DIVISIONS OF NERVOUS SYSTEM Lect.1

Nervous system controls all the activities of the body. It is quicker than the other control systems in the body namely, the endocrine system. Primarily, the nervous system is divided into two parts:

1. Central nervous system.
2. Peripheral nervous system.

CENTRAL NERVOUS SYSTEM

The central nervous system (**CNS**) includes **brain** and **spinal cord**. It is formed by **neurons** and the supporting cells called **neuroglia.** The structures of brain and spinal cord are arranged in two layers namely, the **gray matte**r and **white matter.** The gray matter is formed by **nerve cell bodies** and the **proximal parts, nerve fibers** arising from the nerve cell body. The white matter is formed by **nerve fibers. In brain,** the **white matter is centrally placed** and **gray matter is in the outer part. In spinal cord,** ***white matter is in the outer part*** and ***gray matter is in the inner part***. Brain is situated in the skull. It is continued as spinal cord in the vertebral canal through the foramen magnum of the skull bone. **Brain and spinal cord are *surrounded by three layers of meninges called the outer dura mater, middle arachnoid mater and inner pia mater***. The ***space between the arachnoid mater and pia mater is known as subarachnoid space***. This space is filled with a fluid called ***cerebrospinal fluid (CSF).*** The brain and spinal cord are actually suspended in CSF. The important parts of brain and segments of spinal cord are shown in Fig. 89.1.

Parts of Brain

Brain consists of three major divisions: 1. Forebrain. 2. Midbrain. 3. Hindbrain

1. Forebrain. It is further divided into two parts:

i. Telencephalon which includes **cerebral hemispheres, basal ganglia, hippocampus** and **amygdaloid nucleus.**

ii. Diencephalon which consists of **thalamus, hypothalamus, metathalamus** and **subthalamus.**

2. Midbrain.

3. Hindbrain is subdivided into two portions:

i. Metencephalon formed by **pons** and **cerebellum**.

ii. Myelencephalon or **medulla oblongata** (Fig. 89.2). **Midbrain, pons** and **medulla oblongata** are together called the **brainstem**.

Abdul-Majeed H. Alsaffar

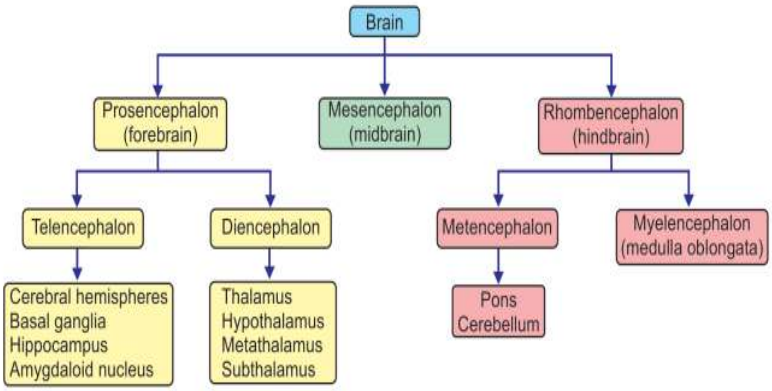

FIGURE 89.2: The parts of brain

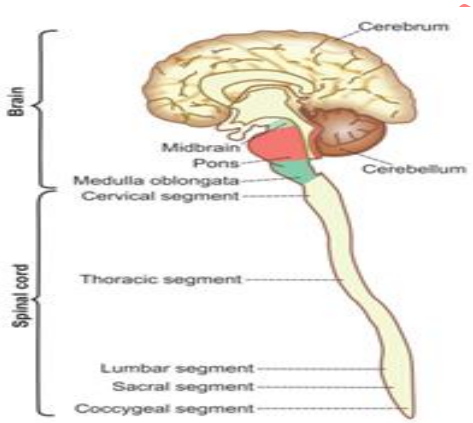

FIGURE 89.1: The parts of central nervous system

PERIPHERAL NERVOUS SYSTEM

The peripheral nervous system (PNS) is formed by the ***neurons*** *and* ***their processes present in all regions of the body***. I***t consists of cranial nerves arising from brain*** *and* ***spinal nerves arising from the spinal cord.*** It is again divided into two subdivisions:
1. Somatic nervous system. 2. Autonomic nervous system.

1. Somatic Nervous System

The somatic nervous system is concerned with ***somatic functions***. It includes the nerves supplying the skeletal muscles. Somatic nervous system controls the movements of the body by acting on the skeletal muscles (Fig. 89.3).

2. Autonomic Nervous System

The autonomic nervous system is concerned with ***regulation of visceral functions***. So, it is otherwise called ***involuntary nervous system***. The autonomic nervous system consists of two divisions, ***sympathetic division*** and **parasympathetic division**.

AbdulMalik Alsaffar

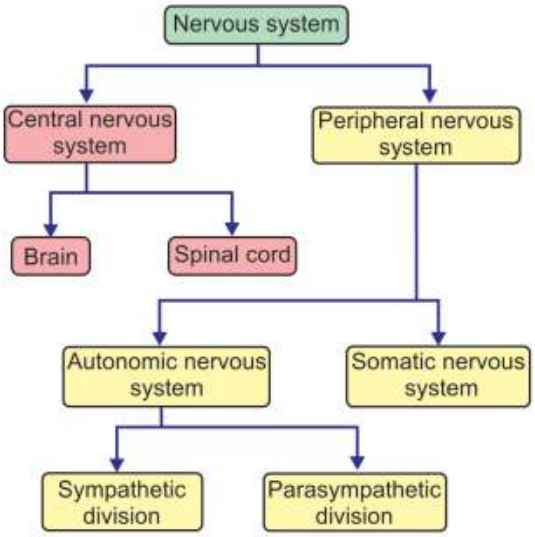

FIGURE 89.3: Organization of nervous system

Neuron and Neuroglia

NEURON

Neuron is ***defined as the structural and functional unit of the nervous system.*** It is otherwise called ***nerve cell***. Neuron is like any other cell in the body having nucleus and all the organelles in the cytoplasm.

However, it is different from other cells by two ways:

1. Neuron has branches or processes called ***axon and dendrites***.

2. Neuron does not have centrosome; ***so it cannot undergo division.***

CLASSIFICATION OF NEURON

The neurons are classified by three different methods:

I. Depending upon number of poles.

II. Depending upon function.

III. Depending upon length of the axon.

Depending upon Number of Poles

Based on the number of poles from which the nerve fibers arise, neurons are divided into three types:

1. Unipolar neurons that have only one pole from which, both the axon and dendrite arise (Fig. 90.1).

2. Bipolar neurons which have two poles. Axon arises from one pole and dendrites arise from the other pole.

3. Multipolar neurons which have many poles. One of the poles gives rise to the axon and, all the other poles give rise to dendrites

Abdul-Majeed H. Alsaffar

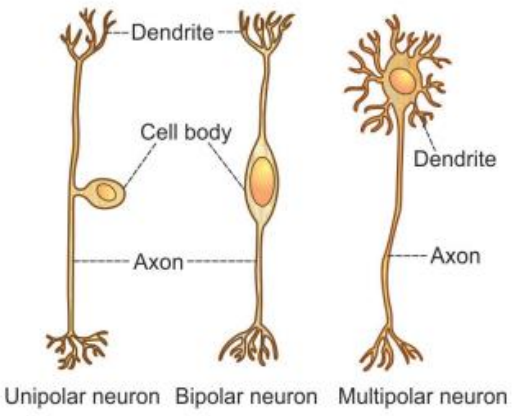

FIGURE 90.1: Types of neuron

Depending upon Function

On ***the basis of function,*** the nerve cells are classified into two types:

1. Motor neurons or efferent neurons

which carry the motor impulses from central nervous system to the peripheral effector organs like muscles, glands, blood vessels, etc.

2. Sensory neurons or afferent neurons

which carry the sensory impulses from periphery to the central nervous system.

Depending upon Length of Axon

Depending upon the length of axon, neurons are divided into two types:

1. Golgi type I neurons **that have long axons**. The cell body of these neurons is in central nervous system and their axons reach the remote peripheral organs.

2. Golgi type II neurons **that have short axons**. These neurons are present in cerebral cortex and spinal cord.

STRUCTURE OF NEURON

Each neuron is made up of three parts:

1. Nerve cell body.
2. Dendrite.
3. Axon.

The dendrite and axon together form the processes of neuron (Fig. 90.2). In general, the *dendrites are short processes* and the *axons are long processes*. The dendrites and axons are usually called nerve fibers.

Nerve Cell Body The nerve cell body is also known as ***soma or perikaryon***. It is irregular in shape and, it is constituted by a mass of cytoplasm called *neuroplasm* which is covered by a cell membrane. The cytoplasm contains a ***large nucleus, Nissl bodies, neurofibrils, mitochondria and Golgi apparatus***. Nissl bodies and neurofibrils are found only in nerve cell and not in other cells.

Nucleus

Each neuron has one nucleus which is centrally placed in the nerve cell body. The nucleus has one or two prominent nucleoli. The nucleus does not contain centrosome. So, the nerve cell cannot multiply like the other cells.

Nissl bodies

Nissl bodies or Nissl granules are small basophilic granules found in cytoplasm of neurons and are named after the discoverer. These bodies are present in the soma except in axon hillock. Nissl bodies re called tigroid substances since these bodies are

Abdul-Majeed H. Alsaffar

responsible for the tigroid or spotted appearance of soma after suitable staining. The Nissl granules flow into the dendrites from soma, but not into axon. So, the dendrites are distinguished from axons by the presence of Nissl granules under microscope. The Nissl bodies are membranous organelles containing ribosomes. So, these bodies are concerned with synthesis of proteins in the neurons. The proteins formed in soma are transported to the axon by axonal flow

Neurofibrils

Neurofibrils are thread like structures present in the form of network in the soma and the nerve processes. Presence of neurofibrils is another characteristic feature of the neurons.

Mitochondria

The mitochondria are present in the soma and in axon. As other cells, the mitochondria form the powerhouse of the nerve cell, where ATP is produced.

Golgi apparatus

Golgi apparatus of the nerve cell body is similar to that of other cells. It is concerned with processing and packaging of proteins into granules.

Dendrite

The dendrite is the branched process of the neuron and it is branched repeatedly. ***The dendrite may be present or absent***. If it is, it may be one or many in number. The dendrite has Nissl granules and neurofibrils. Dendrite is conductive in nature. It transmits impulses towards the nerve cell body.

Axon

The *axon is longer than dendrite*. Each neuron has only one axon. The axon arises from axon hillock of the nerve cell body. The axon extends for a long distance away from the nerve cell body. *The length of the longest axon is about 1 meter*.

Organization of nerve

Many axons together form a bundle called ***fasciculus***. *Many fasciculi together form a nerve*. The whole nerve is *covered by tubular sheath*, which is formed by areolar membrane. *This sheath is called epineurium*. Each fasciculus is covered by *perineurium* and each nerve fiber (axon) is covered by *endoneurium* (Fig. 90.3).

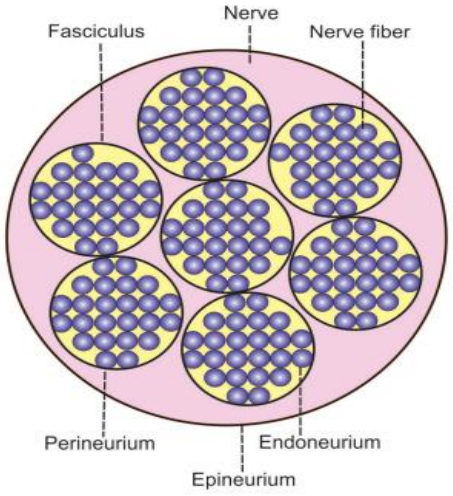

FIGURE 90.3: Cross section of a nerve

Abdul-Majeed H. Alsaffar

Internal structure of axon – axis cylinder

The axon has a long central core of cytoplasm called ***axoplasm***. The axoplasm is covered by the tubular sheath like membrane called ***axolemma*** which is the continuation of the cell membrane of nerve cell body. ***The axoplasm along with the axolemma is called the axis cylinder of the nerve fiber*** (Fig. 90.4). Axoplasm contains mitochondria, neurofibrils and axoplasmic vesicles. ***But, Nissl bodies are absent in the axon.*** The axis cylinder of the nerve fiber is covered by a membrane called ***neurilemma***.

Non-myelinated nerve fiber The nerve fiber described above is the nonmyelinated nerve fiber which is not covered by myelin sheath.

Myelinated nerve fiber

The nerve fibers which are insulated by myelin sheath are called myelinated nerve fibers.

Myelin Sheath

Myelin sheath is a thick lipoprotein sheath that insulates the myelinated nerve fiber. Myelin sheath is not a continuous sheath. It is absent at regular intervals. The area where the myelin sheath is absent is called ***node of Ranvier***. The segment of the nerve fiber between two nodes is called ***internode***. Myelin sheath is responsible for the white color of the nerve fibers.

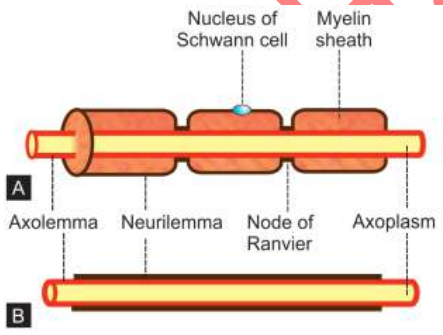

FIGURE 90.4: A. Myelinated nerve fiber; **B.** Non-myelinated nerve fiber.

Chemistry of myelin sheath Myelin sheath

is formed by concentric layers of proteins alternating with lipids. The lipids are cholesterol, lecithin and cerebroside (sphingomyelin).

Formation of myelin sheath – myelinogenesis

The formation of myelin sheath around the axon is called the myelinogenesis. It is formed by Schwann cells in neurilemma.

Functions of myelin sheath

1. Faster conduction:

Myelin sheath is responsible for faster conduction of impulse through the nerve fibers. In the myelinated nerve fibers, the impulses jump from one node to another node by saltatory conduction.

2. Insulating capacity: Myelin sheath has a high insulating capacity. Because of this quality, the myelin sheath restricts the nerve impulse within the single nerve fiber, and prevents the stimulation of neighboring nerve fibers.

Abdul-M... J. Alsaffar

Neurilemma

Neurilemma is a thin membrane which surrounds the axis cylinder. It is also called neurilemmal sheath or sheath of Schwann. It contains Schwann cells, which have flattened and elongated nuclei. The cytoplasm is thin and modified to form the thin sheath of neurilemma.

One nucleus is present in each internode of the axon. The nucleus is situated between myelin sheath and neurilemma.

In non-myelinated nerve fiber, the neurilemma continuously surrounds axolemma. In myelinated nerve fiber, it covers the myelin sheath. At the node of Ranvier (where myelin sheath is absent), the neurilemma invaginates and runs up to axolemma in the form of a finger like process.

Functions of neurilemma

In non-myelinated nerve fiber, the neurilemma serves as a covering membrane. In myelinated nerve fiber, it is necessary for the formation of myelin sheath (myelinogenesis).

NEUROGLIA Lec.2

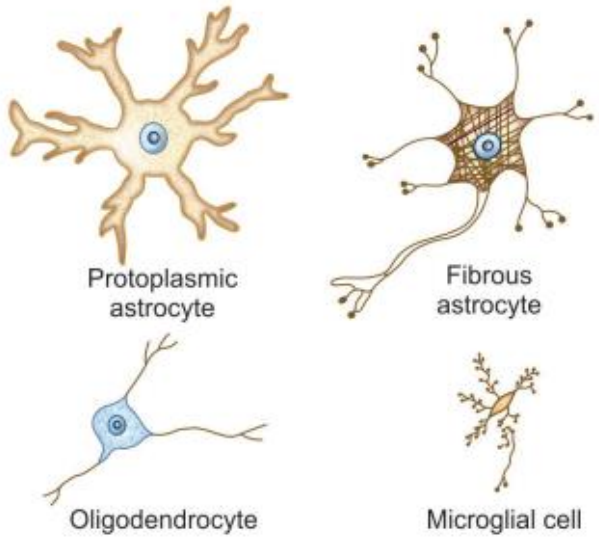

FIGURE 90.8: Neuroglial cells in CNS

CLASSIFICATION OF NEUROGLIAL CELLS

The neuroglial cells are distributed in central nervous system (CNS) as well as peripheral nervous system (PNS).

Central Neuroglial Cells

The neuroglial cells in CNS are of three types:

1. Astrocytes.
2. Microglia.
3. Oligodendrocytes.

1. Astrocytes

Astrocytes are star-shaped neuroglial cells present in all the parts of the brain (Fig. 90.8). Astocytes are of two types, fibrous astrocytes and protoplasmic astrocytes.

Abdul-Alsaffar

i. Twist around the nerve cells and form the supporting network in brain and spinal cord.
ii. Form the blood-brain barrier and thereby regulate the entry of substances from blood into brain tissues.
iii. Maintain the chemical environment of ECF around CNS neurons.
iv. Provide calcium and potassium and regulate neurotransmitter level in synapses.

2. Microglia

Microglia are the smallest neuroglial cells. These cells are derived from monocytes and enter the tissues of nervous system from blood. These phagocytic cells migrate to the site of infection or injury and are often called the macrophages of CNS. Microglia engulf and destroy the microorganisms and cellular debris by means of Phagocytosis.

3. Oligodendrocytes

Oligodendrocytes are neuroglial cells which produce myelin sheath around nerve fibers in CNS. Oligodendrocytes provide myelination around the nerve fibers in CNS where Schwann cells are absent

Peripheral Neuroglial Cells

The neuroglial cells in PNS are of two types:
1. Schwann cells.
2. Satellite cells.

1. Schwann Cells

Schwann cells are the major glial cells in PNS. Schwann cells provide myelination (insulation) around the nerve fibers in PNS. These cells remove cellular debris during regeneration by their phagocytic activity.

2. Satellite Cells

Satellite cells are the glial cells present on the exterior surface of PNS neurons. Satellite cells provide physical support to the PNS neurons

Receptors

Receptors are the ***sensory*** (afferent) nerve endings that terminate in the periphery as bare unmyelinated nerve endings or in the form of specialized capsulated structures. When stimulated, receptors produce a series of impulses which are transmitted through the afferent nerves. Actually receptors function like a transducer. Transducer is a device, which converts one form of energy into another. So, the receptors are often defined as the biological transducers which convert various forms of energy (stimuli) in the environment into action potentials in nerve fiber

CLASSIFICATION OF RECEPTORS

Generally, the receptors are classified into two types:
I. Exteroceptors.
II. Interoceptors.

Abdul-Majeed H. Alsaffar

EXTEROCEPTORS

Exteroceptors are the receptors which give response to stimuli arising from outside the body. The exteroceptors are divided into three groups.

1. Cutaneous Receptors

The receptors situated in the skin are called the cutaneous receptors. Cutaneous receptors are also called mechanoreceptors because of their response to mechanical stimuli such as ***touch, pressure and pain*** (Fig. 91.1). Touch and pressure receptors give response to vibration also. The different types of cutaneous receptors are given in Fig. 91.2

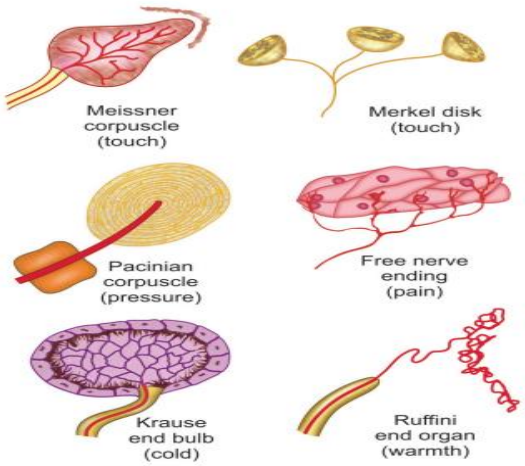

FIGURE 91.1: Cutaneous receptors

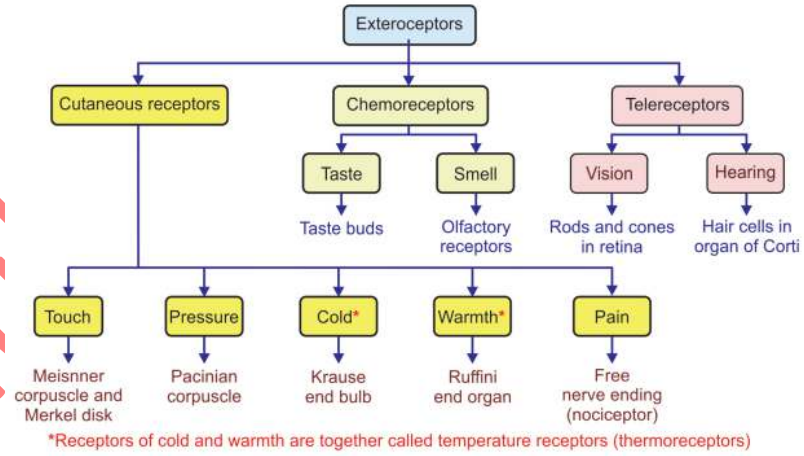

FIGURE 91.2: Exteroceptors

2. Chemoreceptors

The receptors, which give response to chemical stimuli, are called the chemoreceptors. Examples are given in Fig. 91.2.

3. Telereceptors

Telereceptors are the receptors that give response to stimuli arising away from the body. These receptors are also called the distance receptors. Examples are given in Fig. 91.2.

INTEROCEPTORS

Interoceptors are the receptors which give response to stimuli arising from within the body. Interoceptors are of two types.

1. Visceroceptors

Receptors situated in the viscera are called visceroceptors. Visceroceptors are listed in Fig. 91.3.

2. Proprioceptors

Proprioceptors are the receptors which give response to change in the position of different parts of the body. Proprioceptors are listed in Fig. 91.3.

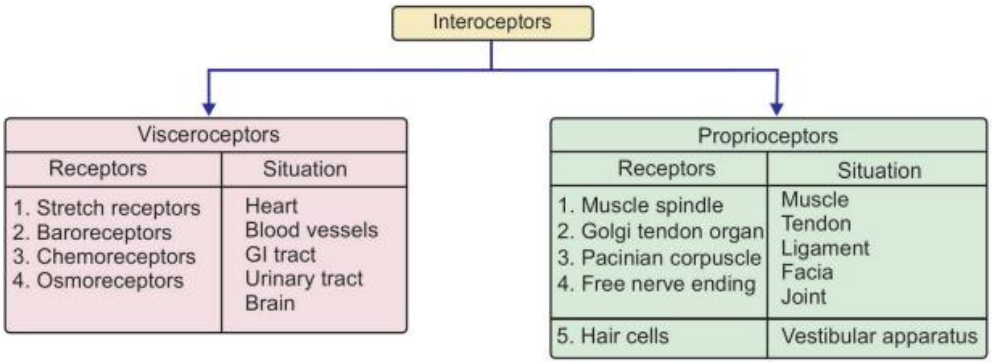

FIGURE 91.3: Interoceptors

Synapse and Neurotransmitters Lec.3

Synapse is the junction between the two neurons. It is a physiological continuity between two nerve cells.

CLASSIFICATION OF SYNAPSE

Synapse is classified by two methods,

1. anatomical classification. 2.Functional classification.

ANATOMICAL CLASSIFICATION

Synapse is formed by axon of one neuron ending on the cell body, dendrite or axon of the next neuron. Depending upon the ending of axon, the synapse is classified into three types (Fig. 92.1):

1. Axoaxonic synapse

in which axon of one neuron terminates on axon of another neuron.

2. Axodendritic synapse

in which axon of one neuron terminates on dendrite of another neuron

Abdul Malik Jaffar

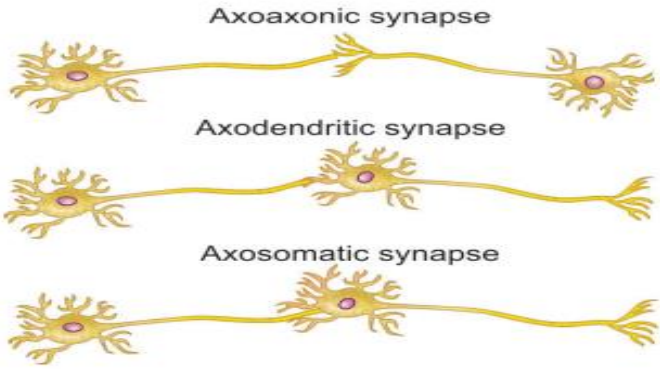

FIGURE 92.1: Anatomical synapses

3. Axosomatic synapse
in which axon of one neuron ends on soma (cell body) of another neuron.

FUNCTIONAL CLASSIFICATION

Functional classification depends upon mode of impulse transmission. On this basis, synapse is classified into two types.

1. Electrical Synapse
Electrical synapse is the synapse in which the physiological continuity between the presynaptic and the postsynaptic neurons is provided by the ***gap junction*** between these two neurons (Fig. 92.2). There is direct exchange of ions between the two neurons though the gap junction. So, the action potential reaching the terminal portion of presynaptic neuron directly enters the postsynaptic neuron.

2. Chemical Synapse Chemical synapse is the junction between a nerve fiber and a muscle fiber or between two nerve fibers, through which the signals are transmitted by the release of chemical transmitter. In the chemical synapse, there is no continuity between the presynaptic and postsynaptic neurons. These two neurons are separated by a space called synaptic cleft between the two neurons.
The functional anatomy of a chemical synapse is shown in Fig. 92.3.

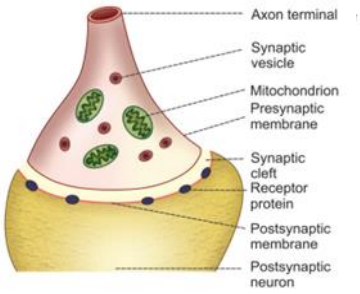

FIGURE 92.3: Structure of chemical synapse

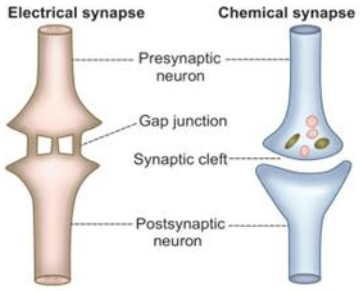

FIGURE 92.2: Electrical and chemical synapse

FUNCTIONS OF SYNAPSE

The function of the synapse is to transmit the impulses from one neuron to another. However, some synapses inhibit the impulses. Accordingly, synapse is divided into two types:

Abdul-Majeed H. Alsaffar

1. Excitatory synapses, which transmit the impulses (excitatory function).
2. Inhibitory synapses, which inhibit the transmission of impulses (inhibitory function).

EXCITATORY SYNAPSE

Excitatory synapse transmits the impulses from presynaptic neuron to postsynaptic neuron by the development of excitatory postsynaptic potential.

Excitatory Postsynaptic Potential

- Excitatory postsynaptic potential (EPSP) is the non-propagated electrical potential that develops during the process of synaptic transmission.
- When the action potential reaches the *presynaptic axon terminal*, the *voltage-gated calcium channels at the presynaptic membrane are opened*.
- Now, the *calcium ions enter the axon terminal from ECF* (Fig. 92.4).
- The *calcium ions cause the release of neurotransmitter substance from the vesicles by means of exocytosis.* The common neurotransmitter in synapse is *acetylcholine.*
- The *neurotransmitter passes through presynaptic membrane and synaptic cleft* and *reaches the postsynaptic membrane.*
- Now, it *binds with the receptor protein present in the neurotransmitter-receptor complex causes opening of ligand-gated sodium channels*.
- Now, the sodium ions from ECF enter the cell body of postsynaptic neuron. As the sodium ions are positively charged, the resting membrane potential inside the cell body becomes slightly positive and a mild depolarization develops. This type of mild depolarization is called EPSP.
- EPSP is confined only to the synapse. It is a graded potential. It is similar to receptor potential and endplate potential. postsynaptic membrane to form the neurotransmitter-receptor complex.

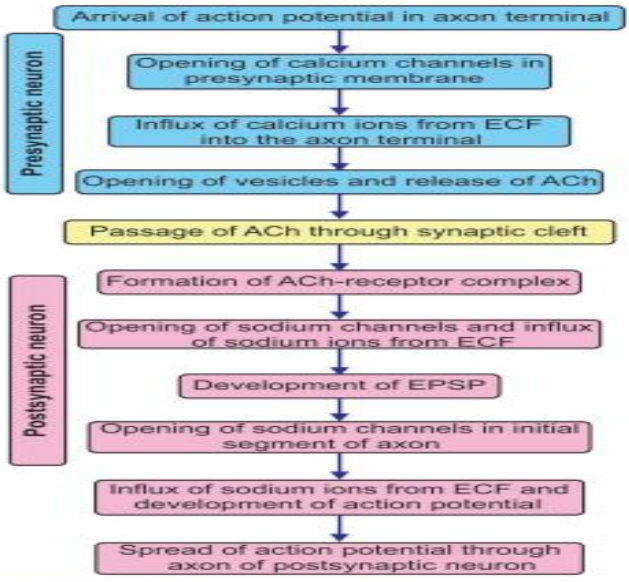

FIGURE 92.4: Sequence of events during synaptic transmission. ACh = Acetylcholine, ECF = Extracellular fluid, EPSP = Excitatory postsynaptic potential.

Abdulmajeed H. Alsaffar

Properties of EPSP

EPSP has two properties:

1. It is nonpropagated.
2. It does not obey all-or-none law.

Significance of EPSP

The EPSP is not transmitted into the axon of postsynaptic neuron. However, it causes development of action potential in the axon. When the EPSP is strong enough, it causes the opening of voltage-gated sodium channels in the initial segment of axon. Now, due to the entrance of sodium ions, the depolarization occurs in the initial segment of axon and thus, the action potential develops. From here, the action potential spreads to other segment of the axon. „

INHIBITORY SYNAPSE

Inhibitory synapse does not transmit the impulses from presynaptic neuron to postsynaptic neuron.

Inhibition of synaptic transmission is classified into three types:

1. Postsynaptic inhibition.
2. Presynaptic inhibition.
3. Renshaw cell inhibition.

1. Postsynaptic Inhibition

Postsynaptic inhibition is the type of synaptic inhibition that occurs due to the release of an inhibitory neurotransmitter from presynaptic terminal instead of an excitatory neurotransmitter substance. *It is also called direct inhibition*.

The inhibitory neurotransmitter develops **inhibitory postsynaptic potential** (**IPSP**) instead of EPSP.

The inhibitory neurotransmitters are gamma-aminobutyric acid (GABA), dopamine and glycine.

Action of GABA – development of IPSP

IPSP is the electrical potential in the form of hyperpolarization that develops during postsynaptic inhibition. The inhibitory neurotransmitter substance acts on postsynaptic membrane by binding with receptor. The transmitter-receptor complex opens the ligand-gated potassium channels instead of sodium channels. Now, the potassium ions which are available in plenty in the cell body of postsynaptic neuron move to ECF. Simultaneously, chloride channels also open and chloride ions (which are more in ECF) move inside the cell body of postsynaptic neuron. The exit of potassium ions and influx of chloride ions cause more negativity inside, leading to hyperpolarization. The hyperpolarized state of the synapse inhibits synaptic transmission.

2. Presynaptic Inhibition

It is the synaptic inhibition which occurs because of the failure of presynaptic axon terminal to release the excitatory neurotransmitter substance. It is also called indirect inhibition.

3. Renshaw Cell Inhibition

It is the type of synaptic inhibition which is caused by Renshaw cells in spinal cord. Renshaw cells are small motor neurons scattered among the large α-motor neurons in anterior gray horn of spinal cord. The motor nerve fibers to effector organs arise from α-motor neurons. Some of these fibers send collateral fibers to Renshaw cells. When the motor neurons send motor impulses to effector organs, some of the impulses

Abdul-Majeed H. Alsaffar

reach the Renshaw cell by passing through collaterals. Now, the Renshaw cell is stimulated. In turn, it sends inhibitory impulses to α-motor neurons, so that the discharge from α-motor neurons is reduced (Fig. 92.5). Significance of synaptic inhibition The synaptic inhibition in CNS limits the number of impulses going to muscles and enables the muscles to act properly and appropriately.

TABLE 92.1: Neurotransmitters

Group	Name	Site of secretion	Action
Amino acids	GABA	Cerebral cortex, cerebellum, basal ganglia, retina and spinal cord	Inhibitory
	Glycine	Forebrain, brain stem, spinal cord and retina	Inhibitory
	Glutamate	Cerebral cortex, brain stem and cerebellum	Excitatory
	Aspartate	Cerebellum, spinal cord and retina	Excitatory
Amines	Noradrenaline	Postganglionic adrenergic sympathetic nerve endings, cerebral cortex, hypothalamus, basal ganglia, brainstem, locus ceruleus and spinal cord	Excitatory and inhibitory
	Adrenaline	Hypothalamus, thalamus and spinal cord	Excitatory and inhibitory
	Dopamine	Basal ganglia, hypothalamus, limbic system, neocortex, retina and sympathetic ganglia	Inhibitory
	Serotonin	Hypothalamus, limbic system, cerebellum, spinal cord, retina, GI tract, lungs and platelets	Inhibitory
	Histamine	Hypothalamus, cerebral cortex, GI tract and mast cells	Excitatory
Others	Nitric oxide	Many parts of CNS, neuromuscular junction and GI tract	Excitatory
	Acetylcholine	Preganglionic parasympathetic nerve endings Postganglionic parasympathetic nerve endings Preganglionic sympathetic nerve endings Postganglionic sympathetic cholinergic nerve endings Neuromuscular junction, cerebral cortex, hypothalamus, basal ganglia, thalamus, hippocampus and amacrine cells of retina	Excitatory

TABLE 92.2: Excitatory and inhibitory neurotransmitters

Excitatory neurotransmitters	Inhibitory neurotransmitters	Neurotransmitters with excitatory and inhibitory actions
1. Acetylcholine 2. Nitric oxide 3. Histamine 4. Glutamate 5. Aspartate	1. GABA 2. Glycine 3. Dopamine 4. Serotonin	1. Noradrenaline 2. Adrenaline

NEUROTRANSMITTERS

Neurotransmitter is a chemical substance that acts as the mediator for the transmission of nerve impulse from one neuron to another neuron through a synapse.

CLASSIFICATION OF NEUROTRANSMITTERS

Depending upon Chemical Nature Depending upon chemical nature, neurotransmitters are classified into three groups (Table 92.1):

1. Amino acids. 2. Amines. 3. Others.

Depending upon Function Depending upon function, neurotransmitters are classified into two types:

1. Excitatory neurotransmitters which are responsible for the conduction of impulse. 2. Inhibitory neurotransmitters which inhibit the conduction of impulse. Details of neurotransmitters are given in the Tables 92.1 and 92.2.

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