NERVOUS COORDINATION

Chapter 17

Major Concept

In this Unit you will learn:

- Nervous system of man
- Steps involved in nervous coordination.
- Neuron structure and types
- Nerve impulse
- Transmission of action potential between cells
- Basic organization of human nervous system
- Sensory receptors
- Effect of drugs on nervous coordination
- Disorders of nervous system
- Diagnostic tests for nervous disorders

NERVOUS COORDINATION

All animals except sponges use a network of nerve cells to gather information about the body's condition and the external environment, to process and integrate that information, and to send commands to the body's muscles and glands.

17.1.1 Steps involved in nervous coordination.

The system of the body that provides communication (coordination) through electrical and chemical signals is called the **nervous system**. Nervous coordination comprises highly specialized cells, called **neurons**. As the fundamental unit of the nervous system, each neuron must perform five functions.

- Receive information from the internal or external environment or from other neurons.
- Integrate the information it receives and produce an appropriate output signal.
- Conduct the signal to its terminal ending, which may be some distance away.
- Transmit the signal to other nerve cell, glands or muscles.
- Coordinate the metabolic activities that maintain the integrity of the cell.

17.1.1.1 Receptors as Transducers

The detection of the energy of a stimulus by sensory cells, most sensory receptors are specialized neurons or epithelial cells that exist singly or in groups with other cell types within sensory organs, such as the eye and ears. All receptors are **Transducers** "structures that convert signals from one form to another form". On the type of energy they detect (Transduce), receptors fall into five categories. **Mechanoreceptors** are stimulated by physical deformation caused by such stimuli as pressure, touch, stretch, motion and sound all forms of mechanical energy. **Pain receptors (Nociceptors)** a stimulus that causes or is about to cause tissue damage is perceived as pain. The receptors that transmit impulses perceived as pain are called pain receptors or nociceptors. **Thermoreceptors** these receptors are responding to either heat or cold help in regulation of body temperature by signaling both surface and body core temperature. **Chemoreceptors** These receptors transmit information about the total solute concentration in a solution and specific receptors that respond to individual kinds of molecules, **osmoreceptors** in human brain (hypothalamus) detect changes in total solute concentration of the blood and stimulate thirst when osmolarity increases. Chemoreceptors found in nasal epithelium are **olfactory receptors** (smell) chemoreceptor found in tongue for tastes are **gustatory receptors**. **Photoreceptors** these receptors detect light stimuli, are organized in eyes (Rods and Cones).

All sensory inputs from receptors are received by the central nervous system (CNS). This collected information is further processed or analyzed for appropriate response by special type of neurons called interneurons.

Effectors

Effectors are generally muscles or glands. An effector produces a response to a stimulus. Effectors receive commands from the central nervous system to produce a response.

17.1.2 The Path of a Message Transmitted to the CNS

The CNS, which is made up of the brain and spinal cord, receives signals and reacts by designating particular assigned neurons through effector organs.

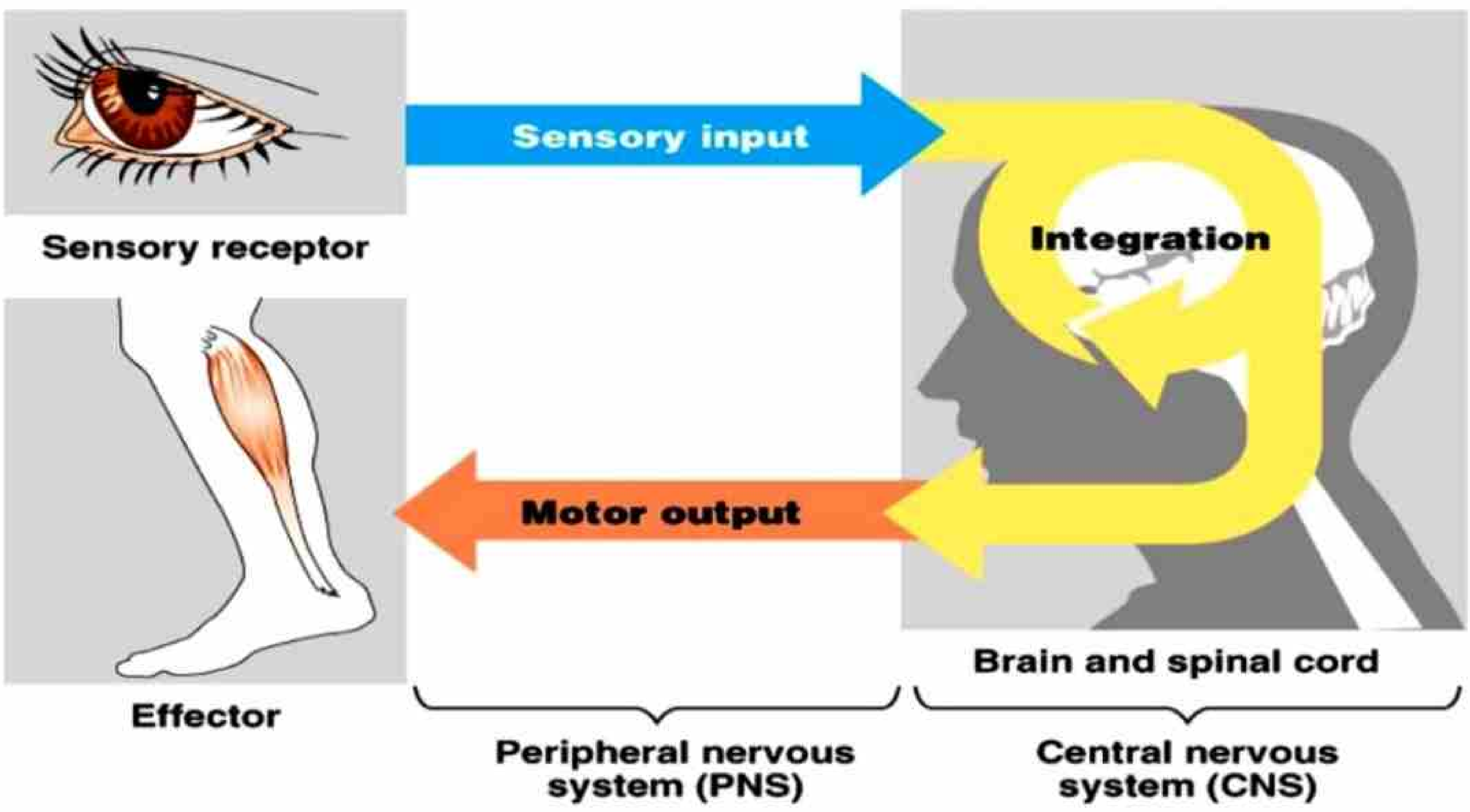


Fig.17.1 Pathway of Nervous Coordination

The messages are picked up by specific sensors, which could be the sensory neuron's nerve ends in an organ or another type of cell that signals the sensory neuron. A nerve impulse that goes to the brain or spinal cord is started by the sensory neuron. Sensors in the eyes, ears, muscles, skin, and other body components send messages to the spinal cord or brain via sensory neurons. In agreement with that, the effector organ receives a message from the brain or spinal cord via a motor neuron.

17.1.2. Neurons

The neuron is a functional and structural unit of the nervous system and is specialized for transmitting signals from one location in the body to another.

Structure of Neuron

A neuron has a relatively large cell body (soma) containing the nucleus and variety of cell organelles in cytoplasm, Nissl's bodies or granules are group of ribosomes and rough endoplasmic reticulum associated with protein synthesis. It is covered with membrane called **neurolemma**, one of the main functions of the cell body is to manufacture **neurotransmitters**, which are chemicals stored in secretory vesicles at the ends of axon.

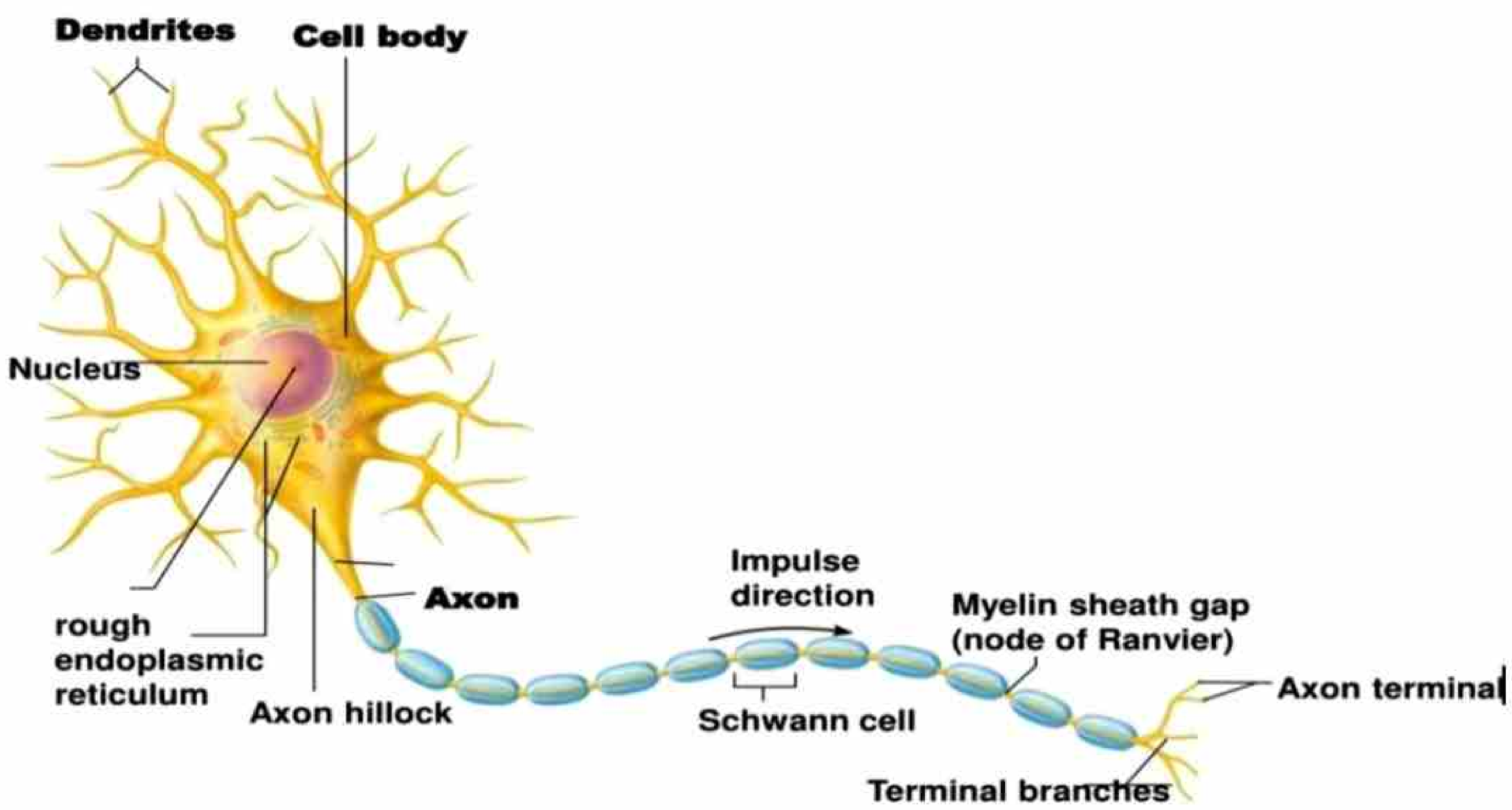


Fig.17.2 Structure of Neuron

Dendrites (Gr: Dendron = Tree)

Branched tendrils that extend outward from the cell body are specialized to respond to signals from other neurons or from the external environment, their branched form provides a large surface area to receive these signals.

Axon (Gr: Axon = Axis)

A long fiber extends outward from the cell body, making neurons the longest cell in the body. The cytoplasm of an axon is called an axoplasm covered with axolemma. The axon is primarily involved in carrying the electrical signals from the cell body to the neuron ending and transmitting it to other neuron or effectors.

Neuroglia (Glial cells)

Structurally and functionally neurons are supported by supporting cells, which are collectively called neuroglia. They serve a variety of functions, including supplying the neurons with nutrients, removing wastes from neurons, guiding axon migration and providing immune functions. Neuroglia are of two types **Schwann cells** and **Oligodendrocytes**.

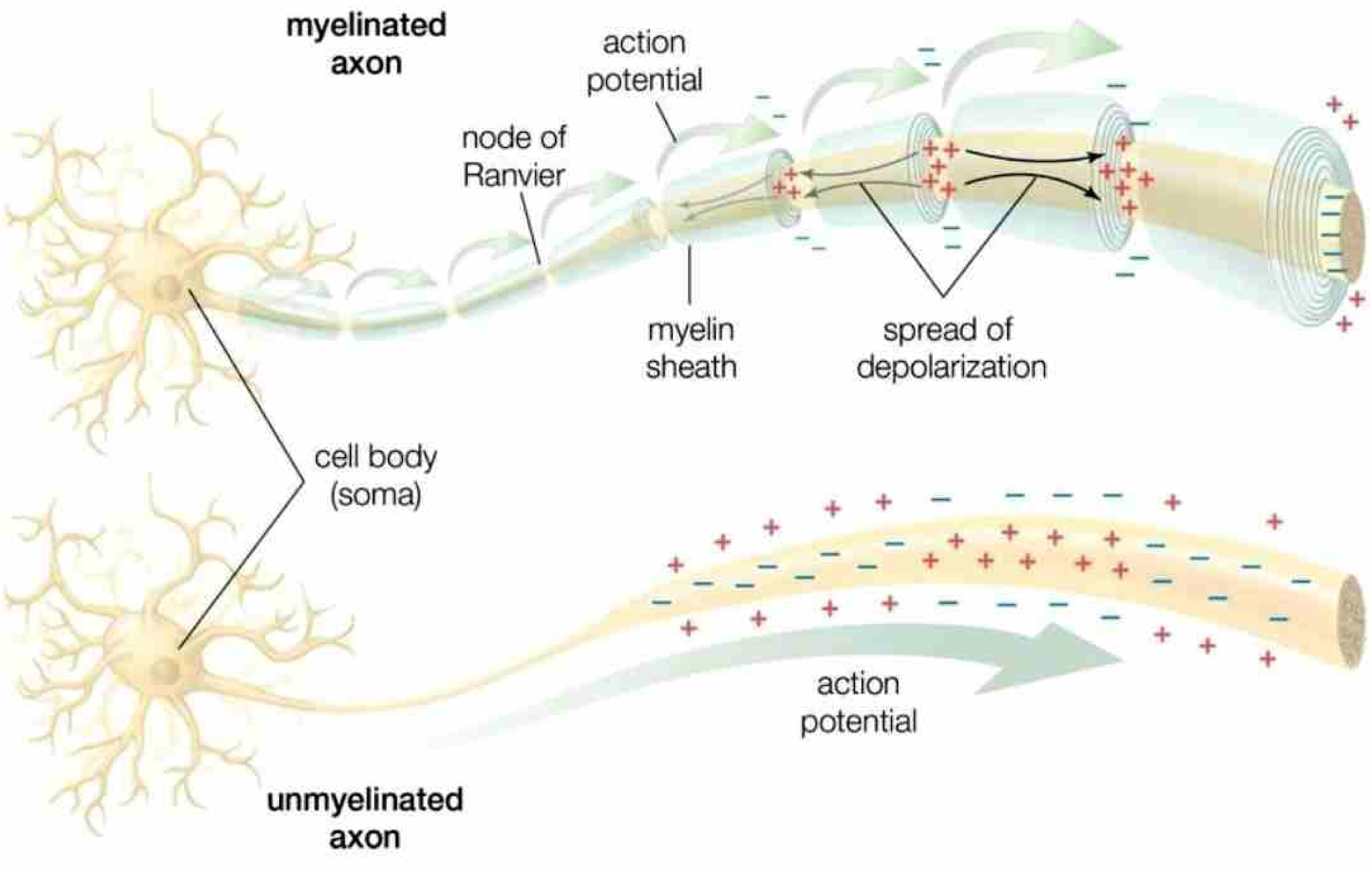


Fig.17.3 Myelinated and Unmyelinated Neuron

Schwann cells produce myelin in peripheral nervous system (PNS) and oligodendrocytes produce myelin in central nervous system (CNS). Axon that have myelin sheath are said to be myelinated fibers, and those that don't are unmyelinated fiber. A non-myelinated part of axon between two Schwann cells is called **Node of Ranvier** or **Neurofibril Nodes**.

Types of Neurons

Functionally, there are three types of neurons,

Sensory Neuron (Afferent neuron)

These neurons are generally found in the sensory organs, such as the eyes, nose, skin, tongue and ear. These nerve cells are triggered by the chemical and physical inputs of our environment, such as sound, heat, and light. The sensory neurons facilitate the movement of sensory impulses from receptors to the central nervous system (CNS).

Motor Neuron (Efferent neuron)

These neurons are the ones that facilitate the transmission of motor impulses from the central nervous system to the effectors. These types of neurons play a major role in the voluntary and involuntary movement of the body.

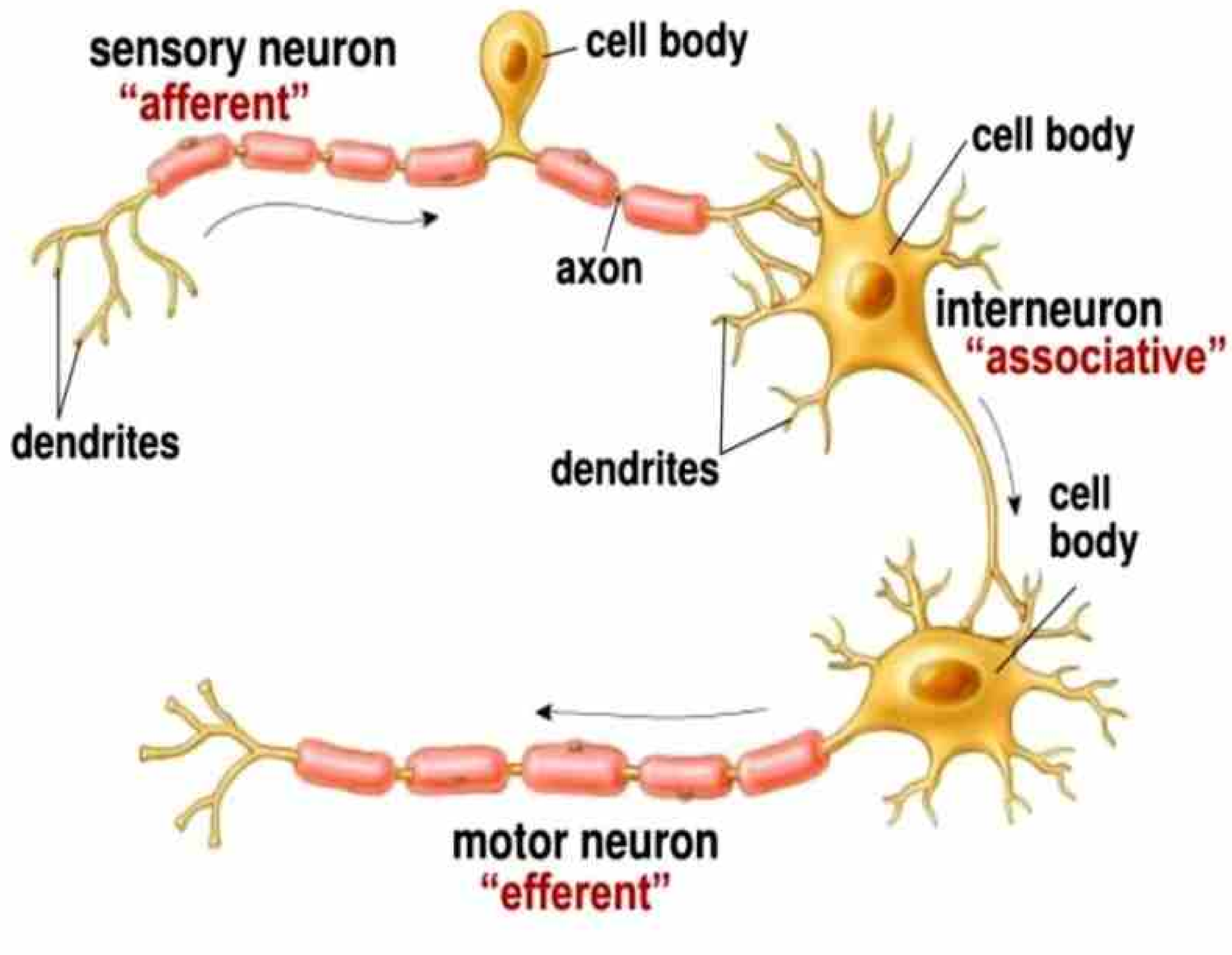


Fig.17.4 Types of Neuron

Interneuron (Association neuron)

These neurons act as a mediator between sensory neurons, motor neurons and the central nervous system. It helps in the smooth transmission of signals.

Reflex action

Each sensory neuron conveys a signal, from a sensory receptor to a motor neuron, which in turn sending signals to an effector the result is often a simple, automatic response called a reflex or **reflex action**. Pathway along which impulses are transmitted from a receptor to an effector called **reflex arc**. Examples of human reflexes include the familiar knee jerk and pain withdrawal reflexes. The pain withdrawal reflex uses one neuron of each type. Reflexes of this sort do not require the interneurons (Brain), although we know, other pathways inform the brain of pricked fingers.

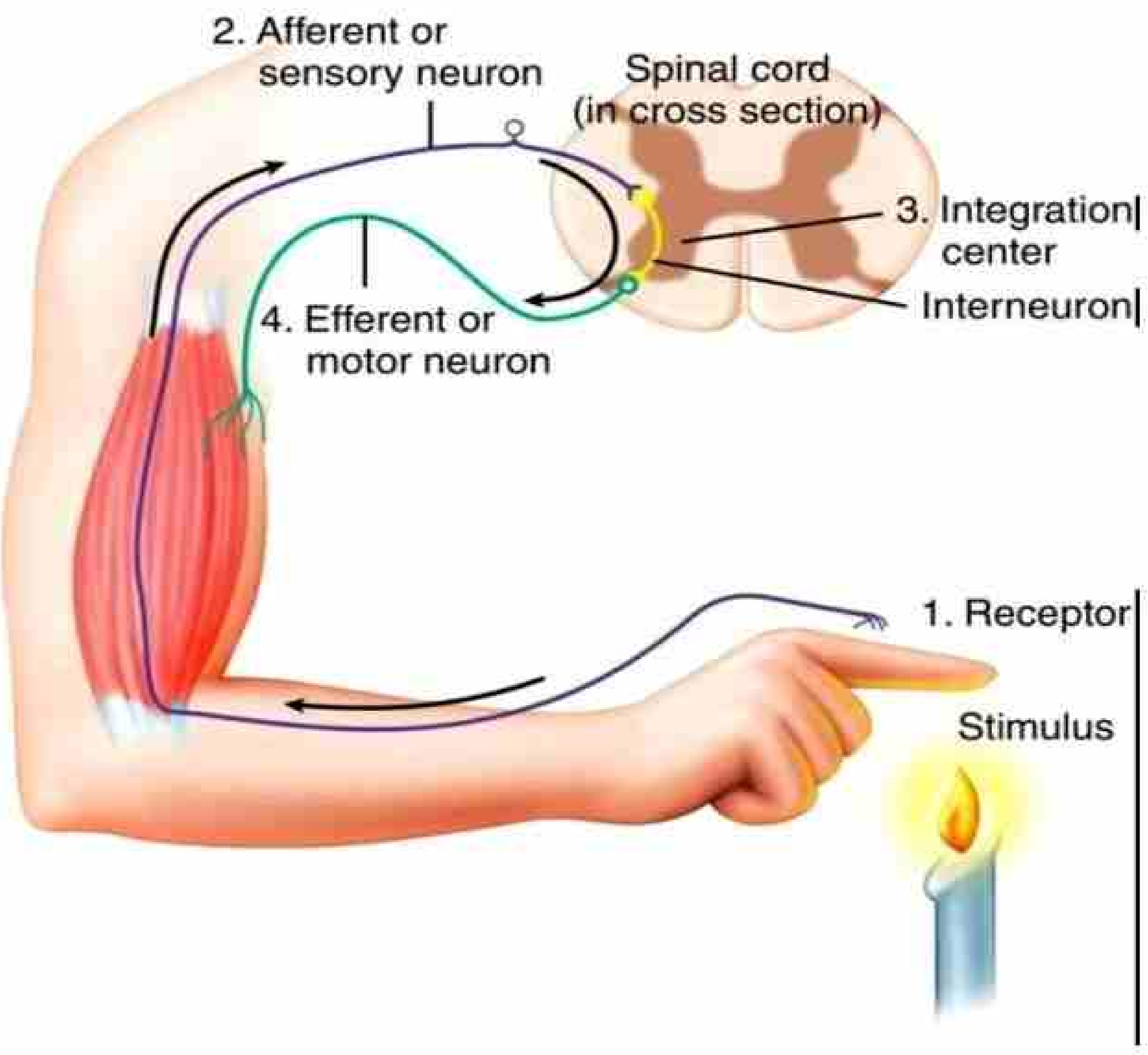


Fig.17.5 Reflex action

17.1.3 Nerve Impulse

Nerve impulse is an electrical signal that depends on the flow of ions across the membrane of a neuron. The signal begins as a change in the electrical gradient across the cell's plasma membrane.

Generation and transmission and nerve impulse

All living cells have an electrical charge difference across their neurolemma. Differences in charge give rise to an electrical voltage gradient across the membrane. The voltage measured across the neurolemma is called **membrane potential.**

The nerve impulse is the electrochemical transmission of messages through neurons. It travels through dendrites or axon due to the voltage proteinic gated channels in the neurolemma. These channel open and close in response to the electrical voltage. Neurolemma is **polarized** and from inside negatively charged with respect to the outside due to distribution of ions.

Distribution of Ions

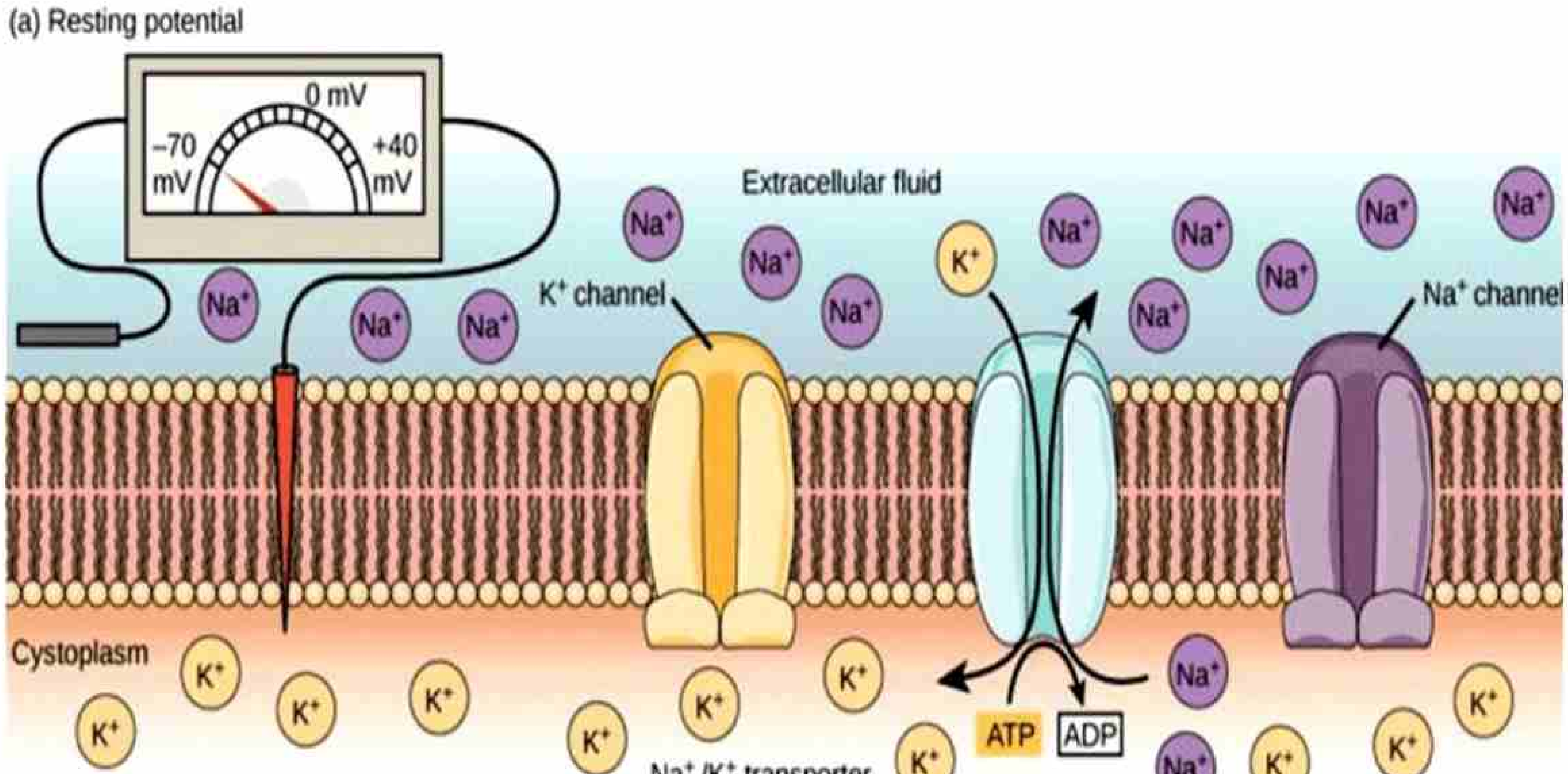
Polarization means the intracellular major positive ions are potassium (K^+) and sodium (Na^+) are major extracellular ions. The concentration of potassium (K^+) is 30 times greater inside the fluid than outside and the concentration of sodium (Na^+) is nearly 10 times greater outside than inside the fluid. Distribution is created largely by the sodium, potassium pumps which actively transport sodium out of the cell and potassium inside the cell. The channels in membrane are specific to ions and allow only one kind of ions and restrict other ions to pass through it. The negative ions inside the neurolemma are chloride (Cl^-), PO_4^{-2}, SO_4^{-2} and some proteins that are produced inside and cannot diffuse outside the cell.

Resting membrane potential (RMP)

A resting nerve cell is the condition when it is not being stimulated to send a nerve impulse. The resting membrane is only slightly permeable to these ions while the threshold established during action potential. The potential difference the positive and negative charges across the cell membrane are called the membrane potential and are measured in millivolts. The resting membrane potential has a value of -70 millivolts. The negative sign is related to the inside excessive negative ions. Neurons are excitable means they respond to changes in their surroundings. These changes or stimuli affect the membrane potential. If the membrane potential becomes more negative than the resting potential the membrane becomes **hyperpolarized** and if the membrane becomes less negative than the resting potential, the membrane depolarized. Sufficient **depolarization** results in an action potential.

When the membrane is at rest, K^+ ions accumulate inside the cell due to a net movement with the concentration gradient. The negative resting membrane potential is created and maintained by increasing the concentration of cations outside the cell (in the extracellular fluid) relative to inside the cell (in the cytoplasm). The negative charge within the cell is created by the cell membrane being more permeable to potassium ion movement than sodium ion movement. In neurons, potassium ions are maintained at high concentrations within the cell while sodium ions are maintained at high concentrations outside of the cell. The cell possesses potassium and sodium leakage channels that allow the two cations to diffuse down their concentration gradient.

However, the neurons have far more **potassium leakage channels** than **sodium leakage channels**. Therefore, potassium diffuses out of the neurolemma at a much faster rate than sodium leaks in. Because more cations are leaving the cell than are entering, this causes the interior of the cell to be negatively charged relative to the outside of the neurolemma. The actions of the sodium potassium pump help to maintain the resting potential, once established. Recall that sodium potassium pumps brings two K^+ ions into the cell while removing three Na^+ ions per ATP consumed. As more cations are expelled from the cell than taken in, the inside of the cell remains negatively charged relative to the extracellular fluid. It should be noted that chlorine (Cl^-) tends to accumulate outside of the cell because they are repelled by negatively charged proteins within the cytoplasm.



At the resting potential, all voltage-gated Na^+ channels and most voltage-gated K^+ channels are closed. The Na^+/K^+ transporter pumps K^+ ions into the cell and Na^+ ions out.

Fig.17.6 Resting membrane potential

Action Membrane Potential (AMP)

Action potential is triggered when any stimulus received by the neuron. The sodium channels open instantly and Na^+ ions rushed inside the cell depending upon the intensity of stimulus. The membrane potential changes from its resting value, depolarize and becomes positive on the inside the membrane. The action potential may reach up to 50 mV. Then the gates of sodium closed and potassium channels open which diffuses out of the membrane. As potassium goes out the membrane potential becomes negatively charged once again and repolarize. This return to the resting state usually takes from 10 to 30 milliseconds.

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

Depolarization

It refers to a graded potential state because a threshold stimulus of about -55 mV causes a change in the membrane potential. The threshold stimulus must be strong enough to change the resting membrane potential into action membrane potential. This results in the alternation in the electro-negativity of the membrane because the stimulus causes the influx of sodium ions (electropositive ions) by 10 times more than in the resting state. For this, sodium voltage-gated channels open. The action potential state is based on the “All or none” method and has two possibilities:
If the stimulus is not more than the threshold value, then there will be no action potential state across the length of the neurolemma.
If the stimulus is more than the threshold value, then it will generate a nerve impulse that will travel across the entire length of the neurolemma.

Voltage-gated sodium channel Open channel carries an influx of Na^+ ions, giving rise to depolarization. As the channel becomes closed or inactivated, the depolarization ends. After a cell has established a resting potential, that cell has the capacity to undergo depolarization. During depolarization, the membrane potential rapidly shifts from negative to positive. For this rapid change to take place within the interior of the cell, several events must occur along the neurolemma of the cell. While the sodium–potassium pump continues to work, the voltage-gated channels that had been closed while the cell was at resting potential are opened in response to an initial change in voltage. As the sodium ions rush back into the cell, they add positive charge to the cell interior, and change the membrane potential from negative to positive. Once the interior of the cell becomes more positively charged, depolarization of the cell is complete, and the channels close again.

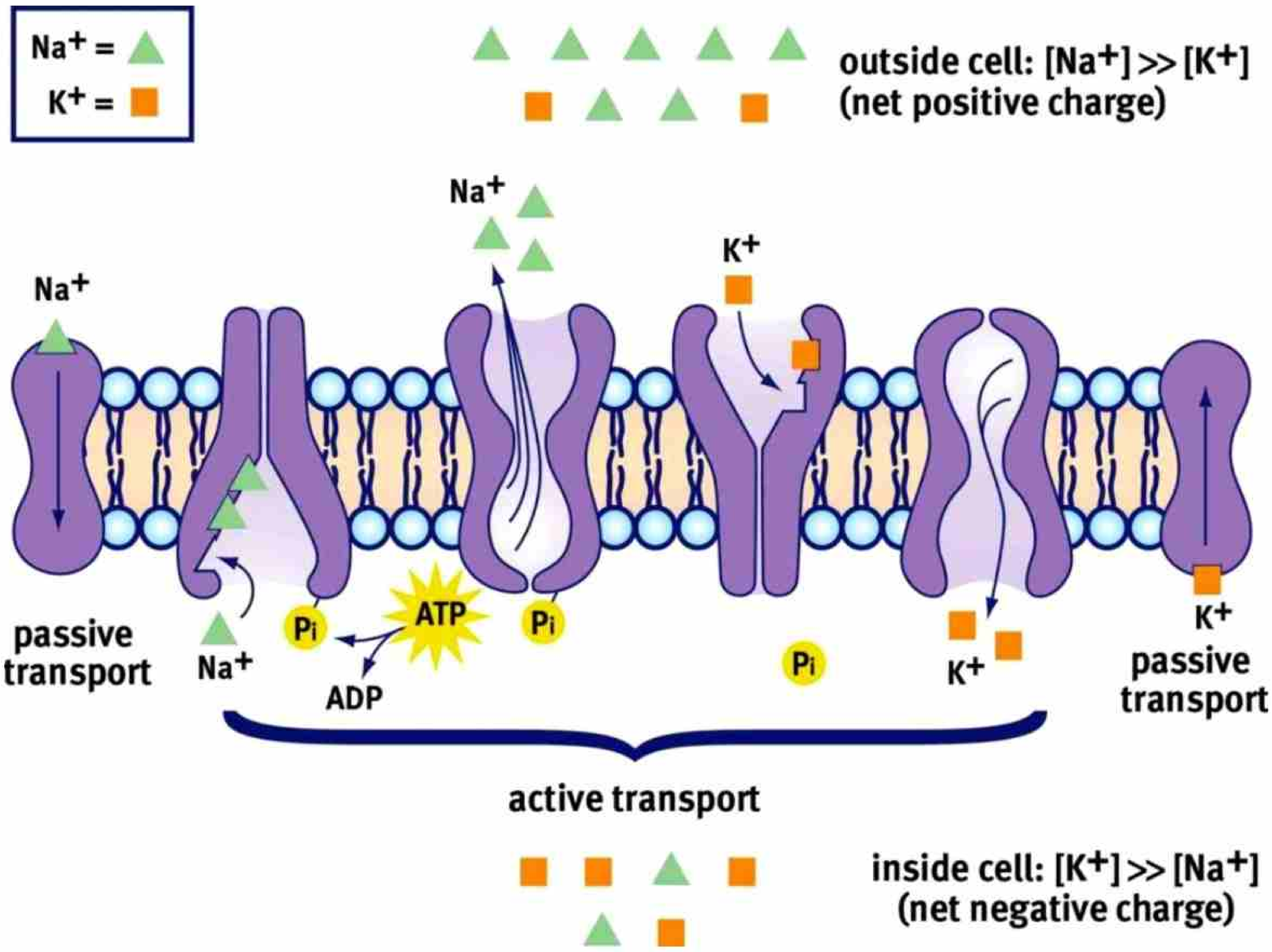


Fig.17.7 Ionic movement across neurolemma

Repolarization

It is a condition during which the electrical balance is restored inside and outside the neurolemma. Due to the high concentration of sodium ions inside the axoplasm, the potassium channels will open. During the repolarization state, efflux of potassium ions through the potassium channel occurs. As a result of the opening of potassium voltage-gated channels, sodium voltage-gated channels will be closed. Thus, no sodium ions will move inside the membrane. Therefore, repolarization helps in maintaining or restoring the original membrane potential state.

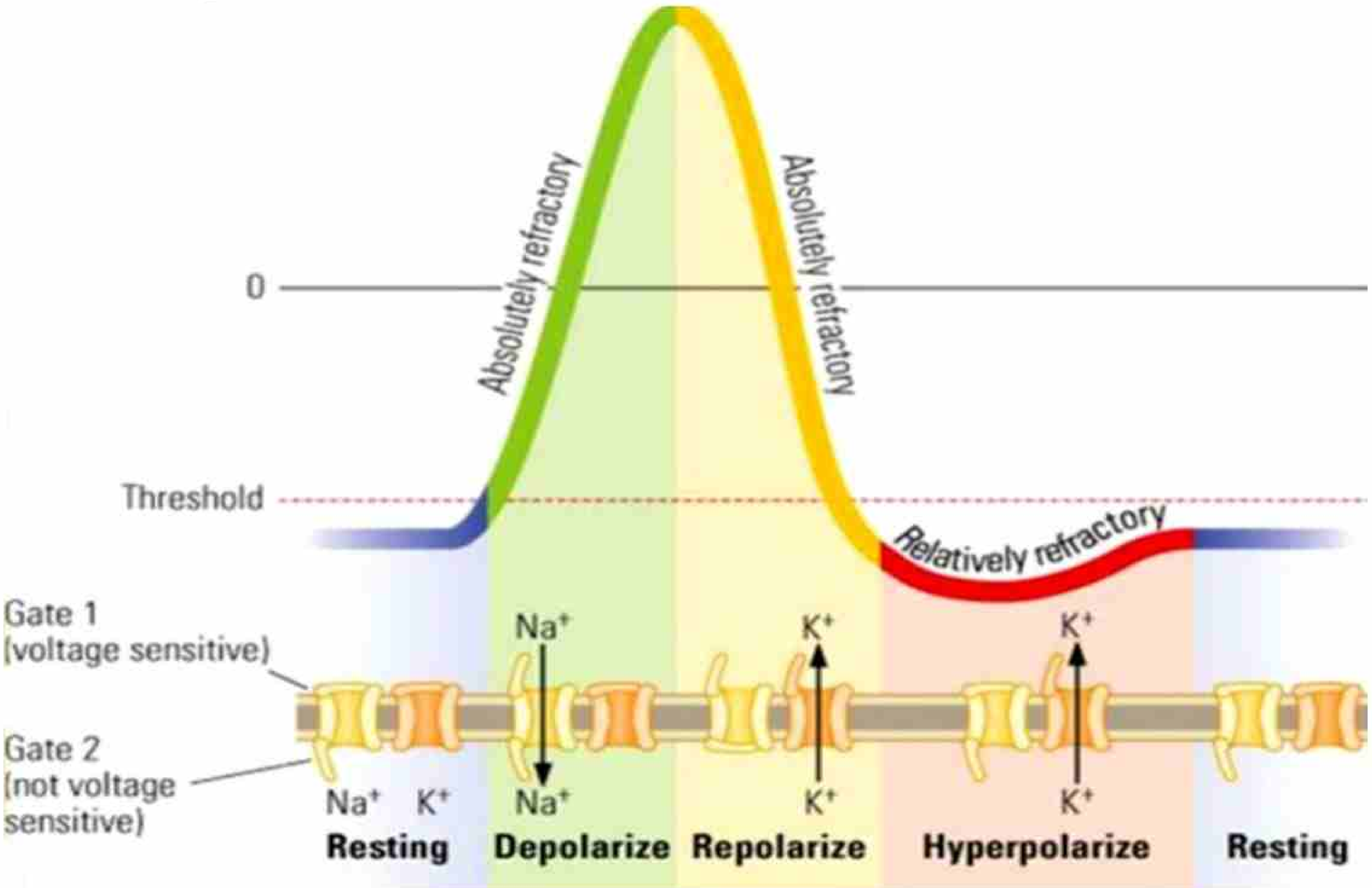


Fig.17.8 Action membrane potential

Until potassium channels close, the number of potassium ions that have moved across the membrane is enough to restore the initial polarized potential state. As a result of this, the membrane becomes hyperpolarized and has a potential difference of -90 mV. After a cell has been depolarized, it undergoes one final change in internal charge. Following depolarization, the voltage-gated sodium ion channels that had been open while the cell was undergoing depolarization close again. The increased positive charge within the cell now causes the potassium channels to open. Potassium ions (K^+) begin to move down the electrochemical gradient (in favor of the concentration gradient and the newly established electrical gradient). As potassium moves out of the cell the potential within the cell decreases and approaches its resting potential once more. The sodium potassium pump works continuously throughout this process.

Refractory Period

The refractory phase is a brief period after the successful transmission of a nerve impulse. During this period, the membrane prepares itself for the conduction of the second stimulus after restoring the original resting state. It persists for only 2 milliseconds.

During this, the sodium ATP driven pump allows the re-establishment of the original distribution of sodium and potassium ions. The sodium and potassium ATP pump, driven by using ATP, helps to restore the resting membrane state for the conduction of a second nerve impulse in response to the other stimulus. It causes the movement of ions both against the concentration gradient. For every two potassium ions that move inside the cell, three sodium ions are transported outside. This process requires ATP because the movement of ions is against the concentration gradient of both ions.

Hyperpolarization

The process of repolarization causes an overshoot in the potential of the cell. Potassium ions continue to move out through K^+ channels or Cl^- influx through CL^- channels therefore the resting potential is exceeded and the new cell potential becomes more negative than the resting potential (-70 mv to -75mv). The resting potential is ultimately re-established by the closing of all voltage-gated ion channels and the activity of the sodium potassium ion pump.

Velocities of Nerve Impulse

Action potentials must travel rapidly. Animals have evolved two ways to increase the velocities of nerve impulses. The velocity of conduction is greater if the diameter of the axon is larger or if the axon is myelinated. Increasing the diameter of an axon increases the velocity of nerve impulse due to the electrical property of resistance. Electrical resistance is inversely proportional to cross sectional area.

So larger diameter axons have less resistance to nerve impulse (current flow) Transmission speed varies from several centimeters per second in very thin axons to about 100 m/sec in the giant axons. Myelinated axons conduct impulses more rapidly than unmyelinated axons because the action potential is myelinated axons are only produced at nodes of Ranvier (small gaps between successive

Schwann cells). Also extracellular fluid is in contact with the axon membrane only at the nodes, so that the flow of ions between the inside and outside of the axon can occur only in these regions. The action potential does not propagate over the length of the axon, but rather jump from node to node, skipping the insulated regions of the membrane between the nodes this mechanism, called **saltatory conduction** results in faster impulse transmission up to 150m/sec in some neurons.

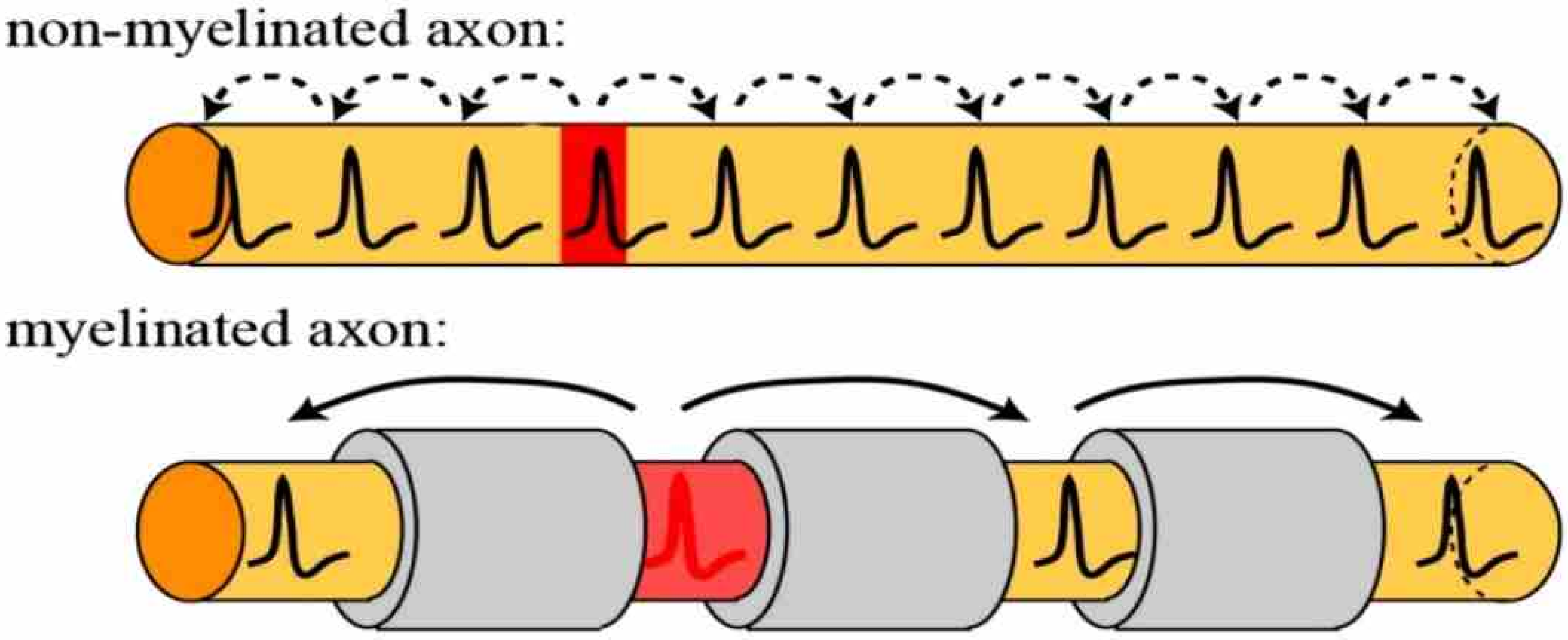


Fig.17.9 Velocities of Nerve impulse

17.1.4. Synapse

Synapse is a junction that controls communication between a neuron and another cell. Synapse is found between two neurons, between sensory receptor and sensory neuron, between motor neuron and the muscle cells, they control and between neuron and glands cells.

Structure of synapse

The neuron whose axon transmits action potential to the synapse is termed the pre-synaptic cell, and the cell receiving the signal on the other side of the synapse is the postsynaptic cell. There is a gap called a synaptic cleft between them.

Mechanism of Synaptic Transmission

The movement of impulse across the synapse is called a synaptic transmission. In animals two basic types of synapses are **electrical synapse** and **chemical synapse**.

An **electrical synapse** involves direct cytoplasmic connections formed by gap junctions between the presynaptic neuron and post synaptic neurons. These make it possible for impulses to transmit from neuron to neuron without delay and with no loss of signal strength. Electrical synapses in the central nervous system synchronize the activity of neurons responsible for some rapid stereotypical movement. Electrical synapses are common in invertebrate nervous systems, but less so in vertebrates.

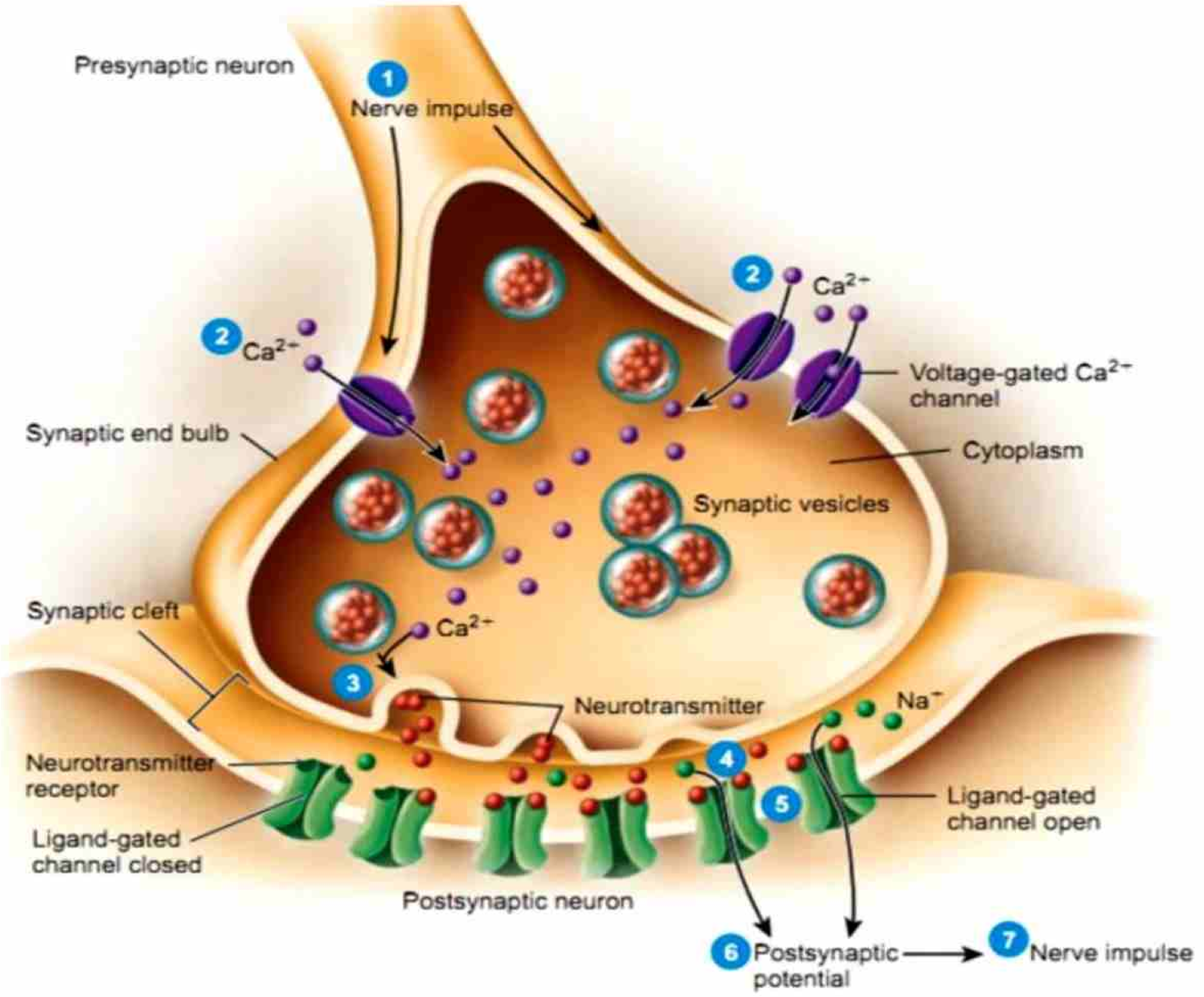


Fig.17.10 Synapse

The vast majority of synapses in vertebrates are **chemical synapse** the key to understanding the function of a chemical synapse is to examine its structure. The end of the presynaptic axon is swollen and contains numerous synaptic vesicles, each packed with chemicals called **neurotransmitters**. When action potential arrives at the end of the axon, they stimulate the opening of voltage gated calcium (Ca^{++}) channels causing rapid inward diffusion of Ca^{++}. This influx of Ca^{++} triggers a complex series of events that leads to the fusion of synaptic vesicles with the plasma membrane and the release of neurotransmitters by exocytosis. Neurotransmitter when binds to its receptors alters the membrane potential of the post synaptic cell.

Depending on the type of receptors and the ions channels they control neurotransmitters binding to the post synaptic membrane may either excite the membrane by bring its voltage closer to the threshold potential or inhibits the post synaptic cell by hyperpolarizing its membrane. Neurotransmitter must be rapidly removed from the synaptic cleft to allow new signals to be transmitted. This is accomplished by a variety of mechanisms, including enzymatic digestion in the synaptic cleft, reuptake of neurotransmitters by the neuron and uptake by glial cells.

Classification of Neurotransmitters

Neurotransmitters are classified as excitatory and inhibitory.

i. Excitatory Neurotransmitters

At an excitatory synapse neurotransmitter receptors control a type of gated channel that allows Na^+ to enter the cell and K^+ to leave the cell cause depolarization, the electrical change cause by the binding of neurotransmitter to the receptor is called an **excitatory postsynaptic potential (EPSP)**. Chemicals cause these changes called excitatory neurotransmitters such as **Acetylcholine** is one of the most common neurotransmitters, it can be excitatory or inhibitory depending on the type of receptor.

The **biogenic amines** are neurotransmitters derived from amino acids most commonly function as transmitters within the CNS. They include **Epinephrine** and **norepinephrine**, which also function as hormones and a closely related compound called **dopamine**, another biogenic amine is **serotonin**. Norepinephrine functions in autonomic nervous system. Dopamine and serotonin affect sleep, mood, attention and learning, imbalance of these neurotransmitters is associated with several disorders. **Parkinson's**

disease is due to low level of dopamine and **schizophrenia** is due to excess level of dopamine.

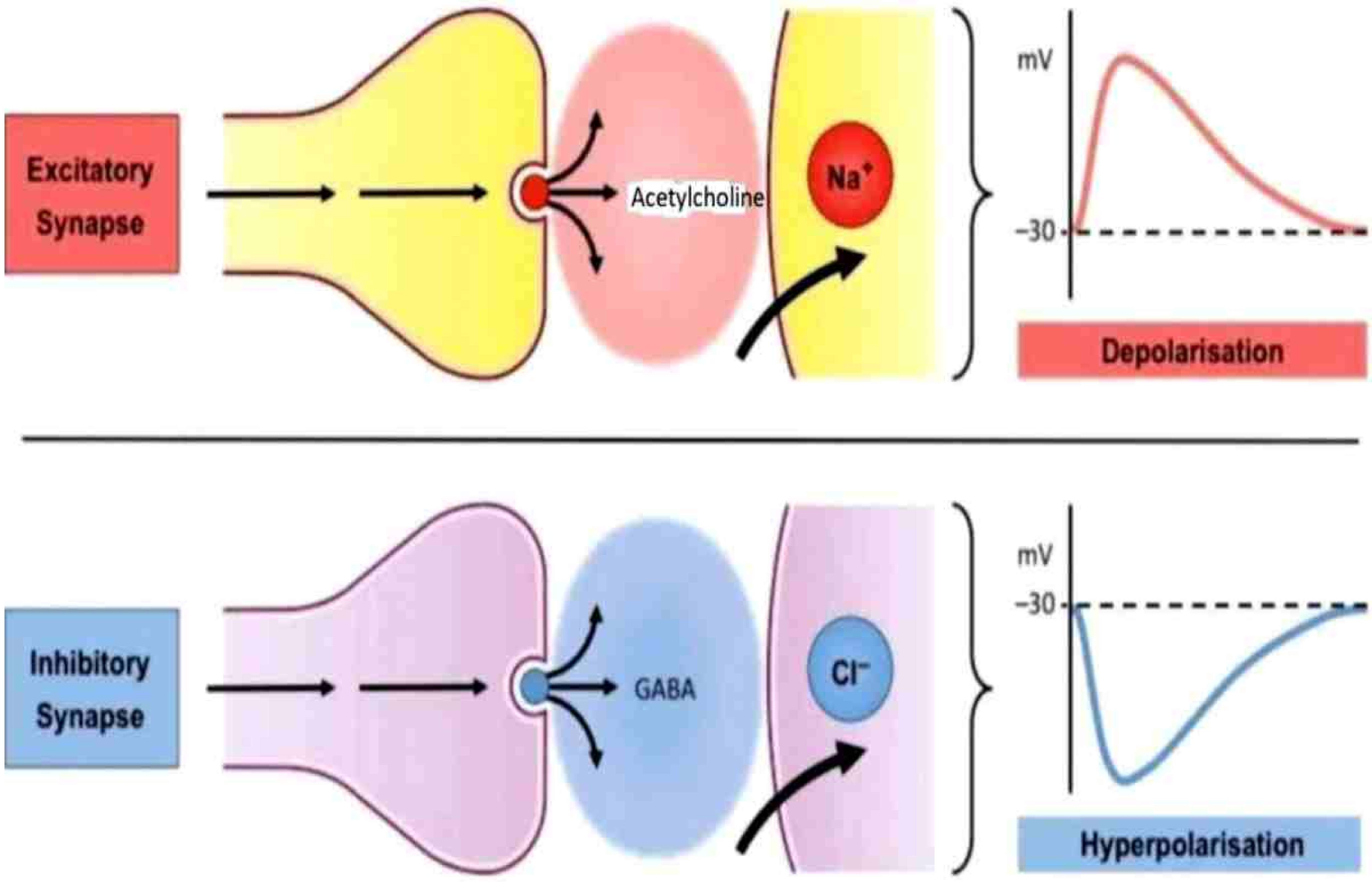


Fig.17.11 Excitatory and Inhibitory Synapse

ii. Inhibitory Neurotransmitters

At an inhibitory synapse, the binding of neurotransmitter molecules to the postsynaptic membrane hyperpolarizes the membrane by opening ion channels that make the membrane more permeable either to K^+, which rushes out of cell or to Cl^- which enters the cell because of a large concentration gradient or to both of these ions, membrane potential even more negative than the resting potential making it more difficult for an action potential to be generated, voltage change associated with chemical signaling at an inhibitory synapse is called **inhibitory postsynaptic potential (IPSP)**. Chemicals cause these voltage changes called inhibitory neurotransmitters such as **gamma amino butyric acid (GABA)**, **Glycine**, **glutamate** and **aspartate**.

17.1.5. Basic organization of human nervous system

The human nervous system consists of central nervous system (CNS) and peripheral nervous system (PNS). The CNS includes the brain and spinal cord, which have a central location, they lie in the midline of the body. The PNS consists of nerves projecting from CNS and have a peripheral location in the body.

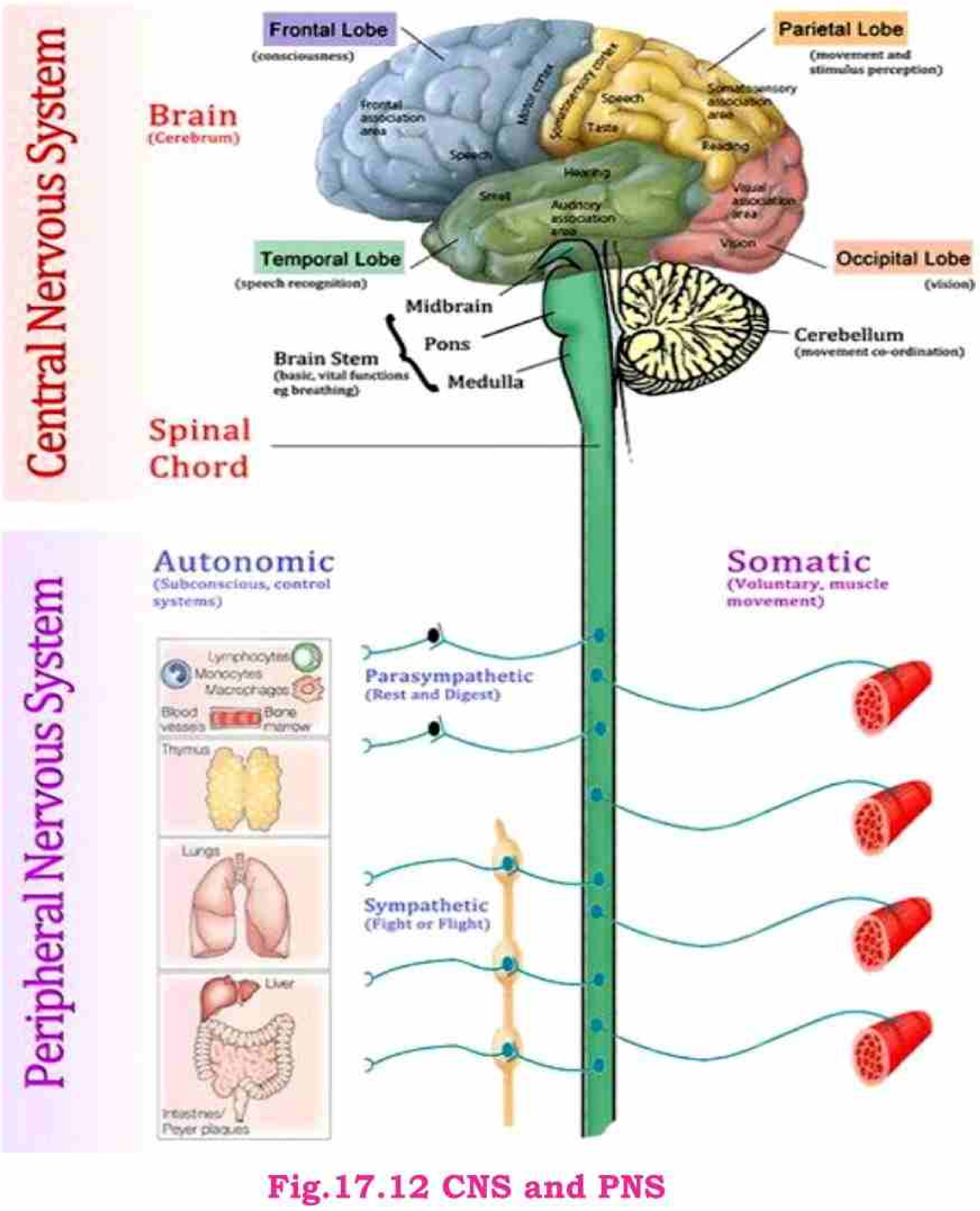
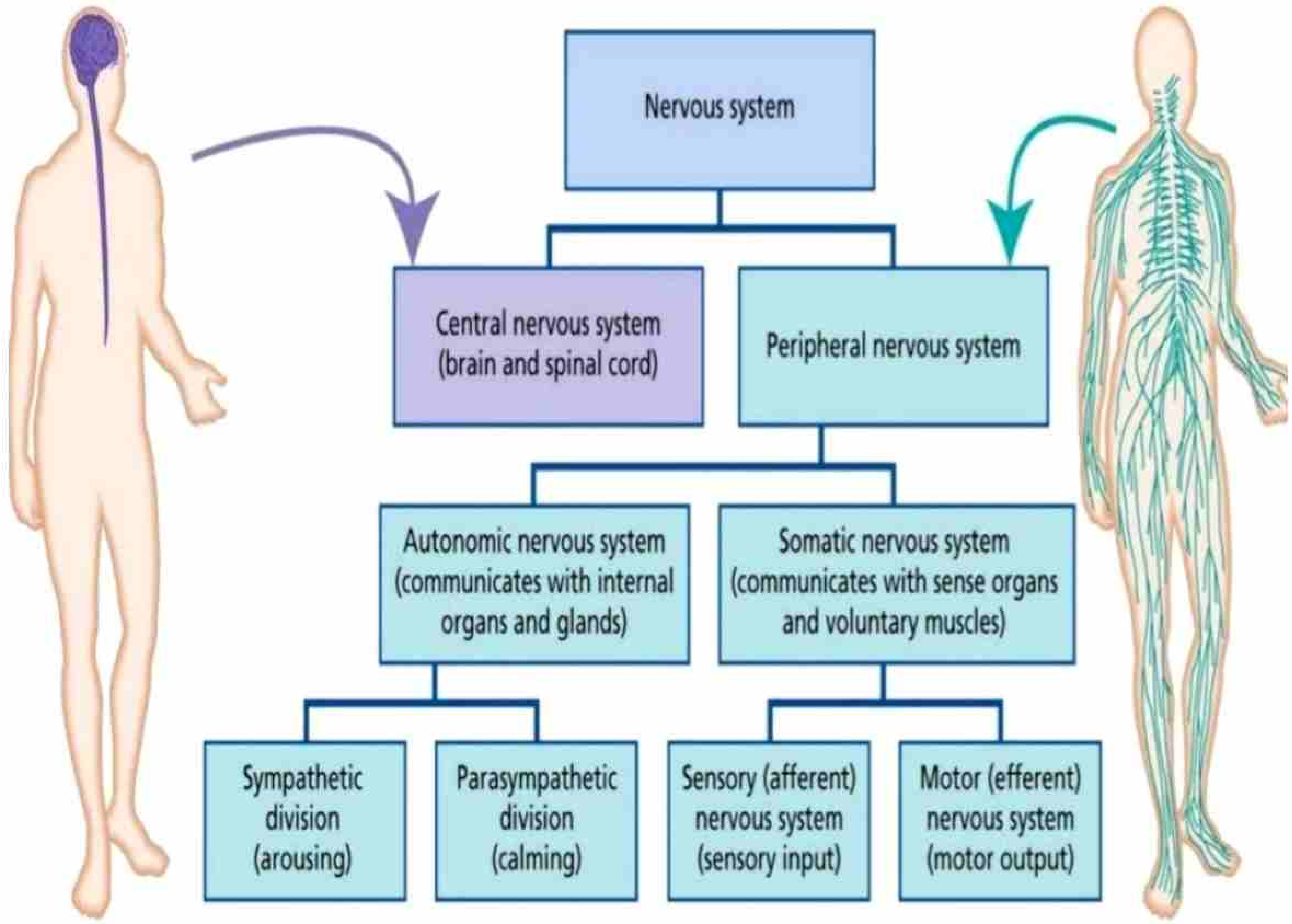


Fig.17.12 CNS and PNS

Architecture of Brain and spinal cord

Central Nervous System (CNS)

CNS is an integrating portion of the nervous system, where sensory information is received and processed, thoughts are generated and responses are directed. The CNS primarily consists of association neurons (Inter neurons) between 10-100 billions.



The CNS is protected in three ways. The first line of defense is bony armor consisting of the skull that surrounds the brain and the vertebral column that protects the spinal cord. Beneath bony armor, a triple layer of connective tissue called meninges. Outer layer next to the cranium called **dura mater**, middle layer called **arachnoid mater** and inner next to the nervous tissue called **pia mater**. Between the arachnoid and pia mater clear lymph like liquid, the **cerebrospinal fluid (CSF)** cushions the brain and spinal cord.

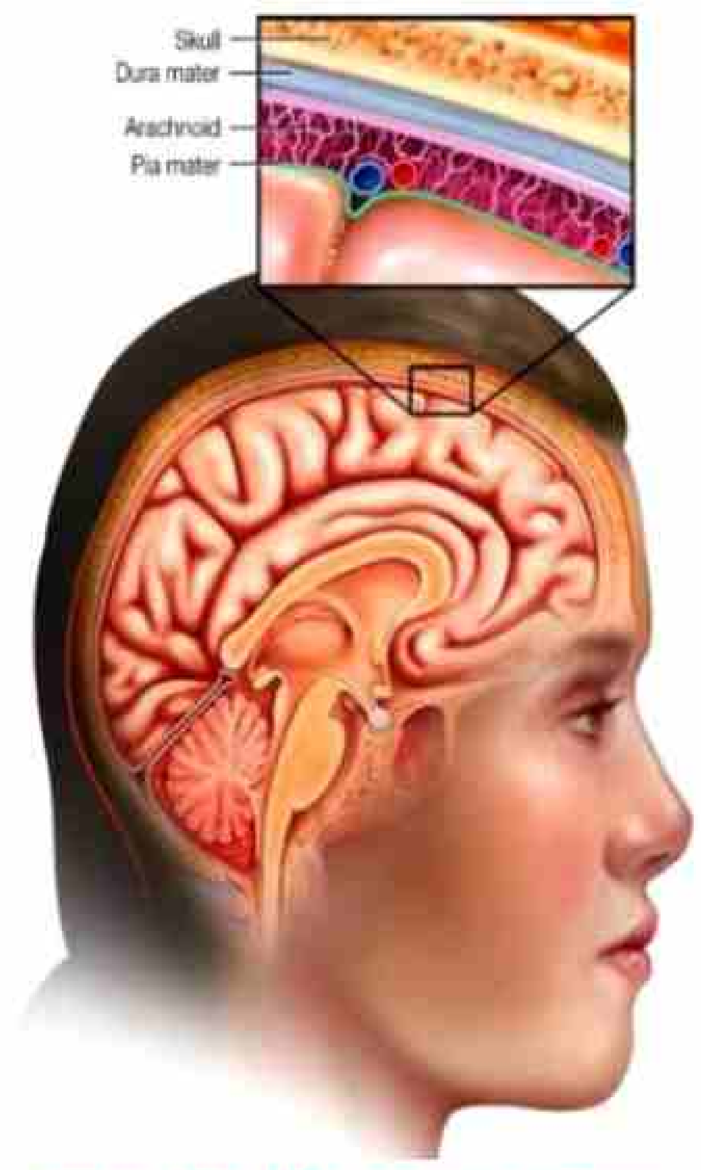


Fig.17.13 Meninges

Brain

The main component of the central nervous system in humans is the brain, which is housed in the skull and shielded by the cranium. The structure and general design of the human brain are similar to those of other animal brains, but the cerebral cortex is more developed in humans. The human brain is incredibly large and complicated, approximately 1.4 kg (3pounds) in weight, depending on the body weight and sex of each individual, it is divided into three parts, fore brain, mid brain and hind brain.

Forebrain The forebrain is the largest and most obvious part of human brain. Forebrain is divided into two regions, the **telencephalon** and the **diencephalon**.

The telencephalon is differentiated into two **cerebral hemispheres** or **cerebrum** that communicates with each other by means of a large band of axons, the **corpus callosum**. Each hemisphere consists of an outer grey matter or cerebral cortex and an inner white matter. Cerebral cortex is the most sophisticated information processing center of the brain. It contains over 10-50 billion neurons are packed into this thin surface layer.

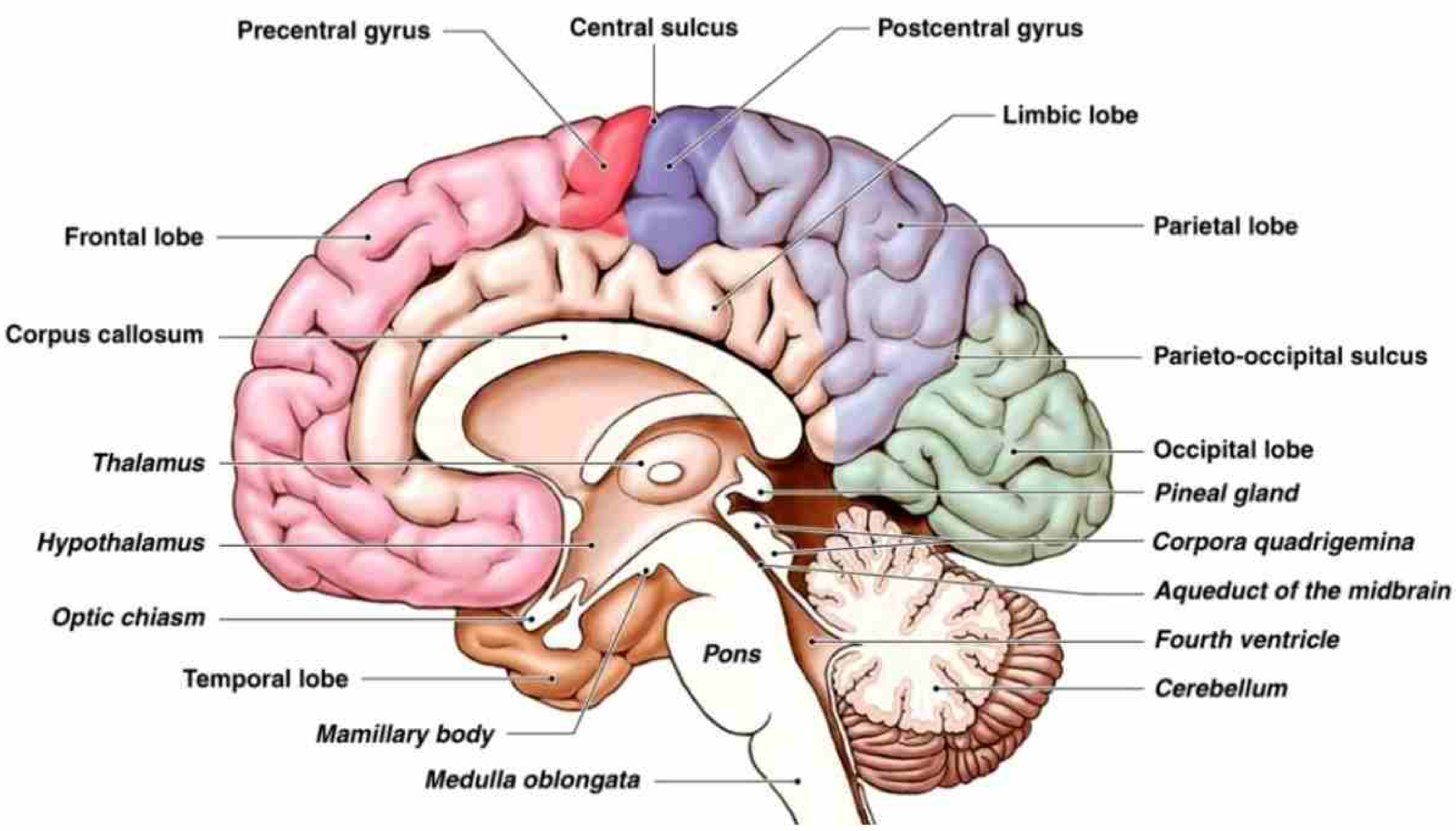


Fig.17.14 Architecture of Human Brain

The surface of the cerebral cortex is highly convoluted which increases the surface area of the cortex threefold. The cerebral cortex is divided into four regions based on anatomical criteria, **frontal**, **parietal**, **occipital** and **temporal lobes**. The activities of the cerebral cortex fall into sensory area, association area and motor area. **Sensory area:** this area receives inputs from different body parts. **Association area:** this area is a site of higher mental activities (intelligence, reasoning and memory) which interpret or analyze the incoming information. **Motor area:** this area controls the responses of the body.

The diencephalon consists of **thalamus** and **limbic system**. The thalamus is major integrating center, it is also the main input center for sensory information going to the cerebrum and the main output center for motor information leaving the cerebrum. Incoming information from all the senses is sorted out in the thalamus and sent onto the appropriate higher brain center for further interpretation and integration.

Limbic system is a diverse group of structures located in an arc between the thalamus and the cerebrum. It includes the hypothalamus, amygdala and the hippocampus. **Hypothalamus** contains many different clusters of neurons. Some of these are neurosecretory cells that release hormones through its hormone production and neural conduction, the hypothalamus act as a major coordinating center, controlling body temperature, hunger, thirst, water balance, the menstrual cycle and the autonomic nervous system. In addition, stimulation of specific area of the hypothalamus elicits emotions such as rage, fear, pleasure and sexual arousal. **Amygdala** is believed to be responsible for the production of appropriate behavioral responses to environmental stimuli. They control feelings and emotions of loner, fear,

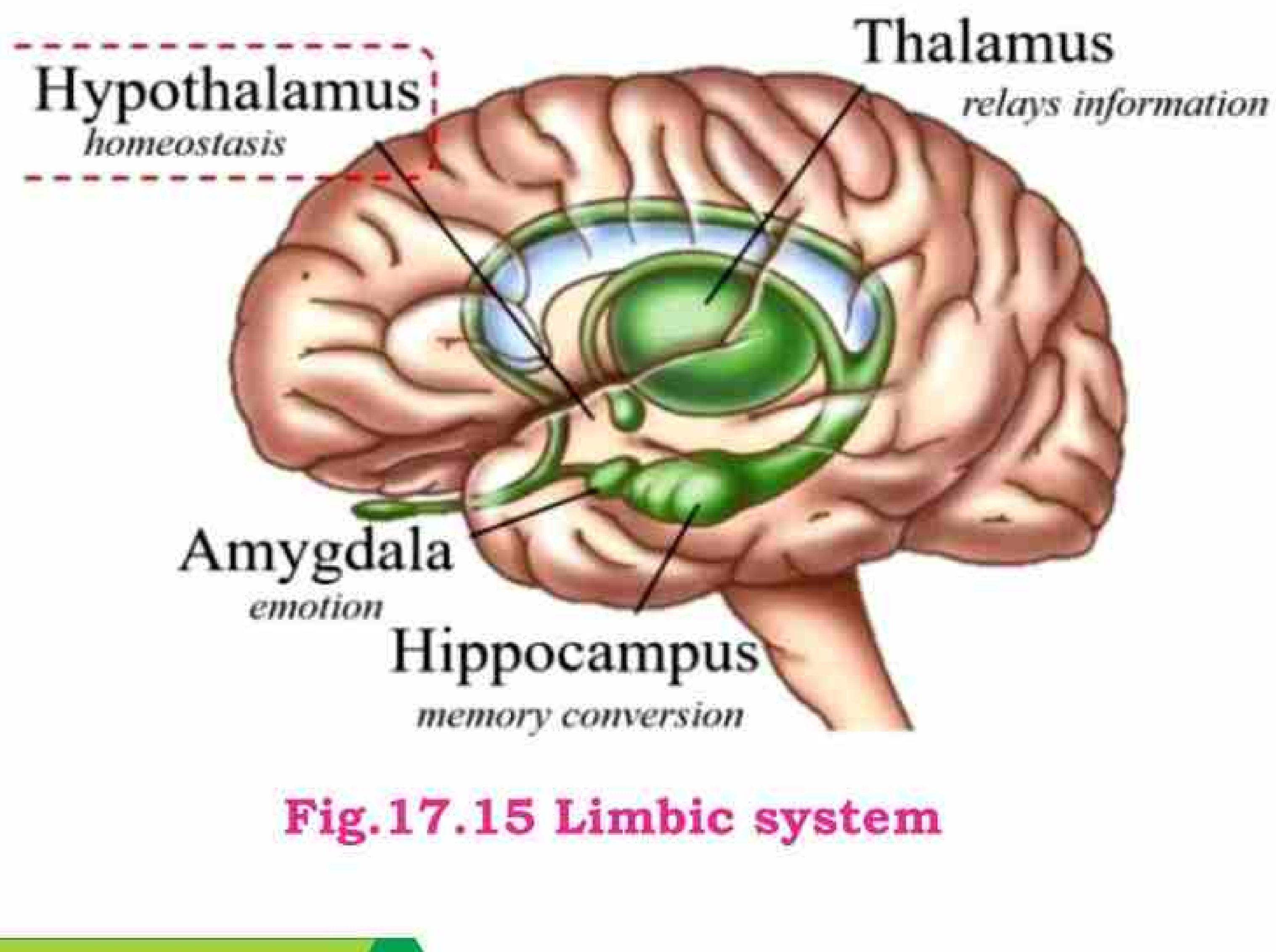


Fig.17.15 Limbic system

hater rage and sexual arousal. **Hippocampus** name from its shape, it resembles that of a seahorse. It plays an important role in the formation of long term memory and is thus required for learning. Short-term memory and procedural memory types (remember of how to do motor acts, like walking), on the other hand, are not mediated by the hippocampus. The cortex and cerebellum are principally responsible for managing them.

Mid brain is extremely reduced in humans but an important relay center midbrain contains **reticular formation**. Which extend all the way from the central core of the medulla, through the pons, the midbrain and on into lower regions of the forebrain, the reticular formation plays a role in sleep and arousal, emotion, muscle tone, certain movement and reflexes.

Hind brain

Hindbrain consists of medulla, pons and cerebellum.

Medulla

The medulla controls several autonomic functions, such as breathing, heart-rate, blood pressure, swallowing etc. **Pons** located above the medulla, tend to influence transitions between sleep and wakefulness and between stages of sleep, other influences include the rate of pattern of breathing. **Cerebellum** is crucially important in coordinating movement of the body. The cerebellum receives sensory information about the position of the joints and the length of the muscles, as well as information from the auditory and visual systems. It also receives input from the motor pathways, telling it which actions are being commanded from the cerebrum. The cerebellum uses this information to provide automatic co-ordination of movement and balance.

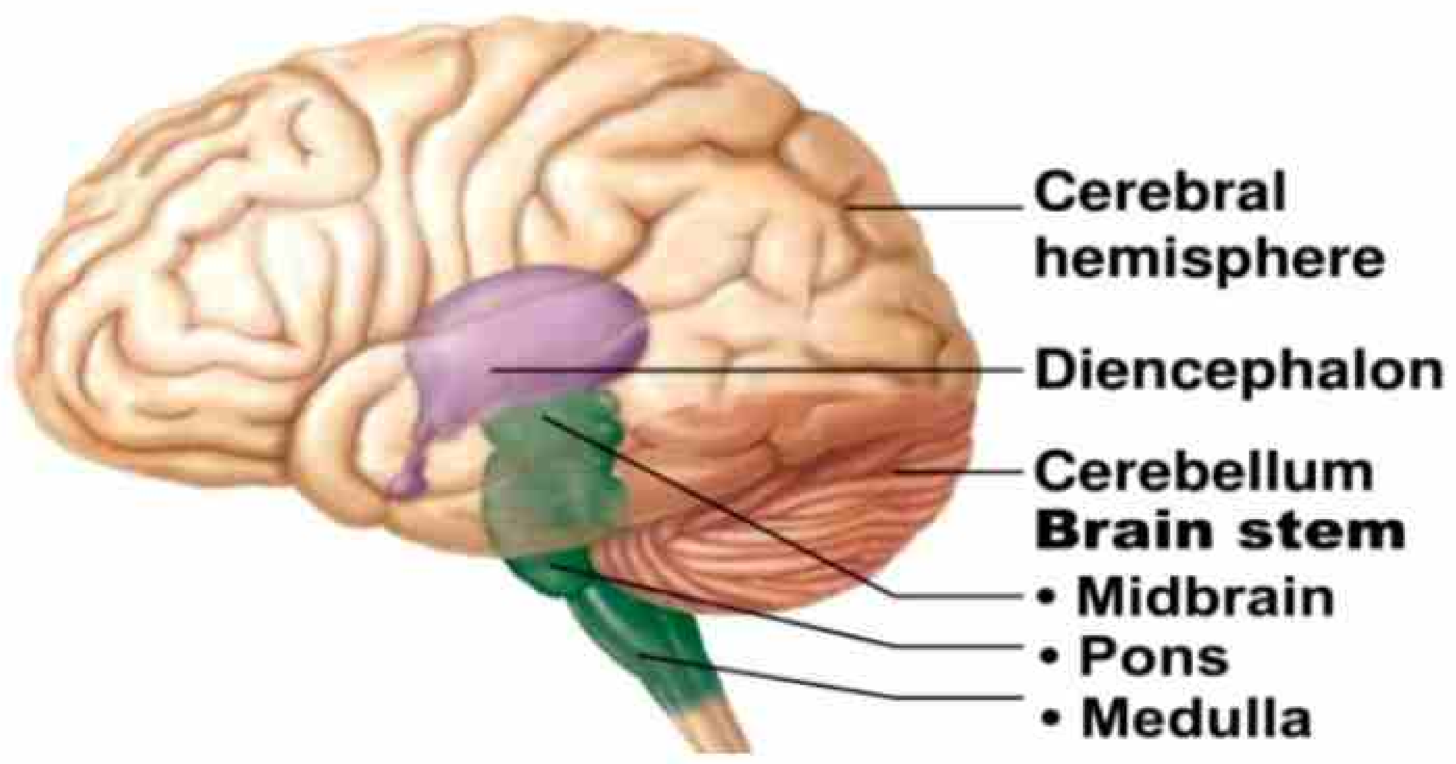


Fig.17.16 Mid and Hind brain

Brainstem is a region at the base of the brain that is located between the cervical spinal cord and the deep cerebral hemispheres. It plays a crucial role in controlling some involuntary bodily functions like breathing and heartbeat. Humans have three distinct parts to their brainstem: the medulla oblongata (myelencephalon), the pons (metencephalon), and the midbrain (mesencephalon).

Spinal cord

The spinal cord is a neural cable extending from the brain down through the backbone, it is enclosed and protected by the vertebral column and layer of membrane called meninges, which also covers the brain. Inside the spinal cord are two zones, the inner zone is Grey matter and primarily consists of the cell bodies of interneurons, motor neuron and neuroglia.

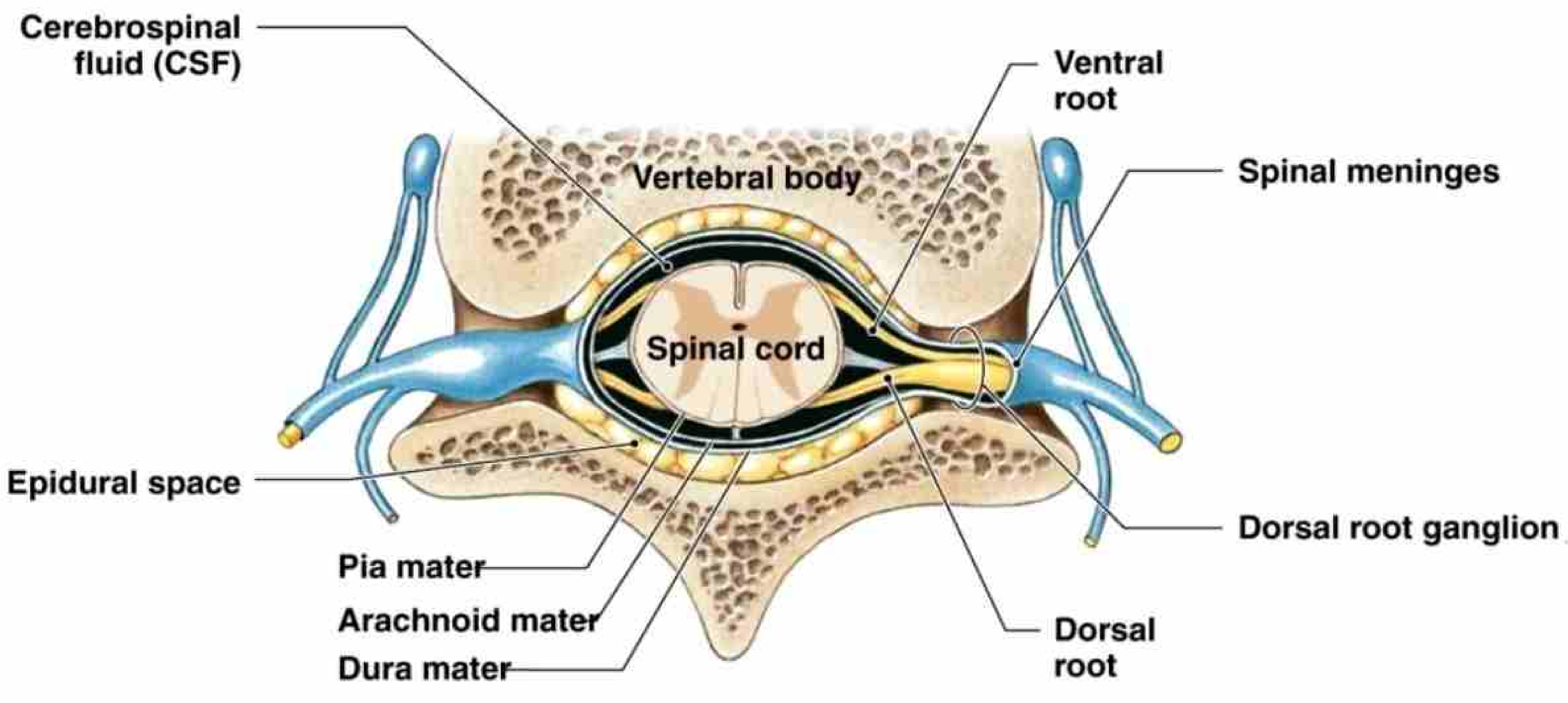


Fig.17.17 Cross section of Spinal cord

The outer zone is white matter and contains axon of sensory neuron in dorsal column and axon of motor neuron in ventral column, these nerve tracts may also contain the dendrites of the nerve cells. Messages from the body and the brain run up and down the spinal cord, the body's information highway. In addition to relaying messages, the spinal cord also functions in reflexes, the sudden, involuntary movement of muscles. A reflex produces a rapid motor response to a stimulus because the sensory neuron passes its information to a motor neuron in the spinal cord.

Cranial and spinal nerves in man: The peripheral nervous system consists of paired cranial and spinal nerves and associated ganglia. The cranial nerves originate in the brain and innervate organs of the head and upper body. The spinal nerves originate in the spinal cord and innervate the entire body. There are 12 pairs of **cranial nerves** and 31 pairs of **spinal nerves** in human. Most of cranial nerves contain both sensory and motor neurons, a few of the cranial nerves are sensory only (the olfactory and optic nerves). Spinal nerve separates into sensory and motor components. The axons of sensory neurons enter the dorsal surface of the spinal cord and form the **dorsal root** of the spinal nerves, whereas motor axons leave from the ventral surface of the spinal cord and form the **ventral root** of the spinal nerve. The cell bodies of sensory neurons are grouped together outside each level of the spinal cord, in the dorsal root ganglia. The cell bodies of motor neurons on the other hand, are located within the spinal cord and so are not located in ganglia.

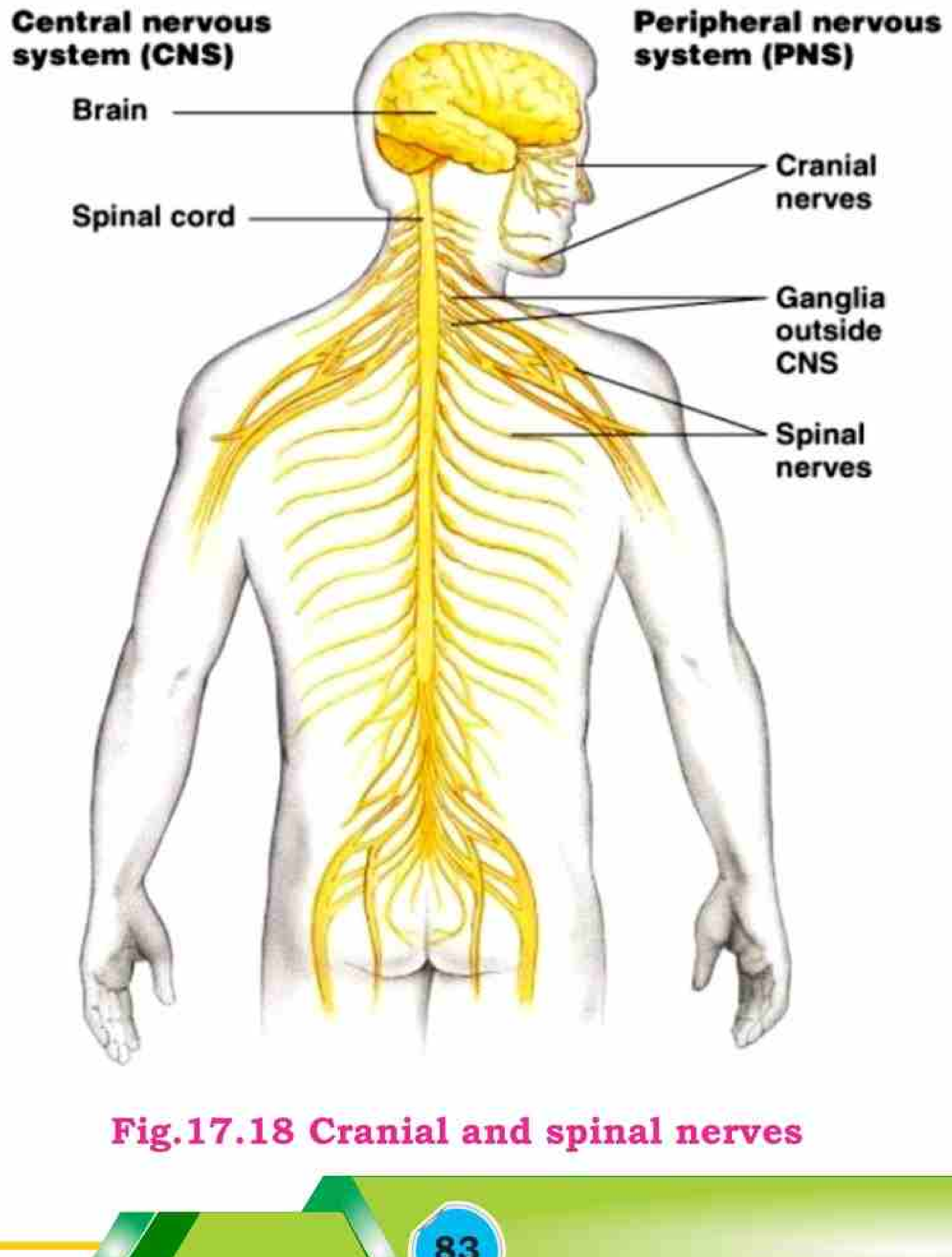


Fig.17.18 Cranial and spinal nerves

Somatic and Autonomic Nervous System

The motor portion of the peripheral nervous system is subdivided into two parts, somatic nervous system and autonomic nervous system.

Somatic Nervous System

The somatic nervous system is often considered voluntary because it is subjected to conscious control. Its neurons stimulate the skeletal muscles of the body to contract in response to conscious commands and as part of reflexes that do not require conscious control.

Autonomic Nervous system

The autonomic nervous system conveys signals that regulate the internal environment by controlling smooth and cardiac muscles and the organs of the gastrointestinal tract, cardiovascular, excretory and endocrine system this control is generally involuntary. The autonomic nervous system consists of two subdivisions that are anatomically, physiologically and chemically distinguishable, the sympathetic and parasympathetic division.

Sympathetic Nervous System

The sympathetic nervous system acts on organs in ways that prepare the body for stressful or highly energetic activity such as fighting, escaping or giving a speech during such “Fight-or-Flight” activities. It consists of thoracic and lumber nerves originate from spinal cord.

Parasympathetic Nervous System

The parasympathetic nervous system in contrast dominates during maintenance activities that can be carried on at leisure, often called “rest and rumination”. Under its control, the digestive tract becomes active, heart rate slows, and air passage in the lungs constrict. It consists of cranial nerves from the brain and sacral nerves from spinal cord.

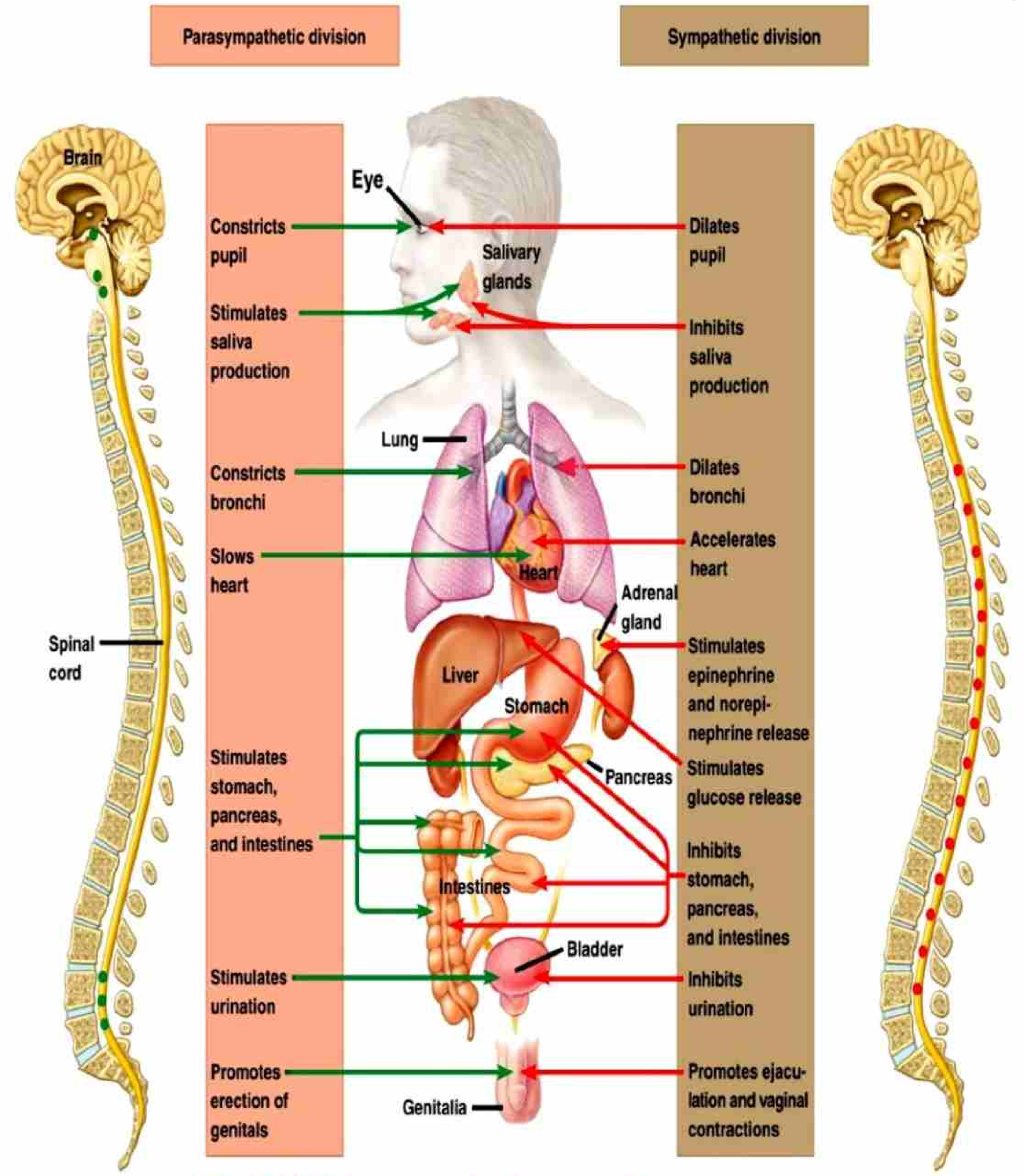


Fig.17.19 Autonomic Nervous System

17.1.6. Sensory receptors and their working

Smell receptors (Olfactory receptors)

In human the sense of **smell (olfaction)** involves chemoreceptors located in the upper portion of the nasal cavity. The human olfactory epithelium is small compared with that of many other mammals (dogs) whose sense of smell is far more active.

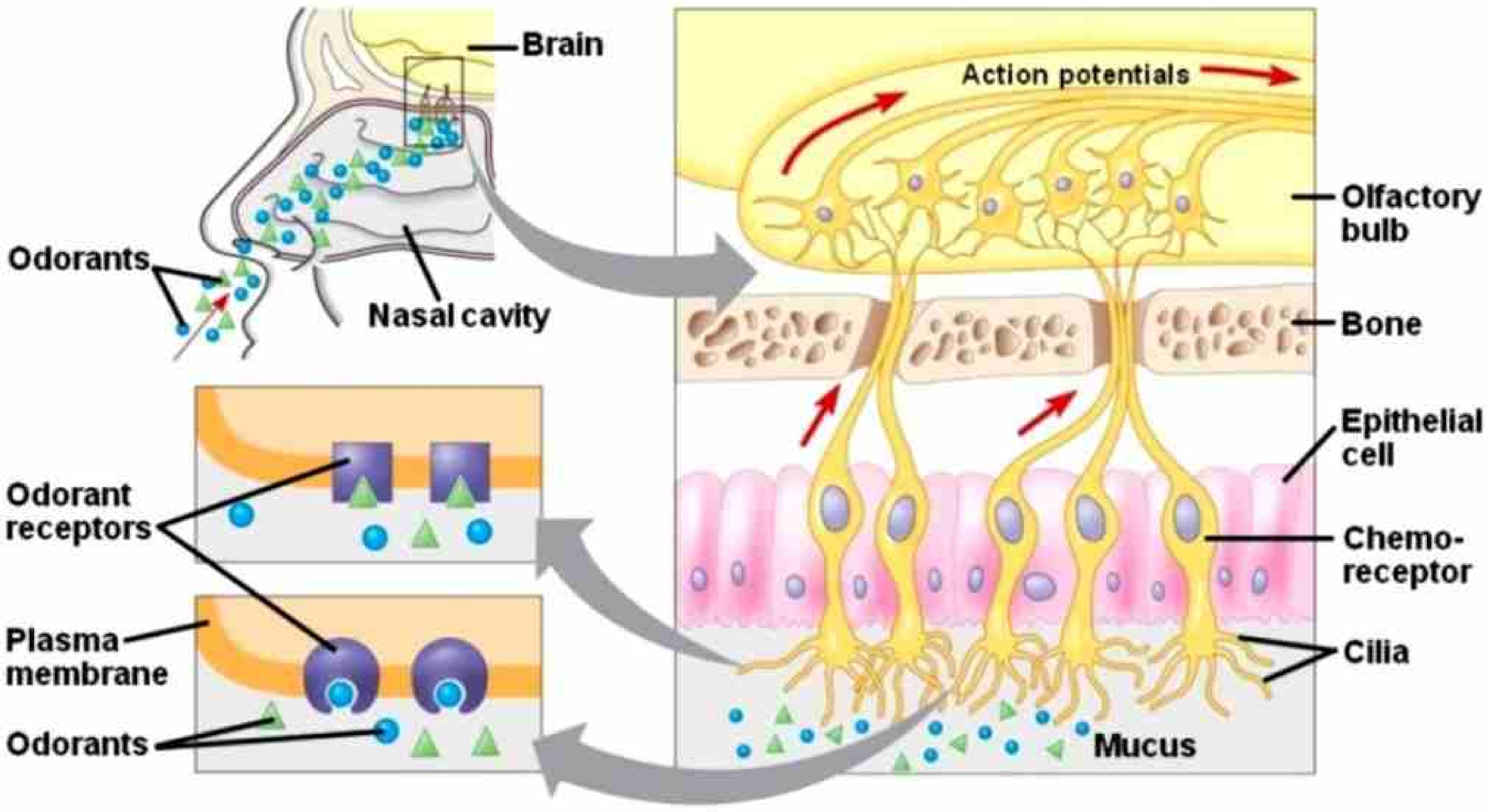


Fig.17.20 Smell receptor

Olfactory neurons dendrites end in tassels of cilia, project into the nasal mucosa, and their axons project directly into the cerebral cortex. When odorous substance diffuses into this region it binds to specific receptor molecules on the plasma membrane of the olfactory cilia, there may be 1000 types of receptor proteins embedded in the olfactory cilia. Each receptor protein is specialized to bind a particular type of molecule and stimulate the olfactory neuron to send a message to the brain.

Taste receptors

The receptors cells for taste (Gustation) are modified epithelial cells organized into taste buds, human tongue bears about 10000 taste buds. Most of the taste buds are on the surface of the tongue or an associated with nipple like projections called papillae on the tongue. Although we cannot distinguish different types of taste receptors from this structure, we recognize five basic taste

Fig.17.21 Taste receptors

perceptions, **sweet**, **sour**, **salty**, **bitter** and **umami** (perception of glutamate and other amino acids that give a hearty taste to many protein rich foods such as meat, cheese and butter).

Sensory receptors in human skin

Several types of mechanoreceptors are present in skin. Some in the dermis and others in the underlying subcutaneous tissues, these receptors contain sensory cells which detect various forms of physical contact, known as the sense of touch. The phasic receptors include hair follicle receptors and **Meissner's corpuscles**, which are present on surfaces that do not contain hair, such as the fingers, palms and nipples. The tonic receptors consist of **Ruffini's corpuscles** in the dermis and touch, dome endings (**Merkel's disks**) located near the surface of the skin. These receptors monitor the duration of touch and the extent to which it is applied. Deep below the skin pressure sensation receptors called **Pacinian corpuscles**. In human a class of naked dendrites in the epidermis of the skin called **nociceptors**, so named because they can be sensation to noxious substances as well as tissue damage.

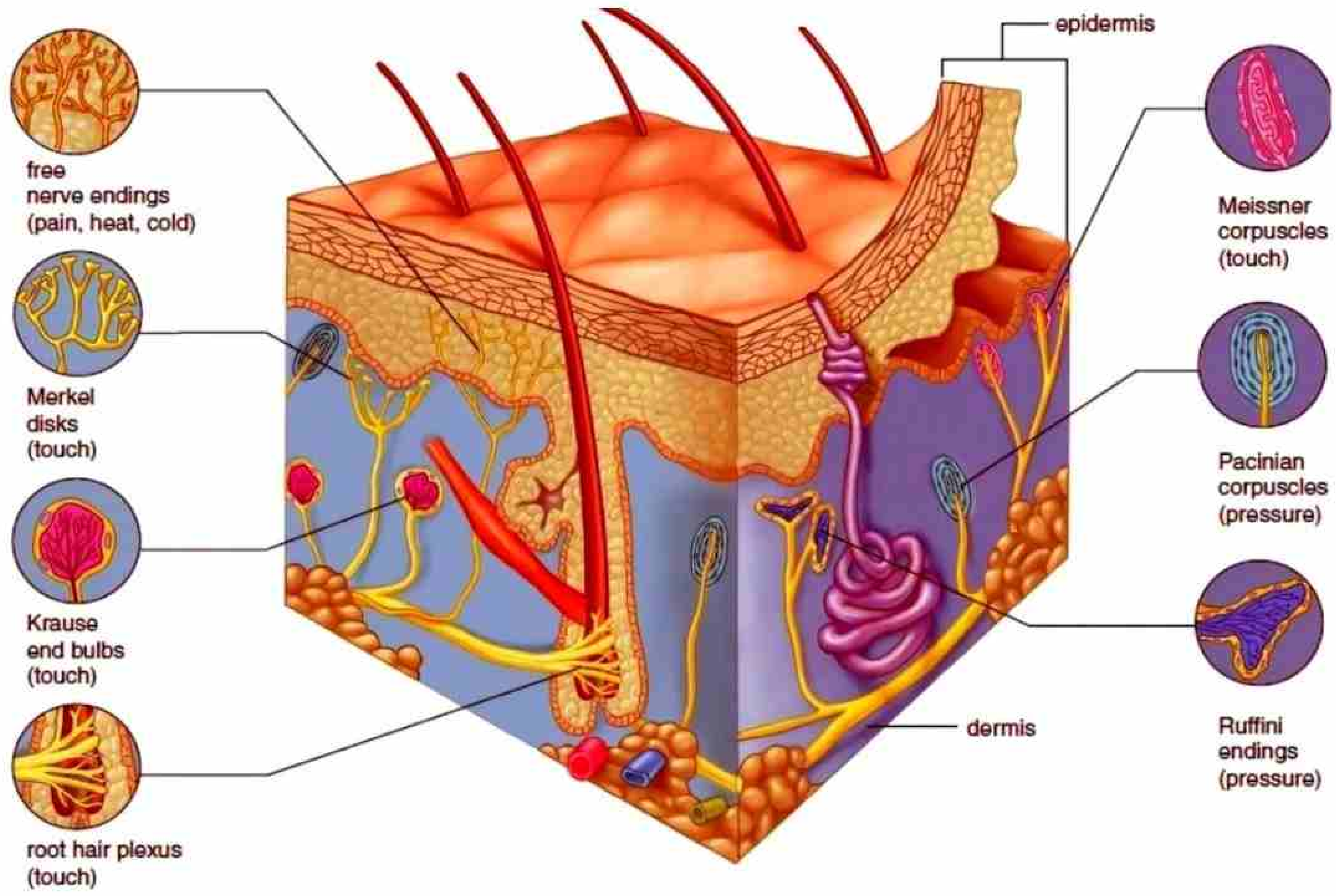


Fig.17.22 Receptors in Human Skin

17.2. EFFECT OF DRUGS ON NERVOUS CO-ORDINATION

Drugs that provide pain relief, such as morphine or Demerol, block synapses in the pain pathways of the brain or spinal cord. In ways that we are just beginning to understand, the brain can modulate its perception of pain through its own narcotic like **endorphins**. In critical situation such as combat or during escape from a fire, endorphins may allow us to function by blocking our perception of pain until the emergency is over.

Narcotic Drugs:

Common narcotic drugs are heroine, cannabis, nicotine, alcohol and inhalants.

Fig.17.23 Opium poppy

Heroin:

A white powder with a bitter taste abused for its euphoric effects. It is a highly addictive drug is derived from the morphine alkaloid found in opium poppy plants. It exhibits euphoric (Rush) anti-anxiety and pain relieving properties.

Cannabis:

It is the dried flowering tops and leaves. The cannabis plant (*Cannabis sativa*) is broadly distributed and grows in temperate and tropical areas, together with tobacco, alcohol and caffeine. It is one of the most widely consumed drugs throughout the world. In many countries, herbal cannabis and cannabis resin are formally known as marijuana and hashish (hash) cause mild euphoria, with alteration in vision and judgment.

Fig.17.24 Cannabis sativa

Nicotine:

It is an alkaloid of **tobacco**, nicotine binds directly to specific receptor on post synaptic neurons of the brain. Nicotine receptors are a class of receptors that normally binds the neurotransmitter acetylcholine, Nicotine stimulates heart rate, blood pressure and increased muscular activity.

Fig.17.25 Tobacco leaves

Alcohol:

Alcohol interferes with the brain's communication pathways, and can affect the way the brain looks and work. These disruptions can change mood and behavior and make it harder to think clearly and move with coordination.

Inhalants:

These are volatile substances easily bought and found in the home or workplace such as spray paints, markers, glues, and cleaning fluids. They contain dangerous substances that have psychoactive (mind altering) properties when inhaled.

Drug addiction and drug tolerance

Drug addiction is a complex neurobiological disorder, which affects a person's brain and behavior in a way that they lose the ability to resist the urge to use drugs.

Drug addiction

Drug addiction or dependence on illegal drugs like cocaine, nicotine you can get addicted to substances like medication drug, alcohol nicotine, marijuana and other legal drugs as well, dependence start with an experiment, you take drugs because you like the way it feels, repeated misuse of drugs changes how your brain works, it makes you lose self-control and messes with the desire to take drugs.

Drug tolerance

Drug tolerance means loss of efficiency with repeated drug exposure when nicotine and caffeine is used for long time, larger and larger doses must be taken to produce the same effect.

17.3. DISORDERS OF NERVOUS SYSTEM AND DIAGNOSTIC TESTS

Nervous disorders may be classified as vascular, infections, structural, functional and degenerative.

17.3.1 Vascular disorders of the CNS

Nervous disorders due to abnormality in blood circulation is called vascular disorder of the nervous system e.g. stroke and Hematoma

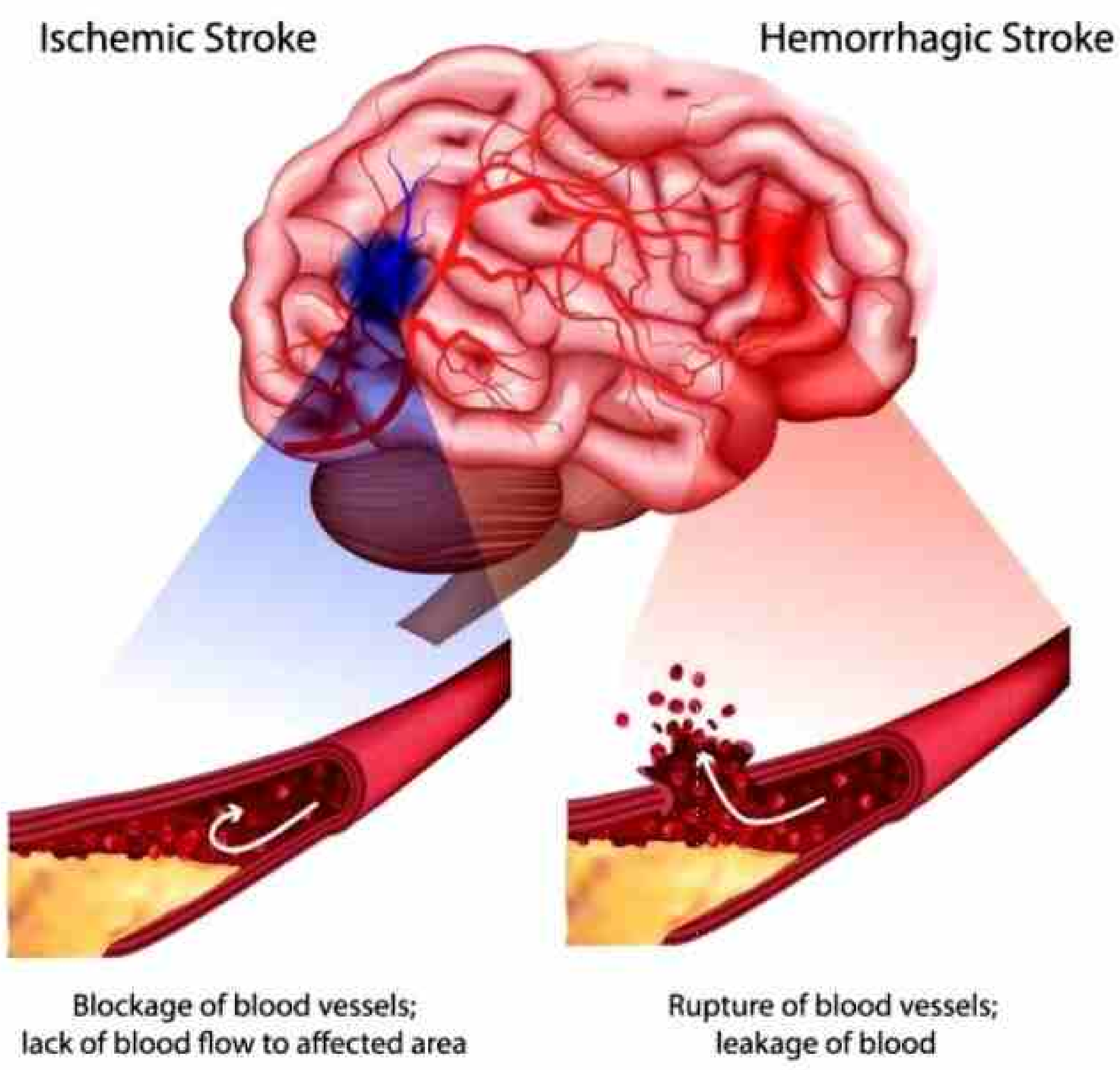


Fig.17.27 Stroke

Stroke: It is caused by an interference with blood supply to the brain. They may occur when a blood vessels bursts in the brain, when blood flow in cerebral artery is blocked by a blood clot.

Cause: The cause of stroke includes hypertension, smoking, diabetes mellitus, high alcohol intake and cocaine abuse.

Symptoms: The loss of blood flow to the brain damage tissues within the brain symptoms of stroke show up in the body parts controlled by the damaged area of the brain. Loss of balance and co-ordination severe and sudden headache, paralysis, weakness in the arm, face and leg.

Treatment: a stroke is a medical emergency; immediate treatment can save lives and reduce disability treatment depends on the severity and type of stroke. Treatment will focus on restoring blood flow anticoagulants and platelets aggregation inhibitor is given blood pressure management and nursing care is essential.

Hematoma: The massive accumulation of blood into the space between the brain and its outermost covering is called hematoma.

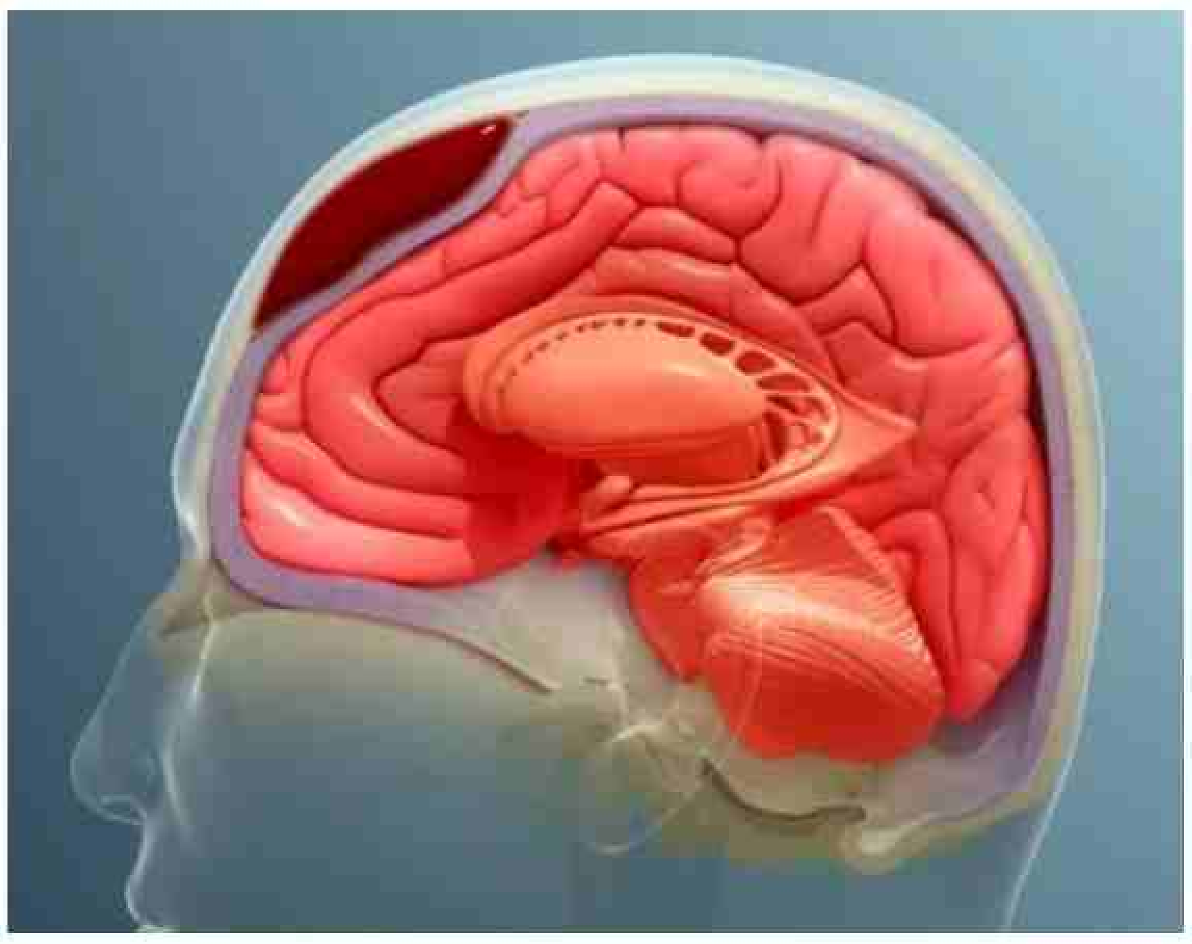


Fig.17.28 Hematoma

Cause: Hematoma is due to hypertension.

Symptoms: Hematoma symptoms include loss of consciousness sudden, confusion, pale skin color and seizures.

Treatment: It depends on the extent of the hematoma and the presence of other injuries. Depending on the severity of the injury, management may include surgery to drain blood and remove the blood clot.

17.3.2 Infectious Disorders of the CNS

Nervous disorders due to infection of virus, bacteria, fungi and protozoan e.g., meningitis and encephalitis

Meningitis It is an inflammation of the fluid and membranes (meninges) surrounding your brain and spinal cord.

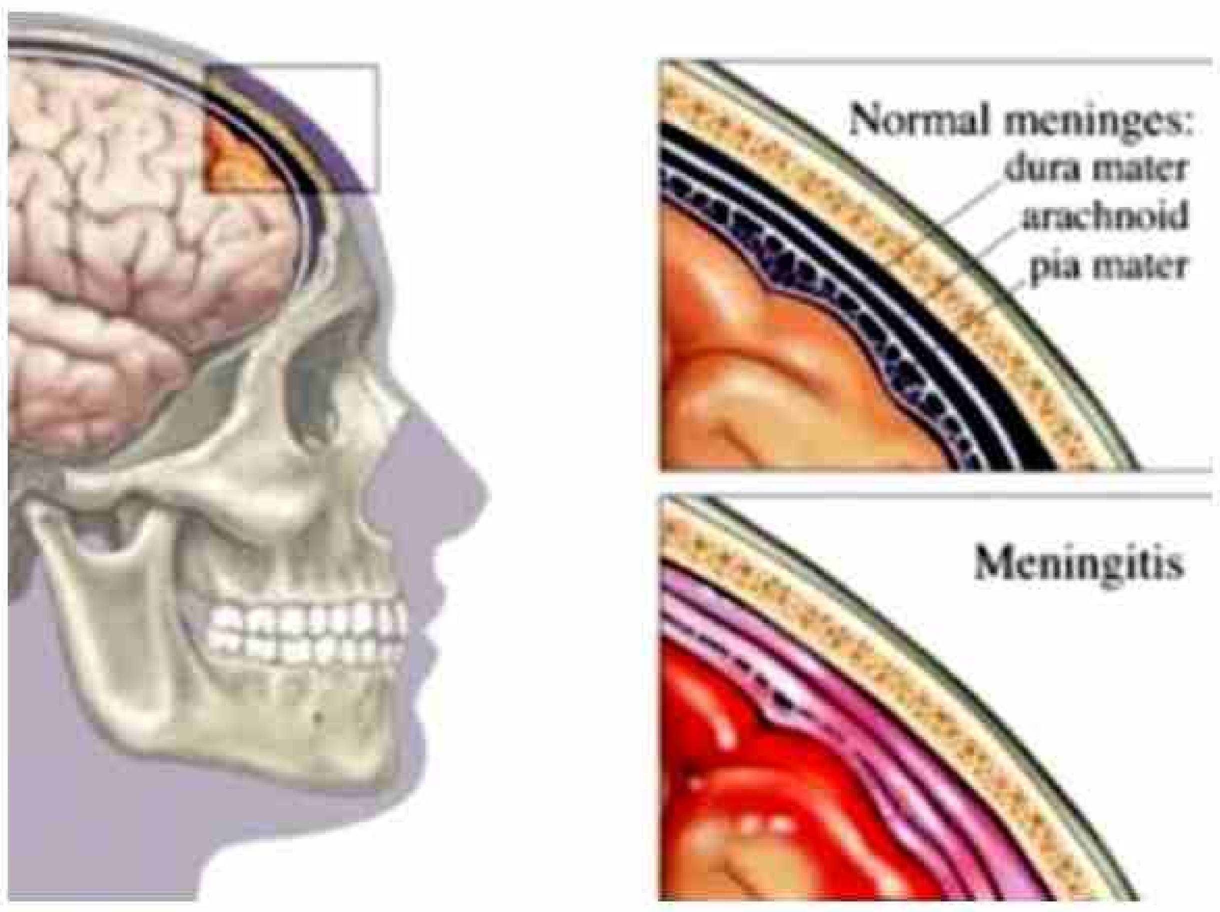


Fig.17.29 Meningitis

Cause: viral infections are the most common cause of this disease, followed by bacterial infections and, rarely, fungal infections.

Symptoms: Usually include sudden high fever, stiffness in neck, and headache with nausea or vomiting, it may cause paralysis coma or death.

Treatment: Depends on the type of disease. Bacterial meningitis must be treated immediately with intravenous antibiotics and more recently, corticosteroids. Viral meningitis cannot be cured with antibiotics and most cases improve on their own in several weeks, spread through coughing, sneezing (air borne rout).

Encephalitis: It is an inflammation of the brain.

Cause: Virus and rarely fungus cause encephalitis.

Symptoms: Encephalitis symptoms include fever, headache and confusion may cause muscle weakness, dementia and irritability.

Treatment: Encephalitis needs to be treated urgently. Treatment involves tackling the underlying cause, relieving symptoms and supporting bodily functions.

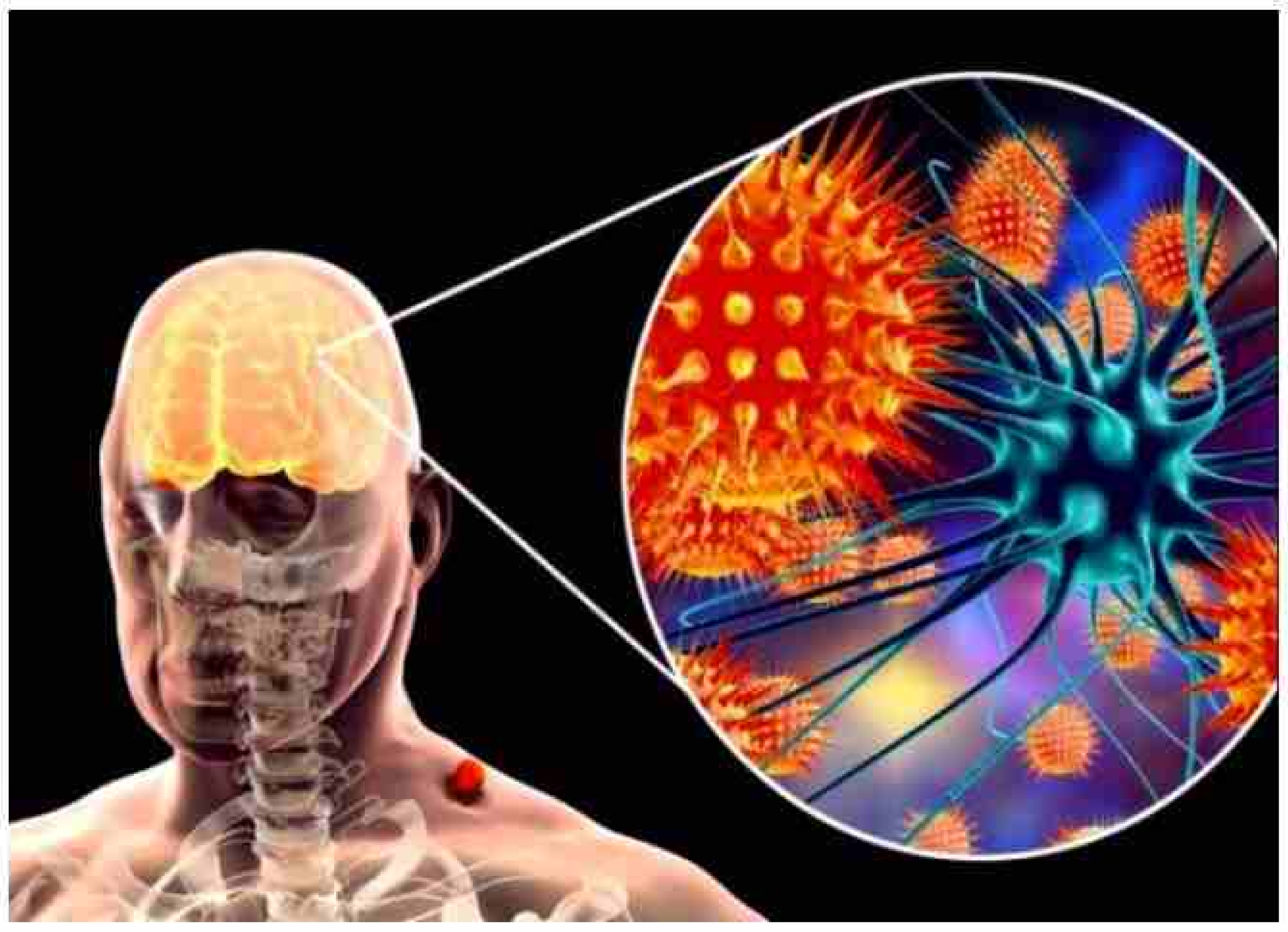


Fig.17.30 Encephalitis virus

17.3.3 Structural disorder of CNS

Nervous disorder which disturbs the structure of brain and spinal cord.

Tumour:

A brain tumour is a growth of cells in the brain that divides in an abnormal, uncontrollable way.

Cause:

It is caused by mutation and radiations.


Fig.17.31 Tumour

Symptoms:

The sign and symptoms depend on the size, location and rate of growth of brain tumour it may include, headache, vision problems, seizures, paralysis, coma and death.

Treatment:

Include surgery, radiation therapy, chemotherapy and targeted therapy.

17.3.4 Functional Disorder of the CNS

Headache:

Headache is defined as pain arising from the head or upper neck of the body. Pain originates from the tissues and structures that surround the skull, the brain itself has no nerves that give rise to the sensation of pain there are three major categories of headache based upon the source of the pain.

Primary headache:

Includes migraine, tension, and cluster headaches.

Secondary headache:

It is due to an underlying or infection problem in the head or neck, dental pain from infected teeth, pain from an infected sinus, and bleeding in the brain or infections like encephalitis or meningitis.

Cranial neuralgias, facial pain and other headache:

Cranial neuroglia means inflammation of one of the 12 cranial nerves coming from the brain that control the muscles and carry sensory signals to and from the head and neck.

Cause:

It is caused by inflammation or irritation of structures that surrounds the brain.

Symptoms:

Pain that begins in the back of the head and upper neck.

Treatment: Most people successfully treat themselves with pain medications to control headaches.

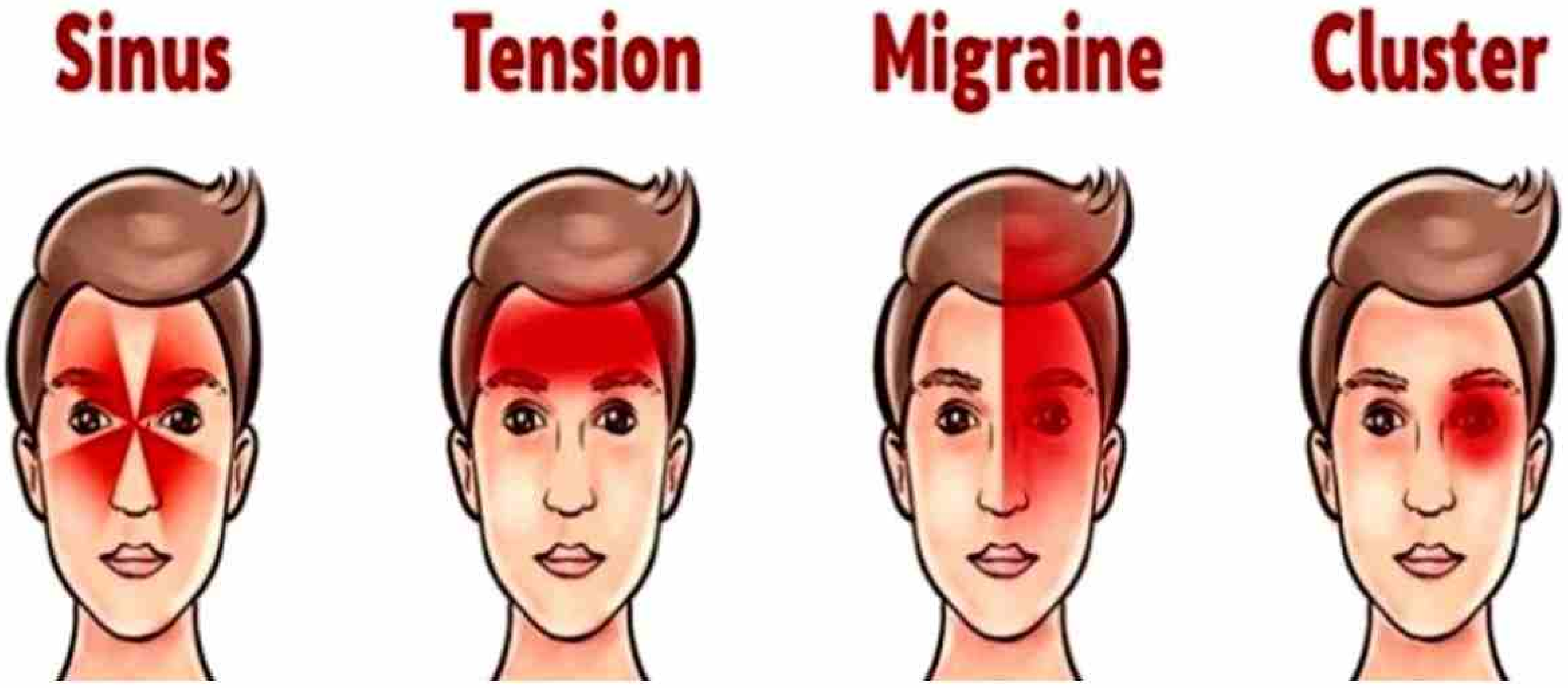


Fig.17.32 Types of Headaches

17.3.5. Degenerative Disorders of the CNS

Nervous disorder due to degeneration in different part of CNS

Alzheimer's disease

Alzheimer's is a progressive disease, where dementia symptoms gradually worsen over a number of years. In its early stage memory loss is mild, but with late stage individual loss the ability to carry on a conversation and respond to their environment.

Cause: It is due to inheriting certain genes.

Extra Reading Material

Multiple sclerosis: It is an autoimmune disease affects central nervous system.

Huntington's disease: It is due to gradual breakdown in brain nerve cells, it affects physical movement, emotions and cognitive abilities

Symptoms: In the early stage, new or recent memories are difficult to recall and hard to learn. In mild stage individual may have delusion, hallucination.

Treatment: There is no cure for Alzheimer. The goal of treatment is to manage symptoms and slow the progression of the disease.

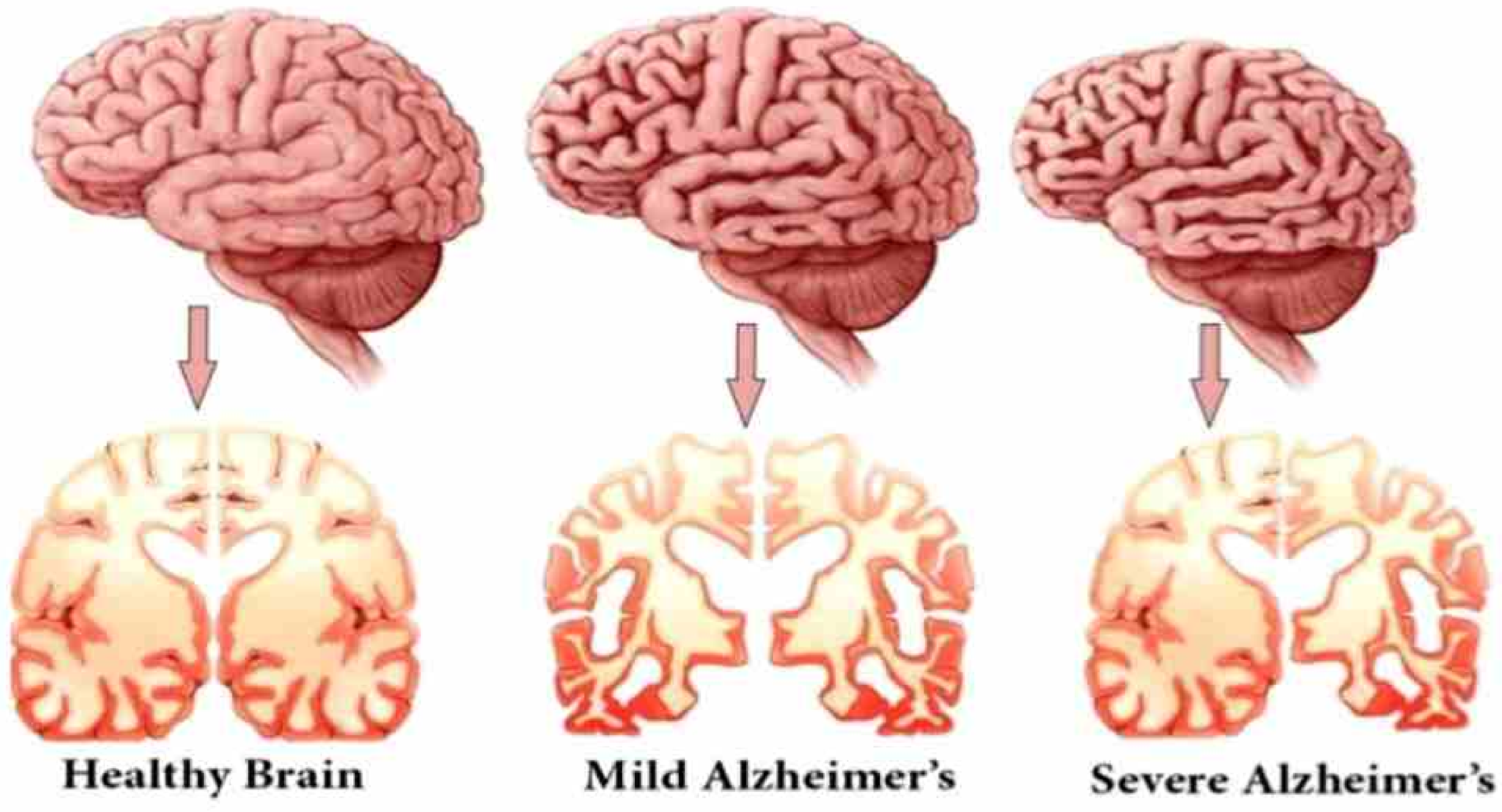


Fig.17.33 Alzheimer's disease

Parkinson's disease

It is a brain disorder caused either by degeneration or damage to nerve tissues within the basal ganglia of the brain.

Cause: Death of dopamine producing neurons.

Symptoms: It includes tremors in the arm or leg which is worse at the time when limb is in rest. Later the disease affects both sides of the body and cause stiffness, weakness and trembling of the muscles.

Treatment: There is no cure for Parkinson disease, but treatments are available to help relieve the symptoms and maintain your quality of life.

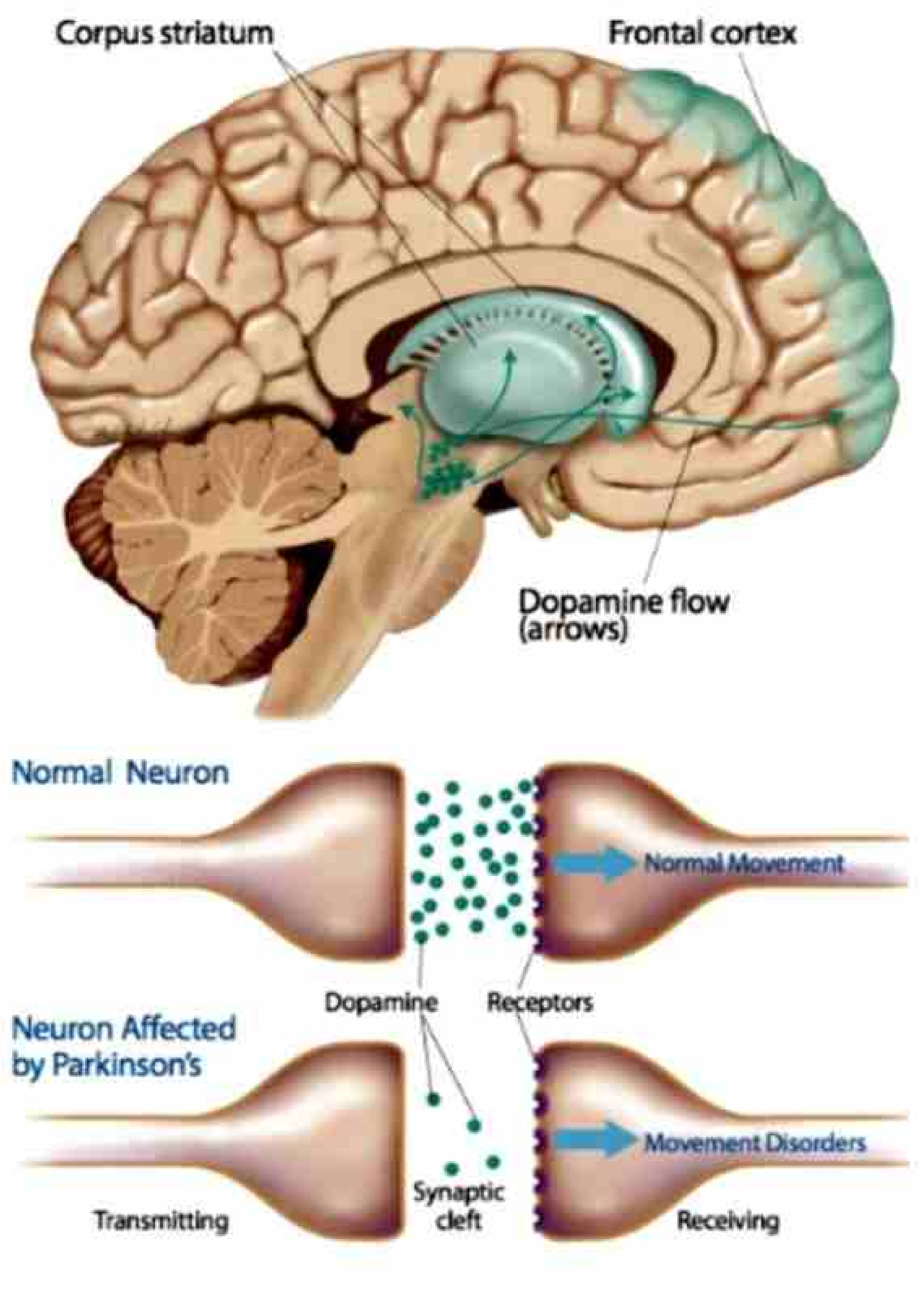


Fig.17.34 Parkinson's Disease

17.3.6 Diagnostic Test for nervous disorders

To diagnose a nervous disorder number of diagnostic test have been developed e.g. EEG, CT scan and MRI

Electroencephalogram (EEG)

It is a neuroimaging test which can detect and record minute changes in electrical activity within the brain this test using macro-electrodes (large, flat electrodes stuck to the skin or scalp). It produces a chart (an encephalogram) which shows how brain waves vary by frequency and amplitude of electrical output from the brain changes over time.

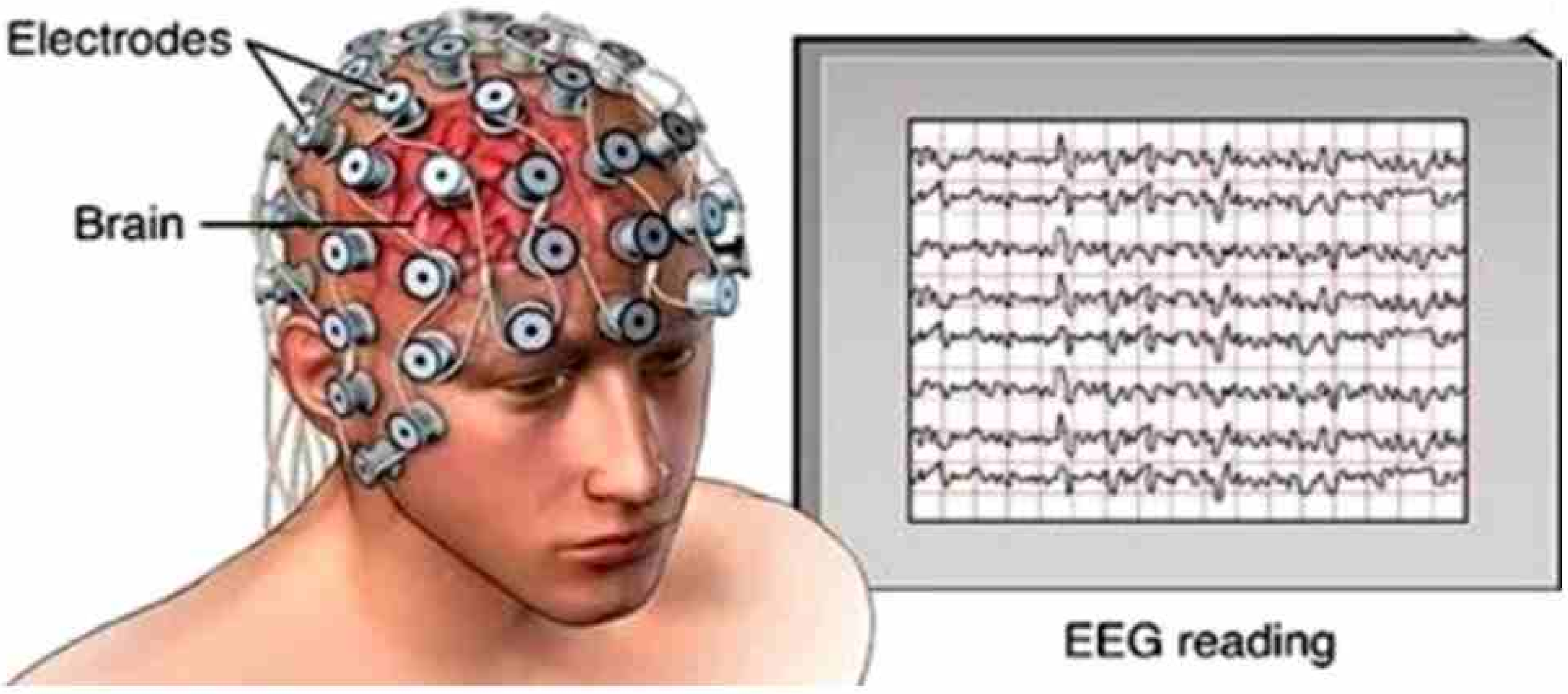


Fig.17.35 Electroencephalogram

Computed tomography (CT scan)

Computed tomography refers to a computerized x-ray imaging procedure in which an x-ray beam rotates around the body, producing signals that are processed by the machine's computer to generate cross sectional images or slices. These slices are called tomographic images and can provide more detailed information than conventional x-rays.

Fig.17.36 CT scan

Magnetic Resonance Imaging (MRI)

It is a radiological technique that uses magnetism, radio wave and a computer to produce detailed image of body structures. The MRI scanner is a tube surrounded by a circular magnet. The patient is placed on a moveable bed that is inserted into the magnet. The magnet creates a strong magnetic field that aligns the protons of hydrogen atoms. Which are then exposed to a beam of radio wave, this spins the various protons of the body, and they produce a faint signal that is detected by the receiver portion of the MRI scanner, a computer processes the receiver information, which produces an image.

Fig.17.37 MRI

SUMMARY

- Nervous co-ordination mainly comprises on highly specialized cells, called neurons.
- All receptors are transducers that convert signals from one form to another form.
- Schwann cells produce myelin in peripheral nervous system (PNS) and oligodendrocytes produce myelin in central nervous system (CNS).
- Nerve impulse is an electrical signal that depends on the flow of ions across the membrane of a neuron.
- The voltage measured across the plasma membrane is called membrane potential and it is typically in the range from -50mv to -100mv in an animal cell.
- Action potential is a sudden reversal of the electrical charge across the membrane, triggered by a temporary, localized increase in its permeability to sodium.
- Depolarization makes the membrane potential less negative, whereas hyperpolarization makes the membrane potential more negative.
- The level of depolarization needed to produce an action potential is called threshold potential.
- Velocity of conduction is greater if the diameter of the axon is larger or if the axon is myelinated.
- Synapse is junction that control communication between a neuron and another cell.
- The movement of impulse across the synapse is called a synaptic transmission.
- Electrical synapse involves direct cytoplasmic connections formed by gap junctions between the presynaptic neuron and post synaptic neurons.
- Biogenic amines are neurotransmitters derived from amino acids most commonly function as transmitters within the CNS.
- Human nervous system consists of central nervous system and peripheral nervous system.
- Central nervous system is integrating portion of the nervous system.

- The CNS is protected in three ways the first line of defense is bony armor, beneath bony armor a triple layer of connective tissue called meninges and cerebrospinal fluid cushion the brain and spinal cord.
- The forebrain is the largest and most obvious part of human's brain.
- The midbrain is extremely reduced in humans but an important relay center.
- Hind brain consists of medulla, pons and cerebellum.
- The PNS consists of paired cranial and spinal nerves and associated ganglia.
- Sense of smell involves chemoreceptors located in the upper portion of the nasal cavity.
- The receptors cells for taste are modified epithelial cells organized into taste buds.
- Drug that provide pain relief, such as morphine or Demerol, block synaspses in the pain pathways of the brain or spinal cord.

EXERCISE

1. Encircle the correct choice.

i) Most of the neurons in the human brain are
(a) Sensory neurons (b) Motor neurons
(c) Interneurons (d) Auditory neurons

ii) A nervous system can alter activities in its target cells in muscles and gland because
(a) They are electrically coupled by gap junctions.
(b) The target cells have receptor proteins for the signals released by the nervous system.
(c) The nervous system releases signals into the blood to control the target cells.
(d) The target cells that become disconnected from the nervous system rapidly die.

iii) For a neuron with an initial membrane potential at -70mv, an increase in the movement of potassium ions out of that neuron's cytoplasm would result in
(a) Depolarization of the neuron
(b) Hyperpolarization of neuron
(c) The replacement of potassium ions with sodium ions.
(d) The replacement of potassium ions with calcium ions.

iv) Action potentials move along axons
(a) More slowly in axons of large than in small diameter.
(b) The direct action of acetylcholine on the axon membrane.
(c) Activating the sodium-potassium pump at each point along the axon membrane.
(d) More rapidly in myelinated than in non-myelinated axons.

v) The surface on a neuron that discharges vesicles is the
(a) Dendrite (b) Axon hillock
(c) Presynaptic membrane (d) Postsynaptic membrane.

vi) An inhibitory postsynaptic potential occurs in a membrane made more permeable to
(a) Potassium ions (b) Sodium ions
(c) Calcium ions (d) ATP

vii) The major inhibitory neurotransmitter of the brain is
(a) Acetylcholine (b) Epinephrine
(c) GABA (d) Endorphin

viii) Where are neurotransmitter receptors located
(a) On the nuclear membrane
(b) In the myelin sheet
(c) At nodes of Ranvier
(d) On the postsynaptic membrane

ix) Which selection is incorrectly paired?
(a) Forebrain → Diencephalon
(b) Fore brain → Cerebrum
(c) Midbrain → Brainstem
(d) Midbrain → Cerebellum

x) Which of the following receptors is incorrectly paired with the type of energy is transduces?
   (a) Mechanoreceptors → Sound
   (b) Pain receptors → Electricity
   (c) Chemoreceptors → Solute concentration
   (d) Thermo receptors → Heat

2. Write short answers of the following questions:

i) Why receptors are called transducers?
ii) Why neurolemma is polarized?
iii) What do you mean by threshold potential?
iv) Why impulses move faster in myelinated neurons?
v) Why interneurons are called association neuron?
vi) What do you mean by saltatory conduction?
vii) Differentiate between following
   (a) Electrical and Chemical synapse
   (b) CNS and PNS
   (c) Excitatory neurotransmitters and Inhibitory neurotransmitters
   (d) Parasympathetic nervous system and Sympathetic nervous system
viii) Define following terms
   (a) Endorphins
   (b) Pacinian corpuslces
   (c) Nociceptors
   (d) Reflex arc
   (e) Stroke
   (f) Meningitis

3. Write detailed answers of the following questions:

i. Describe structure and function of neurons.
ii. Describe mechanism of action membrane potential.
iii. Explain vascular and infectious disorders of CNS.
iv. Describe anatomy and physiology of human brain.
v. Describe sensory receptors and their working.