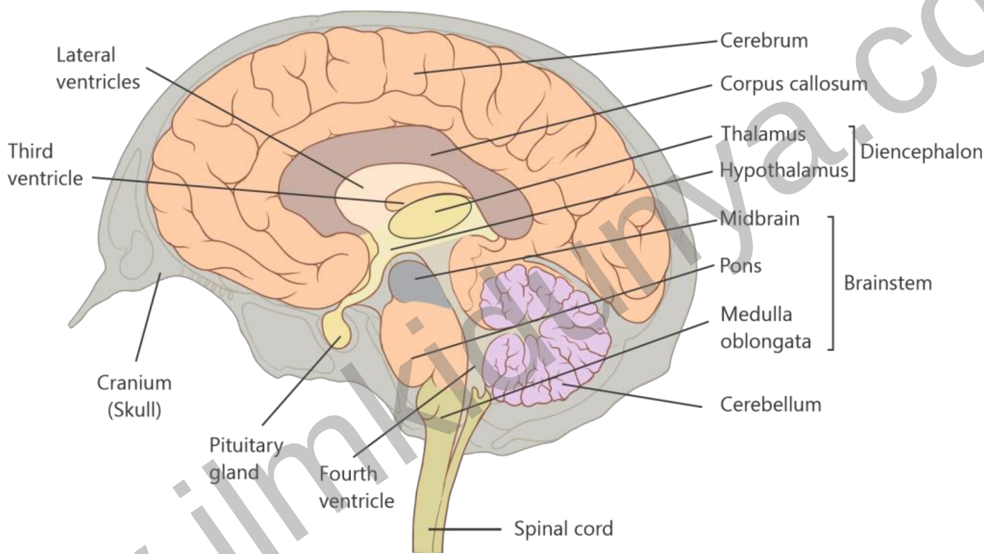


Figure 15.10: Major parts of human brain

The human brain consists of the following major parts.

1- Cerebrum

It is the largest portion of human brain. Its outer layer is highly folded. It is divided by a deep groove (fissure) into two parts called left and right cerebral hemispheres. At the base of deep groove, both cerebral hemispheres are connected by the **corpus callosum** (a band of axons). Each hemisphere receives sensory information from the opposite side of the body and sends motor commands to that side.

Tidbit
Damage to one hemisphere results in a loss of sensation and paralysis on the opposite side of body.

Each cerebral hemisphere is divided into four lobes:

i- The **frontal** lobes are associated with executive functions including self-control, planning, reasoning, and abstract thought.

ii- The **parietal** lobes process sensory information, give awareness of position of the body and the environment, control attention, plan and execute motor movements.

iii- The **temporal** lobes are involved in processing sensory input for appropriate retention of visual memory, language comprehension, and emotions.

iv- The **occipital** lobes control vision.

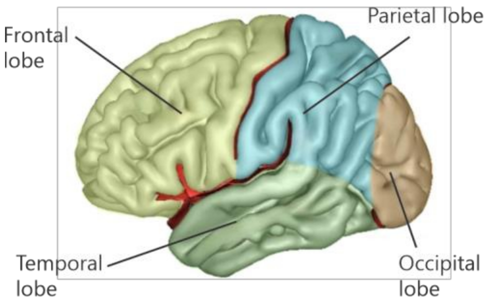


Figure 15.11: Four lobes of cerebrum

Tidbit

Ridges in cerebral hemispheres are called **gyri** (singular, gyrus). Gyri are separated by grooves. A shallow groove is called **sulcus** (plural, sulci) and a deep groove is called **fissure**.

Cerebral Cortex: It is the folded outer layer of cerebrum. It is made of grey matter (containing cell bodies and non-myelinated axons). It is densely packed with inter-neurons (about 10% of all neurons in brain). It contains the following areas.

i- The **motor areas** send impulses to the voluntary (skeletal) muscles.

ii- The **sensory areas** receive information from different parts. A specialized area called **auditory cortex** within the temporal lobe deals with different sound frequencies. The **visual cortex** in the occipital lobe deals with information from the eye.

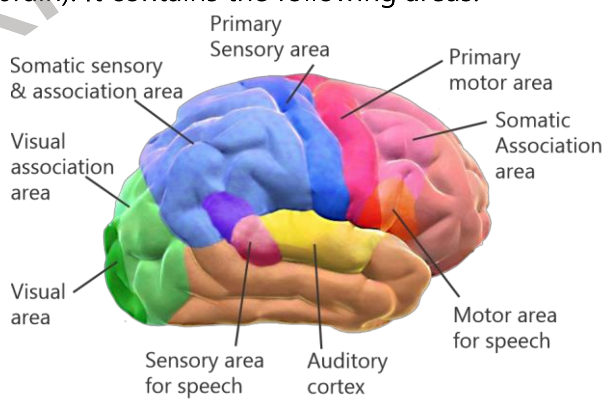


Figure 15.12: Sensory, motor and association areas

iii- **Association areas** of the cortex are the sites of higher mental activities. Some functions are associated with one side, such as language in the left and visual-spatial ability in the right.

Below cerebral cortex is the white matter (composed of myelinated axons). It links specific regions of the cortex with each other and with other neural centres.

2- Brainstem

The cerebrum is connected to the spinal cord through brainstem. This region lies below the cerebrum and consists of three main divisions:

i- **Midbrain**: It relays visual and auditory information. It also contains **reticular formation**, which connects hindbrain with forebrain.

ii- **Pons:** It transmits impulses between the cerebral hemispheres and cerebellum.

iii- **Medulla oblongata:** It serves as both a relay centre and a control centre for heart rate, respiration rate, and other homeostatic activities.

3- Diencephalon

It is present deep within the brain's center, above the brainstem and beneath the cerebrum (specifically between the cerebral hemispheres). It consists two major parts:

i- **Thalamus** is a relay centre between sensory information and the cerebrum.

ii- **Hypothalamus** integrates the visceral activities. It regulates body temperature, hunger and satiety, thirst, and various emotional states. It also controls the pituitary gland, which in turn regulates many of the other endocrine glands.

Tidbit
The pineal gland is located where the two halves of the thalamus join. It produces a hormone melatonin which controls sleep patterns.

Limbic system

It is a group of linked structures. It lies on both sides of the thalamus, just under the cerebrum. It includes the hypothalamus, the amygdala, the hippocampus, and several other nearby areas. The **amygdalae** (singular: amygdala) are two almond-shaped structures present deep within the temporal lobes. 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 plays role in the consolidation of information from short-term memory to long-term memory.

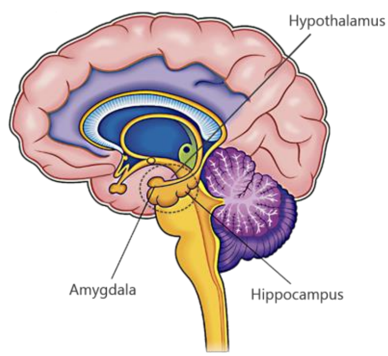


Figure 15.13: Limbic system

4- Cerebellum

It is the second major structure in brain. It lies below and behind the cerebral hemispheres. It coordinates muscle actions. It consists of a tightly folded layer of cortex, with white matter underneath. It receives sensory impulses from muscles, tendons, joints, eyes, and ears. It also receives information from other brain centres. It processes information about body position and controls posture. The cerebellum coordinates rapid and ongoing movements. It acts with the brainstem and with the cerebral cortex to coordinate skeletal muscles.

Ventricles of Brain

The brain and spinal cord are hollow structure. It means that they contain fluid-filled cavities called ventricles. There are four ventricles in human brain. There are two large **lateral ventricles** in cerebrum. The **third ventricle** is in diencephalon between the right and left thalamus. The **fourth ventricle** is located between the cerebellum and the brainstem, and it is continuous with the central canal of spinal cord. The main function of ventricles is the production and circulation of cerebrospinal fluid.

Structure of Spinal Cord

The spinal cord is a cable of neurons extending from the medulla oblongata of brain down through the backbone. It is enclosed and protected by the vertebral column and layers of meninges. Like brain, the neurons and neuroglia of spinal cord make grey and white matter, but the arrangement of grey and white matter in spinal cord is opposite to that of brain.

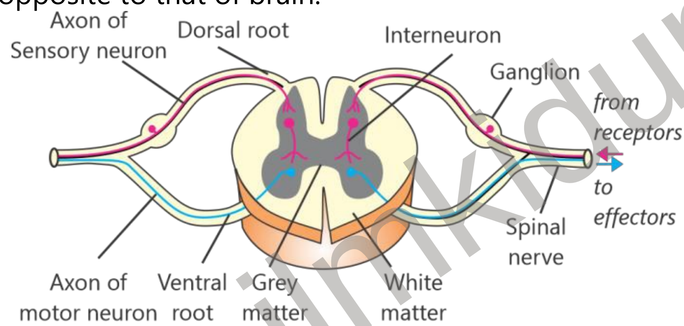


Figure 15.14: Structure of spinal cord and Spinal nerves

> **Tidbit**
> The diameter of spinal cord is between 0.25 to 0.5 inch. It is wider in cervical and lumbar regions. In cervical region, it deals with sensory input and motor output for arms and trunk. In lumbar region, it handles sensory input and motor output for legs.

There are two zones inside spinal cord. The inner H-shaped or butterfly-shaped zone is made of grey matter. It contains cell bodies of inter-neurons and motor neurons. It also contains neuroglia cells and non-myelinated axons. The outer zone is made of white matter. It contains myelinated axons. The inner zone also contains a central fluid-filled canal. It is a continuation of the fourth ventricle of brain. Spinal cord acts as information highway on which messages are transmitted between body and the brain.

15.5.2- Peripheral Nervous System – Cranial & Spinal Nerves

The peripheral nervous system consists of nerves and ganglia. Nerves are cable-like collections of axons. Ganglia are aggregations of cell bodies located outside CNS. The nerves which arise from brain are called cranial nerves while those which arise from spinal nerves are called spinal nerves

Cranial Nerves

There are 12 pairs of cranial nerves. The first two pairs of cranial nerves (olfactory nerve and optic nerve) arise from cerebrum. The other 10 cranial nerve pairs arise from the brainstem. Some of cranial nerves are sensory, some are motor and others are mixed nerves (contain axons of sensory and motor neurons).

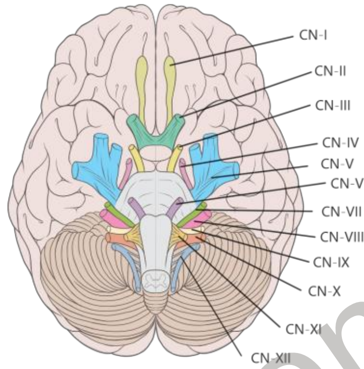


Figure 15.15: Cranial nerves

Table: Twelve Pairs of Cranial Nerves & their Functions

Cranial Nerve	Nature	Major Function
I	Sensory	Sense of smell
II	Sensory	Sense of vision
III	Motor	Movement of eye
IV	Motor	Movement of the superior oblique muscle of eye
V	Mixed	Sensation in the face; control of the muscles involved in chewing
VI	Motor	Movement of the lateral muscles of eye which are responsible for outward gaze
VII	Mixed	Facial expressions and the sense of taste in the front of the tongue.
VIII	Sensory	Hearing and balance
IX	Mixed	Sense of taste in the back of tongue; movement of the muscles involved in swallowing
X	Mixed	Controls many organs, including heart, lungs, and digestive system
XI	Motor	Controls the muscles in the neck and shoulders
XII	Motor	Controls the muscles of the tongue

Spinal Nerves

There are thirty-one pairs of spinal nerves. All spinal nerves are mixed. They transmit sensory and motor information between the spinal cord and the rest of the body.

Each spinal nerve emerges from the spinal cord by two short branches or roots. The dorsal root contains the axons and dendrites of sensory neurons. The ventral root contains the axons of motor neurons. The two roots join just before a spinal nerve leaves the vertebral column. The cell bodies of sensory neurons are grouped together outside spinal cord in the dorsal root ganglia. The cell bodies of somatic motor neurons are located within the spinal cord and so are not located in ganglia. The 31 pairs of spinal nerves include;

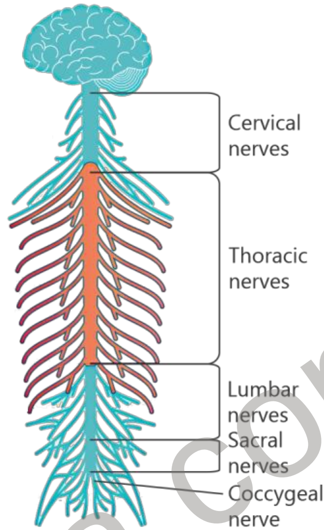


Figure 15.16: Spinal nerves

- 8 pairs of cervical nerves
- 12 pairs of thoracic nerves
- 5 pairs of lumbar nerves
- 5 pairs of sacral nerves
- 1 pair of coccygeal nerves

15.5.3- Divisions of the PNS

The PNS makes two types of pathways or divisions i.e., sensory pathways and motor pathways. The sensory pathways contain the sensory neurons of spinal and cranial nerves that connect the receptors of body to CNS. The motor pathways contain the motor neurons of spinal and cranial nerves that connect the CNS the effectors of body. The motor pathways make of two systems i.e., the somatic nervous system and the autonomic nervous system.

1- Somatic Nervous System

It consists of those motor neurons of spinal and cranial nerves which control skeletal muscles. The somatic system is voluntary. It means that skeletal muscles can be moved at will. For reflex action, the somatic system operates without conscious control.

2- Autonomic Nervous System

It consists of those motor neurons of spinal and cranial nerves which control smooth muscles and glands. The autonomic system is involuntary and it controls internal body conditions by regulating smooth muscles. For example, it controls respiration, heartbeat, digestion, and other functions. The autonomic system has two subdivisions i.e., the sympathetic division and the parasympathetic division.

a- Sympathetic Nervous System

It prepares the body under physical or emotional stress. The motor neurons of sympathetic nervous system originate from the thoracic and lumbar regions of spinal cord. The axons of these neurons reach different visceral organs (smooth muscles and glands). When the sympathetic nervous system is activated, its motor neurons stimulate various smooth muscles and glands to prepare the body for fight or flight. For example, the heart beats faster and stronger, blood glucose concentration increases, blood flow is diverted to the muscles and heart, and the bronchioles dilate.

b- Parasympathetic Nervous System

This system antagonises the response of sympathetic nervous system after the threat or stress has passed. The motor neurons of parasympathetic nervous system originate from the brain and sacral regions of spinal cord. Many of these motor neurons are in vagus (the tenth cranial) nerve. These motor neurons reach the internal organs. These neurons bring the internal organs to their normal conditions. For example, heart beat slows down, blood flow to heart and skeletal muscles decreases, digestive organs increase secretion and other activities, and so on.

Table: Effects of Autonomic Nervous System on Body Parts

Body Parts	Effect of Sympathetic Nervous System	Effect of Parasympathetic Nervous System
Pupil of eye	Dilation	Constriction
Salivary glands	Decreased secretion	Increased secretion
Gastric glands	Inhibition of secretion	Stimulation of secretion
Liver	Stimulation of glucose secretion	Inhibition of glucose secretion
Digestive tract	Decreased motility	Increased motility
Urinary bladder	Relaxation	Contraction
Heart muscle	Increased rate and strength	Decreased rate
Bronchioles	Dilation	Constriction
Blood vessels in muscles	Dilation	No effect
Blood vessels in skin	Constriction	No effect

15.6- Receptors in Human Body

You know that receptors are the organs, tissues, cells or parts of cells that detect changes (stimuli) in external or internal environment and create nerve impulses in the associated sensory neurons. We will discuss the receptors for taste, smell, touch, and pain.

15.6.1- Receptors of Taste

Special chemoreceptors called taste buds sense the taste. There are about 10,000 taste buds. Most of them are embedded between bumps called papillae on the tongue. Some taste buds are present in the throat and on the roof of oral cavity. A taste bud is bulb-shaped and is made up of receptor cells with hair-like structures and basal cells (for making new receptor cells). A taste bud opens out into the mouth through a taste pore.

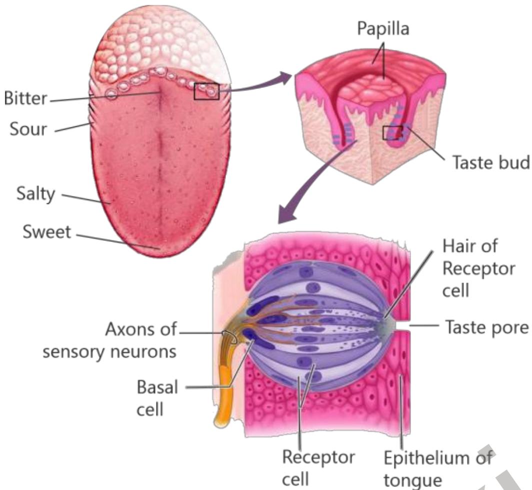


Figure 15.17: Receptors of taste

For Information
The simplest receptors are free nerve endings that respond various stimuli e.g., changes in temperature, chemicals in extracellular fluid.

For Information
The effect of smell on the sense of taste can easily be demonstrated by eating an onion with the nose open and then eating it with the nose plugged.

When the chemoreceptor cells of taste buds are stimulated by the chemicals present in food or drink, they produce nerve impulses in associated sensory neurons. The nerve impulses travel along nerves (cranial nerve VII, IX, and X) and reach brainstem. From here, the impulses are transmitted to the taste-sensing areas of cerebral cortex. The cortex processes this information with other sensory information, such as smell and texture, to create the complete perception of taste.

Humans have four kinds of taste buds which respond to salty, sweet, sour, and bitter tastes. Taste buds for specific tastes are concentrated in specific regions of tongue: **sweet** at the tip, **sour** at the sides, **bitter** at the back, and **salty** over most of the tongue's surface. All the four regions overlap at certain places.

15.6.2- Receptors of Smell

The chemoreceptors located in the upper part of nasal cavities are responsible for the sense of smell (olfaction). These receptors are actually the ends of sensory neurons. These sensory neurons are present in a thin layer of tissue called nasal epithelium. They are packed tightly between two other types of cells: supporting cells, which provide protection, and basal cells, which act as stem cells to replace old neurons.

The dendrites (the receiving ends) of these sensory neurons have tiny, hair-like structures called **cilia**. These cilia project outward into the moist mucus that lines the nasal cavity. When air enters the nasal cavities, the air-borne chemicals dissolve in the mucus. These dissolved chemicals bind to specific receptor sites on the cilia. This binding creates nerve impulse in sensory neurons, which is transmitted to the olfactory bulb through olfactory nerves (cranial nerve I). The olfactory bulb produces the perception of smell.

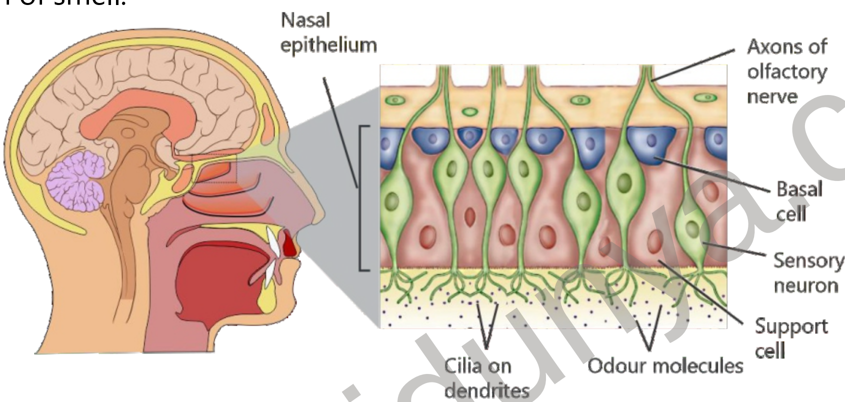


Figure 15.18: Olfactory receptors

15.6.3- Receptors of Pain & Touch

Different cutaneous receptors (receptors of the skin) respond to touch, pressure, heat, cold, and pain.

Nociceptors

Nociceptors detect pain. Pain is defined as a stimulus that causes or is about to cause tissue damage. Nociceptors consist of free nerve endings located throughout the body, especially near surfaces. Different nociceptors may respond to extremes in temperature, very intense pressure, or specific chemicals (including some that are released by injured cells).

Touch Receptors

The skin contains a variety of touch receptors. They are mechanoreceptors that respond to different physical stimuli.

For Information

Thermoreceptors: are naked dendrite endings of sensory neurons. They detect fall and rise in temperature. Cold receptors are located immediately below the epidermis, while warm receptors are located slightly deeper, in the dermis. Thermoreceptors are also found within the hypothalamus of the brain, where they detect the temperature of the blood and thus monitor the body's internal (core) temperature.

i- **Meissner's corpuscles** are endings of sensory neurons surrounded by a capsule. They are found in the upper layer of the skin (especially in lips, fingertips, palm, and soles). They detect light touch and vibration.

ii- **Hair follicle receptors** are endings of neurons and are located around the base of hair follicles. They detect the movement of hairs, which occur due to mechanical or thermal stimuli.

iii- **Merkel cells** are oval-shaped receptors in the deepest layer of epidermis. They detect light touch and are present in highly touch-sensitive areas like fingertips.

iv- **Pacinian corpuscles** are sensory neuron endings, surrounded by a capsule. They are located deeper in the skin. They detect deep pressure and vibration.

v- **Ruffini endings** are also sensory neuron endings enclosed in capsule. They are located in the dermis. They detect sustained pressure and stretching.

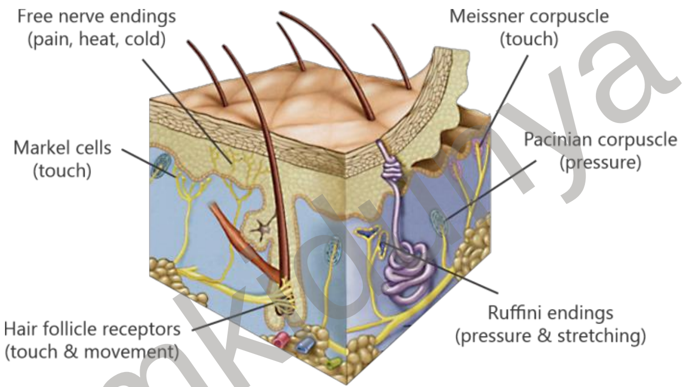


Figure 15.19: Touch and pain receptors

These touch receptors generate and transmit impulses via sensory neurons to the spinal cord and then to brain, where the signals are processed to create the sensations of touch.

15.7- Effects of Drugs on Nervous Coordination

> **For Information**
> All narcotics are psychoactive drugs, but all psychoactive drugs are not narcotics.

A **drug** is defined any substance (other than food) that is used to prevent, diagnose, treat, or relieve symptoms of a disease or abnormal condition. Drugs can also affect the working of brain and cause changes in mood, awareness, thoughts, feelings, or behavior. A **psychoactive drug** is a type of drug that alters brain functions, resulting in changes in mood, perception, consciousness, and behaviour. Examples of psychoactive drugs include alcohol, caffeine, nicotine, and illicit drugs such as cocaine, heroin etc. A **narcotic drug** (or simply narcotic) is a type of opioid drug that is used for pain relief and has a high potential for addiction and abuse. Narcotics include drugs such as morphine, codeine, and oxycodone.

15.7.1- Addiction, Tolerance and Withdrawal Symptoms

The abuse of psychoactive drugs often leads to dependence. **Dependence** is a state in which a person relies on a drug physically or emotionally in order to function. Dependence often results in addiction. Drug **addiction** means the disorder of uncontrollable drug desire and use despite its negative effects.

As a person continues to use a drug, the body becomes adaptive and less sensitive to its effects. This condition is called drug **tolerance**. After drug tolerance, the person may require higher doses to achieve the same level of response. This leads to an increased addiction.

When addicts stop taking an addictive drug, they experience **withdrawal symptoms**. Withdrawal symptoms may include vomiting, headache, insomnia, breathing difficulties, depression, mental instability, and seizures.

Changes in Nervous System during Addiction and Tolerance

Addictive drugs affect the regions of brain which regulate pleasure and motivation. When these drugs reach brain, the presynaptic neurons release dopamine neurotransmitter, which produces feelings of pleasure and reward. The drug molecules block the dopamine reabsorption receptors in presynaptic neuron. So, large amount of dopamine accumulates in synaptic cleft. Brain adapts and reduces the number of dopamine receptors on postsynaptic neuron. This leads to tolerance i.e.; the user requires higher doses of drug to achieve the same pleasure or reward. When the drug is stopped abruptly, dopamine release becomes normal but due to less receptors, the postsynaptic neuron is less-stimulated and it leads to withdrawal symptoms.

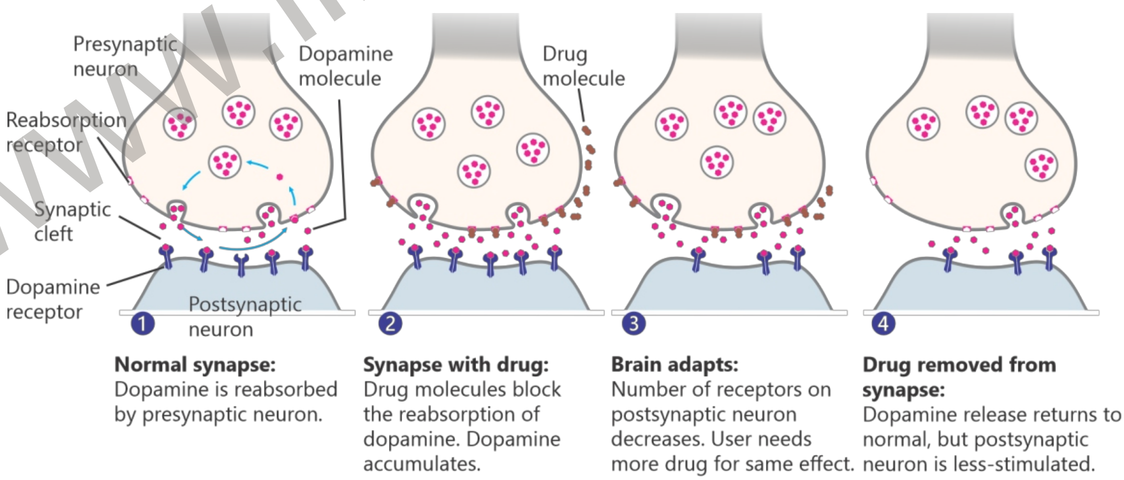


Figure 15.20: Neural changes during drug usage, addiction, tolerance, and withdrawal

Addiction and Tolerance of Caffeine

Caffeine is found in many common beverages, such as coffee, tea, and energy drinks. It can block the action of a neurotransmitter called adenosine, which promotes sleep and relaxation. As a result, caffeine increases alertness and energy levels.

Regular caffeine use can lead to tolerance. So, the user requires higher doses to achieve the same level of alertness. If caffeine use is stopped abruptly, withdrawal symptoms such as headaches and fatigue can occur.

Addiction and Tolerance of Nicotine

Nicotine is highly addictive stimulant present in tobacco products (cigarettes, cigars, and smokeless tobacco). It binds to nicotine receptors in brain. These receptors release dopamine and other neurotransmitters to produce pleasurable feelings.

Regular nicotine use leads to tolerance. So, the user requires higher doses to achieve the same level of pleasure. When nicotine use is stopped abruptly, the user experiences withdrawal symptoms, such as irritability, anxiety, and cravings. Long-term nicotine use is also associated with a variety of negative health effects, including an increased risk of cancer, heart disease, and respiratory problems.

15.7.2- Use and Abuse of Drugs

The term "use" refers to the appropriate or prescribed use of drugs for medical purposes. The term "abuse" generally refers to the inappropriate use of psychoactive drugs. The abuse of common psychoactive drugs is described next.

1- Heroin

It is a highly addictive opioid drug that is derived from the opium poppy plant. It is injected, smoked, or snorted. It produces false senses of euphoria (intense excitement and happiness) and relaxation. Its use quickly leads to dependence and addiction. It has a range of negative physical and mental health effects, including respiratory depression, infections, and mental health disorders.

2- Cannabis

Cannabis is a psychoactive drug that is made from dried flowering tops, leaves and stem of Indian hemp plant *Cannabis sativa*. It includes drugs like marijuana and hashish. It can be smoked, vaporized, or consumed in edibles. The use of cannabis produces sense of relaxation, euphoria, altered perception, and increased appetite. Its long-term use leads to negative effects, such as impaired cognitive function, respiratory problems, and mental health disorders.

3- Nicotine

Nicotine is a highly addictive drug found in tobacco products, including cigarettes, cigars, and smokeless tobacco. Its use leads to addiction and dependence, as well as a range of negative physical and mental health effects, including respiratory problems, cancers, cardiovascular disease, and mental health disorders.

4- Alcohol

Alcohol is a psychoactive drug that is commonly consumed in various forms, such as beer, wine, and spirits. It produces feelings of relaxation and euphoria (intense happiness or excitement). Its negative effects include impaired cognitive and motor functions, liver diseases, cardiovascular diseases, and mental health disorders.

5- Inhalants

Inhalants, such as nail polish remover and glue, are psychoactive substances that are inhaled to produce senses of euphoria, relaxation, and altered perception. They can produce a range of negative health effects, such as respiratory problems, cognitive impairment, and neurological damage.

Withdrawal Symptoms of Drug Abuse

The withdrawal symptoms of drug abuse include anxiety, depression, fatigue, agitation, mood swings, shakiness or tremors, headache, sweating, nausea, loss of appetite, insomnia, rapid heart rate, high blood pressure, hallucinations (visual, auditory, or tactile), and seizures.

15.8- Disorders of Nervous System

15.8.1- Vascular Disorders

Vascular disorders of nervous system are the conditions in which the blood vessels of brain and spinal cord are affected. Examples include stroke and cerebral venous thrombosis.

Stroke

A stroke means damage in brain cells due to interruption in the blood supply to a part of brain. Such interruption may be due to a blockage or a rupture of a blood vessel of brain. **Causes** of stroke include high blood pressure, smoking, diabetes, high cholesterol, obesity, and family history of stroke. **Symptoms** of a stroke vary depending on the area of brain affected. Paralysis occurs on the side of body opposite the cerebral infarction (death of tissue). Other common symptoms are aphasia

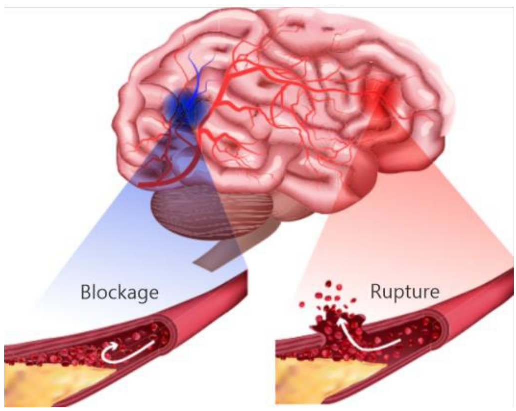


Figure 15.21: Main types of strokes

(inability to express through words); sudden trouble in seeing and walking, dizziness, loss of balance; and severe headache

For Information
Ischemic stroke occurs when the brain's blood vessels become narrowed or blocked
Haemorrhagic stroke occurs when a blood vessel in brain leaks or ruptures.
Transient ischemic attack (ministroke) occurs by a temporary decrease in blood supply to part of brain, which may last as little as five minutes.

Treatment should be given as soon as possible to minimize damage to brain. Treatment may include: medications (such as blood thinners, clot-dissolving drugs, or antihypertensive drugs); surgery to remove a blood clot or repair a ruptured blood vessel; and rehabilitation (to help patients recover physical and cognitive function)

15.8.2- Infectious Disorders

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

Meningitis

Meningitis is an inflammation of the meninges due to infection. **Causes:** Bacterial meningitis is the most severe and life-threatening. Viral meningitis is usually less severe. Fungal meningitis is rare and usually occurs in people with weak immune systems. Other causes include parasitic infections. **Symptoms** include stiffness in the neck, headache, and fever. In severe cases, meningitis may also cause paralysis, or coma. **Treatment:** Bacterial meningitis requires immediate treatment with antibiotics. Viral meningitis is usually self-limiting, although antiviral medications may be used. Fungal meningitis requires long-term treatment with antifungal medications. Vaccines are available for some of the bacterial meningitis, which can prevent infection.

15.8.3- Structural Disorders

Structural disorders of nervous system result from abnormalities or damage to the physical structure of nervous system. Examples include brain tumour, and spinal cord injuries.

Brain Tumour

A brain tumor is an abnormal growth or mass of cells in brain. Brain tumors can be benign (non-cancerous) or malignant (cancerous). Brain tumour can arise from glial cells or from the neurons themselves. **Causes:** The exact cause of brain tumors is unknown, but risk factors include exposure to radiation, family history, and certain genetic mutations. **Symptoms** depend on the location of tumour. These may include headaches, severe nerve pain, paralysis, seizures, and coma. **Treatment:** Common treatments include surgery, radiation therapy, and chemotherapy.

15.8.4- Functional Disorders

Functional disorders are the conditions that affect the normal functioning of the nervous system without any apparent structural or organic cause.

Headache

Headache is a common condition characterized by pain or discomfort in head or neck. Primary headaches are due to headache itself and not due to another cause e.g., migraine, tension headache. Secondary headaches are due to an underlying structural problem in head or neck such as bleeding in the brain, tumour, meningitis etc. **Treatments** include pain-killing (analgesic) medicines, and reducing stress, getting regular exercise, and improving sleep habits.

For Information
Migraine is a type of headache that is characterized by intense, throbbing pain on one side or in one region of head. Migraines are caused by changes in the brain and blood vessels, which lead to inflammation and pain.

15.8.5- Degenerative Disorders

These are the conditions in which there is progressive deterioration of nerve cells in brain, spinal cord, or peripheral nerves. Examples include **Parkinson's disease** (progressive death or weakening of the neurons in brain that produce dopamine leading to movement issues and cognitive changes), **Huntington's disease** (progressive damage to neurons in the brain, leading to movement disorders, cognitive decline, and psychiatric symptoms), multiple sclerosis (autoimmune disease of the CNS in which myelin sheath is damaged leading to vision loss, pain, fatigue, and impaired coordination), and Alzheimer's disease.

Alzheimer's Disease

Alzheimer's disease is a progressive degenerative brain disorder that affects memory, thinking, and behaviour. It leads to dementia in older adults. Its onset usually occurs in aged people, but it is not particularly associated with aging. **Causes:** It is due to a combination of genetic, environmental, and lifestyle factors. **Symptoms** typically begin with mild memory loss and confusion and progress to more severe cognitive impairment, including difficulty with language, problem-solving, and completing familiar tasks. **Treatment:** There is no cure for Alzheimer's disease, but there are medicines to slow its progression and to improve memory and cognitive function.

15.9- Diagnostic Tests for Nervous Disorders

A number of tests have been developed to diagnose the disorders of nervous disorders.

15.9.1- Electroencephalography (EEG)

EEG test measures the electrical activity of brain. Its basic principle is based on detecting the electrical nerve impulses being transmitted among the neurons.

Procedure: During EEG, metal electrodes are attached to the scalp. These electrodes are connected to an amplifier. The amplifier magnifies the electrical signals detected by the electrodes. The signals are then recorded and displayed as a series of **waveforms** on a computer screen or paper.

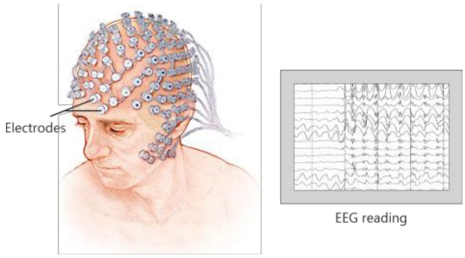
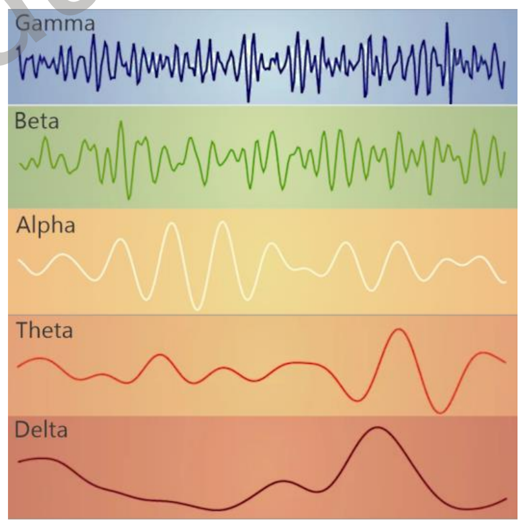


Figure 15.22: Electroencephalography

Uses: EEG is done to evaluate various neurological conditions, including seizures, epilepsy, and brain tumors. It is painless and does not require sedation or anaesthesia.

For Information
Each wave of EEG is associated with different states of brain activity.

- Gamma waves are associated with high perception, learning, problem-solving activities.
- Beta waves are associated with normal alert state and active thinking.
- Alpha waves show physically and mentally relaxed state.
- Theta waves show deep sleep (dreams and reduced consciousness).
- Delta waves show deepest sleep and dreaming.



15.9.2- Computed Tomography (CT)

CT scan is an imaging technique that uses X-rays and computer processing to generate detailed images of body's internal structures. The basic principle of CT is based on the fact that different tissues in body have varying degrees of X-ray absorption. These differences can be used to create detailed images of internal structures.

Procedure: During a CT scan, the patient is on a motorized table that slides into a doughnut-shaped machine called a **gantry**. The gantry contains an X-ray tube that rotates around the patient. Multiple detectors on the opposite side of gantry record the absorption of X-rays through different tissues. This information is then used by a computer to construct a detailed, cross-sectional image of the internal structures.

Uses: CT scans are useful for imaging soft tissues, such as brain, lungs, and abdomen, as well as for detecting abnormalities in bone structure. CT scans are used to diagnose cancers, infections, and injuries.

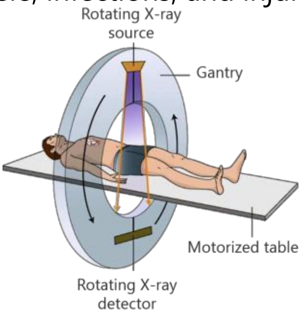


Figure 15.23: Computed tomography scan

15.9.3- Magnetic Resonance Imaging (MRI)

This imaging technique uses a strong magnetic field and radio waves to produce detailed images of body's internal structures. The basic principle of MRI is based on the fact that different tissues in the body have varying amounts of hydrogen atoms, which have magnetic properties.

Procedure: The patient is on a motorized table that slides into a large tube-like machine called a **scanner**. The scanner contains a powerful magnet that creates a strong magnetic field around the patient's body. Radio waves are then used to cause the hydrogen atoms in the body to produce a signal. These signals are then detected by a receiver. This information is used by a computer to construct a detailed, three-dimensional image of the internal structures.

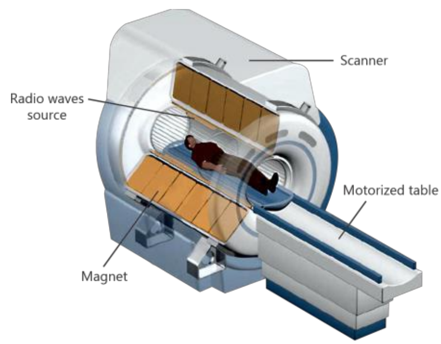


Figure 15.23: Magnetic Resonance Imaging

Uses: MRI is used for imaging soft tissues, such as brain, spinal cord, and internal organs, as well as for detecting abnormalities in blood vessels and certain types of tumors.

EXERCISE

SECTION 1: MULTIPLE CHOICE QUESTIONS

1. Neurotransmitter receptors are located on;
   (a) Nuclear membrane (b) Nodes of Ranvier
   (c) Postsynaptic membrane (d) Myelin sheath
2. Which neurotransmitter is released by all motor neurons at their synapses with skeletal muscles?
   (a) Acetylcholine (b) GABA (c) Norepinephrine (d) Dopamine
3. Which part of the nervous system prepares the body during emergency?
   (a) Central nervous system (b) Sympathetic nervous system
   (c) Parasympathetic nervous system (d) Sensory pathway
4. Which of these is closest to the brain tissue?
   (a) Acetylcholine (b) Arachnoid (c) Pia mater (d) Cranium
5. In meninges, the cerebrospinal fluid is present between;
   (a) Skull and dura mater (b) Dura mater and arachnoid
   (c) Arachnoid and pia mater (d) Pia mater and brain or spinal cord
6. Which is NOT a function of cerebrospinal fluid?
   (a) Cushions brain (b) Produces hormones
   (c) Transport nutrients to brain (d) Protects the spinal cord
7. During saltatory conduction, the nerve impulse jumps from one ________ to another.
   (a) Axon (b) Synapse (c) Myelin sheath (d) None of Ranvier
8. In a resting neuron, which of these ions has the highest permeability?
   (a) Chloride (b) Sodium (c) Potassium (d) Calcium
9. If nerve impulses in a neuron 'a' are travelling faster than the impulses in neuron 'b', what might be the reason?
   (a) Hyperpolarization in neuron 'a'
   (b) Neuron 'a' is myelinated
   (c) There is a high concentration of sodium ions inside neuron 'a'
   (d) Neuron 'a' is thicker than neuron 'b'
10. Dorsal root of spinal nerve contains?
    (a) Sensory neurons (b) Inter-neurons
    (c) Motor neurons (d) Sensory and motor neurons
11. Which ions cause the presynaptic vesicles to fuse with the presynaptic membrane and release a neurotransmitter into the synaptic area?

(a) Sodium (b) Potassium (c) Calcium (d) Iodine

12. The most common cause of dementia is;
    (a) Alzheimer's disease (b) Brain tumour
    (c) Stroke (d) Meningitis
13. Nociceptors are specialized receptors that detect:
    (a) Light touch (b) Deep pressure (c) Pain (d) Taste
14. Which receptor detects deep pressure and vibration?
    (a) Meissner's corpuscles (b) Pacinian corpuscles
    (c) Merkel cells (d) Ruffini endings
15. Which of the following is a narcotic drug used for pain relief?
    (a) Caffeine (b) Morphine (c) Alcohol (d) Nicotine
16. Withdrawal symptoms of drug abuse include:
    (a) Improved concentration (b) Headache, nausea, and anxiety
    (c) Increased euphoria (d) Faster drug metabolism
17. Caffeine increases alertness by:
    (a) Increasing dopamine receptors (b) Blocking adenosine receptors
    (c) Stimulating nociceptors (d) Enhancing serotonin degradation

SECTION 2: SHORT QUESTIONS

1. Enlist the basic elements of nervous coordination.
2. Define receptors and effectors with examples.
3. State the path of a message transmitted through the nervous system.
4. Define nerve impulse.
5. Name the factors responsible for the resting membrane potential of neuron.
6. What are the main components of the nervous system?
7. Define narcotic drugs and give examples.
8. Briefly describe the effects of drug addiction and tolerance on the functioning of nervous system.
9. State the causes, symptoms and treatment of stroke and meningitis.
10. State the causes, symptoms and treatment of brain tumor.
11. State the causes, symptoms and treatment of Alzheimer disease.
12. Differentiate between;
    - Axon and dendrite
    - Sensory neuron, inter-neuron, and motor neurons
    - Myelinated and nonmyelinated neurons
    - White matter and grey matter
    - Cranial and spinal nerves

- Resting membrane potential and active membrane potential
- Polarization and depolarization
- Repolarization and hyperpolarization
- Presynaptic and postsynaptic neuron
- Synaptic knob and synaptic vesicles
- Somatic and autonomic nerves system
- Drug addiction and drug tolerance

SECTION 3: LONG QUESTIONS

1. Explain the structure of a neuron.
2. Explain the function of the three types of neurons with the help of a reflex arc.
3. Describe the generation and transmission of nerve impulse.
4. Describe polarization, depolarization and hyperpolarisation of neuron membrane.
5. Describe the saltatory conduction of nerve impulse.
6. Describe the structure of synapse.
7. Explain synaptic transmission of nerve impulse.
8. Classify neurotransmitters as inhibitory and excitatory and list some common examples.
9. Explain briefly the functions of major parts of brain.
10. Describe the structure of human brain and compare it with that of spinal cord.
11. Explain the types and functions of autonomic nervous system.
12. Write a detailed note on the receptors for smell.
13. Explain the structure of the receptors for taste.
14. Describe the receptors for touch and pain.
15. Describe the use and abuse of narcotic drugs with examples.
16. What is meant by drug addiction and drug tolerance? Explain with reference to caffeine and nicotine.
17. Explain the classification of nervous disorders with examples.
18. Explain the principles and use of EEG, CT scan and MRI.

INQUISITIVE QUESTIONS

1. Predict from every day experience what various kinds of receptor can be found in human body.
2. Conceptualize the electrical activity of brain, which can be recorded using magnets and tomography.
3. Justify the way nervous system helps to coordinate complex and intricate movements of hand to play a piano, or write alphabets.
4. Justify that the development of a modern computer is in fact a product of the understanding of the way nervous coordination occurs in complex organisms like humans.