Topic 7. Nervous tissue

Control questions

1. Structural components of nervous tissue.
2. Neurons: development, morphofunctional characteristic, classifications, ultrastructural features.
3. Neuroglia: classification of neuroglial cells; origination and morphofunctional characteristic of the different types of glial cells.
4. Formation and structure of unmyelinated nerve fibers.
5. Formation and structure of myelinated nerve fibers.
6. Relationship between neurons, glia and blood vessels. Blood-brain and blood-cerebrospinal fluid barriers.
7. Structure and classification of synapses.
8. Efferent nerve endings: classification and structure.
9. Afferent nerve endings: classification and structure.
10. Regeneration of the nervous tissue.

Question 1. Structural components of nervous tissue.

Nervous tissue can percept irritation from various physical and chemical stimuli of the external or internal environment and to transmit an excitation to other nerve cells or effector organs, such as muscles and glands. Thus, the main functions of nervous tissue are irritability conductivity.

Nervous tissue consists of 2 types of cells:

1) Neurons;
2) Neuroglial cells.

Neurons provide the main functions of nervous tissue. They are specialized to receive information and conduct it, as impulses, to other parts of the nervous system.

Neuroglial cells provide a variety of support functions for neurons.

Question 2. Neurons: development, morphofunctional characteristic, classifications, ultrustructural features.

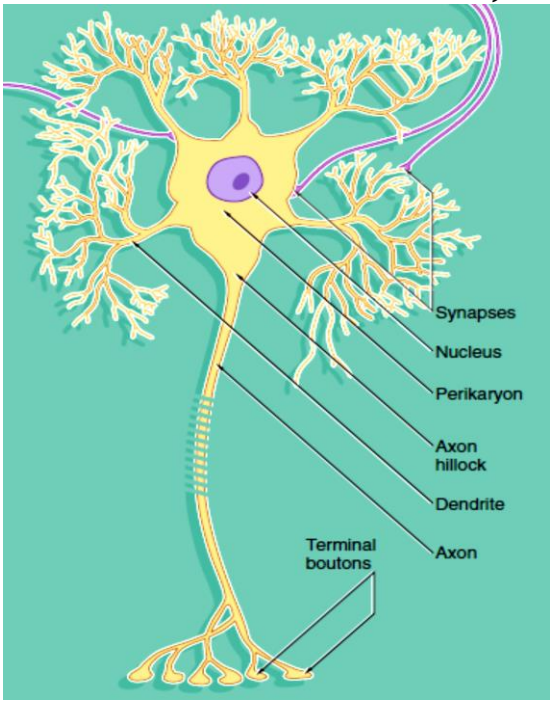

Figure 7.1. Diagram of neuron [14].

The neurons are produced from the cells called neuroblasts of the nervous tube. The neuron is the structural and functional unit of the nervous system. The neuron consists of cell body or perikaryon and cell processes – dendrites and axon.

Neurons usually have several more short and branch dendrites, that transmit impulses from the periphery toward the cell body.

Neurons have only one more long and less branch axon, extending from the cell body, which transmits impulses away from the cell body to axon terminal part. Axon arises from a small conical elevation on the perikaryon, called the axon hillock. The plasma membrane of the axon is called the axolemma; the cytoplasm is called the axoplasm.

The cell body of neuron contains a large, euchromatic nucleus with a prominent nucleolus and surrounding perinuclear cytoplasm. The perinuclear cytoplasm reveals abundant rough endoplasmic reticulum (rER), free ribosomes, numerous mitochondria, a large perinuclear Golgi apparatus, lysosomes and microtubules [14].

Ultrastructural features of neurons

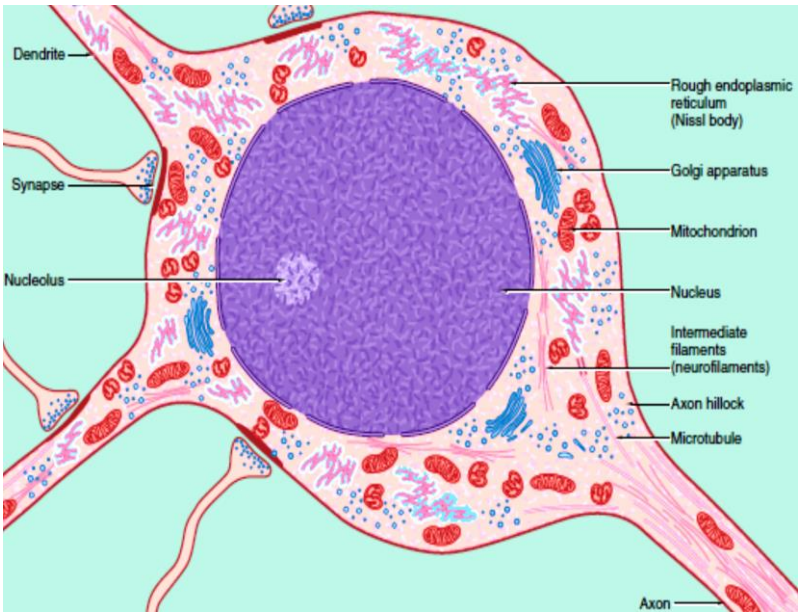

Figure 7.2. Diagram of the neuron's cell body [14].

In the cytoplasm of neurons cell bodies and dendrites, the large clusters of ribosomes and r-EPR appear as areas of basophilia called Nissl bodies or chromophilic substance. Each Nissl body corresponds to a stack of rER. Nissl bodies are usually absent in the axon.

Numerous r-EPR is evidence of a high level of protein synthetic activity of the neurons that produce enzymes, neurotransmitter substances, membrane components and so on.

Special organelles of neurons are named neurofilaments and neurofibrils. Neurofilaments belong to the intermediate filaments. Neurofibrils are bundles of microfilaments and microtubules. Special organelles constitute the support and drain system of neurons and their processes [13].

Multipolar neuron of spinal cord (slide)

Stain: Toluidine blue

Using this illustration you must perform the exercise 3 of album (topic "Nervous tissue")

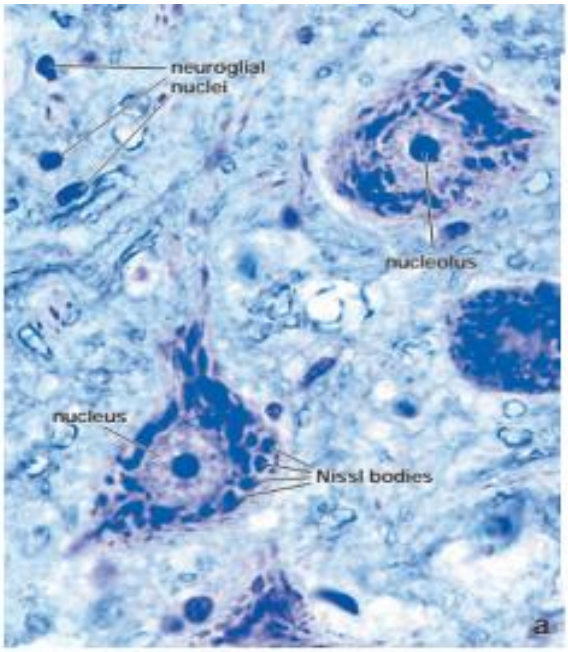

Figure 7.3. Photomicrograph of neurons with Nissl bodies [13].

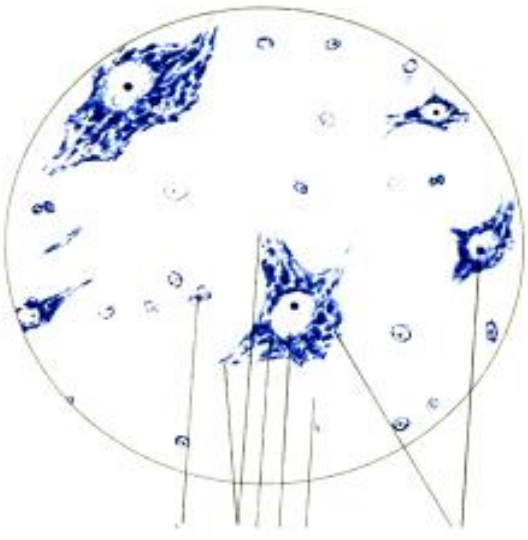

Figure 7.4. Diagram of neurons with Nissl bodies [17].

Functional classification of neurons

There are 3 types of neurons according to their functions:

1. Sensory (afferent) neurons. The dendrites of these cells always end with the receptors.

2. Motor (efferent) neurons, which transmit impulses to muscles or glands. The axons of motor neurons are always ended with the motor nerve endings.
3. Interneurons (intercalated neurons) form a communicating and integrating network between the sensory and motor neurons. It is estimated that more than 99.9% of all neurons belong to this integrating network [13].

Morphological classification of neurons

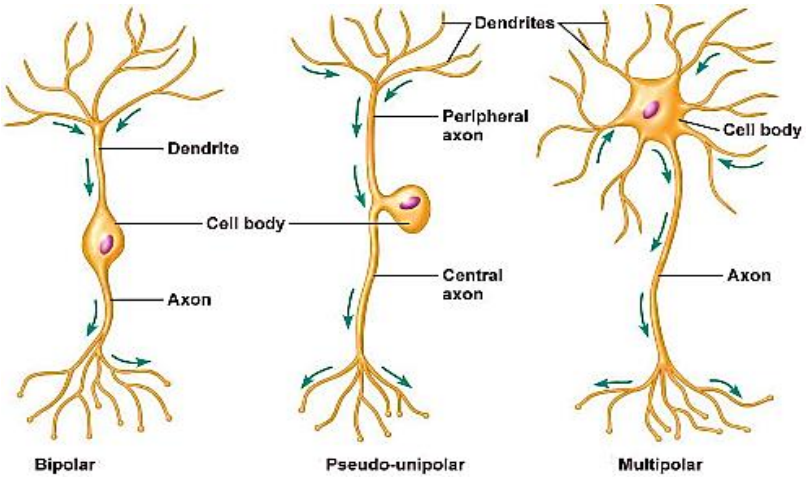

Figure 7.5. Diagram of the types of neurons.

There are 3 types of neurons according to the number of processes extending from the cell body of neurons.

1. Bipolar neurons have two processes - one is axon and one is dendrite. They release from opposite poles of neuron cell body. They generally found within the retina of the eye, nasal olfactory epithelium and the ganglia of the vestibulocochlear nerve of the ear.

2. Pseudounipolar neurons (unipolar) have one axon dividing near cell body into two long branches. One branch extends to the periphery and another extends to the central nervous system (CNS). The branch of axon extending to periphery performs the function of dendrite and forms here the sensory (receptor) ending. Therefore, the unipolar neurons are sensory neurons. Their cell bodies situate in the spinal and cranial ganglia.

3. Multipolar neurons have several dendrites and one axon. They form the most numerous type [6].

Question 3. Neuroglia: classification of neuroglial cells; origination and morphofunctional characteristic of the different types of glial cells.

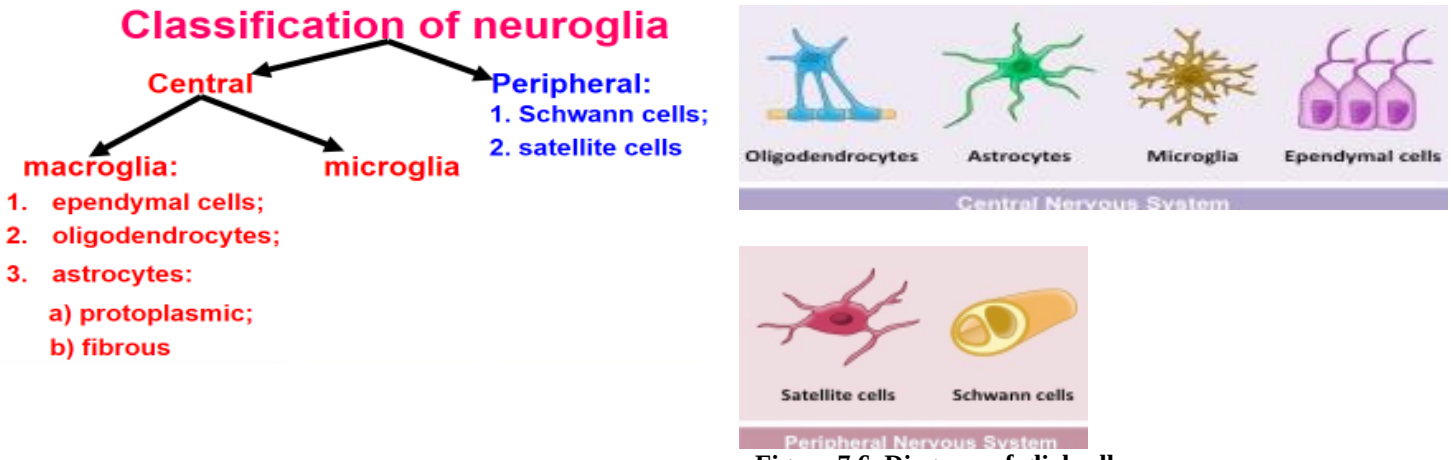

Figure 7.6. Diagram of glial cells.

Embryonic development of glial cells

The cells of central neuroglia except microglial cells are developed from neuroectodermal cells of the neural tube.

Peripheral neuroglia is developed from the neural crest.

Microglial cells arise from blood-borne monocytes and represent the mononuclear phagocyte system in nervous tissue [13].

Microglial cells

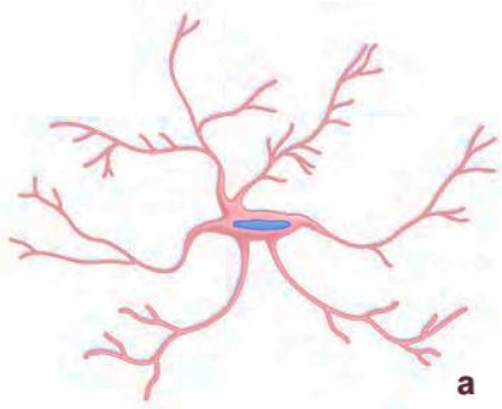

Figure 7.7. Diagram of microglial cell [13].

Microglial cells are macrophages of nervous tissue. They arise from blood-borne monocytes and represent the mononuclear phagocyte system in nervous tissue.

Microglial cells are small cells with few short extensions. They are scattered everywhere throughout the brain and spinal cord and can migrate and provide phagocytosis (**protective function**). Therefore, microglial cells play an important role in defense against invading microorganisms and neoplastic cells. They remove bacteria, injured cells, and the debris of cells that undergo apoptosis. They also mediate neuroimmune reactions [13].

Ependymal cells

Ependymal cells are columnar cells that line the ventricles of the brain and the central canal of the spinal cord. They are bathed by the cerebrospinal fluid, which fills these cavities. Most ependymal cells contain motile cilia and microvilli on their apical parts. Cilia serve to provide movement of the cerebrospinal fluid. Microvilli are involved in absorbtion of the cerebrospinal fluid.

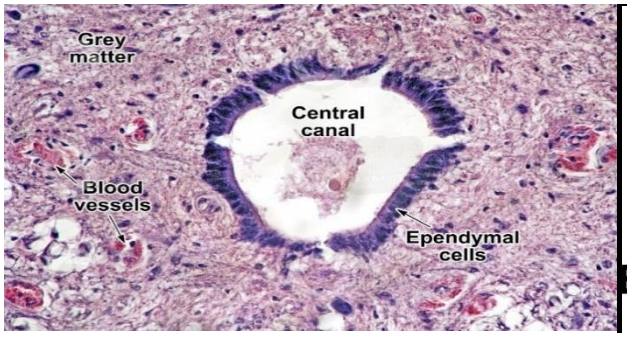

Figure 7.8. Photomicrograph of the central canal of the spinal cord.

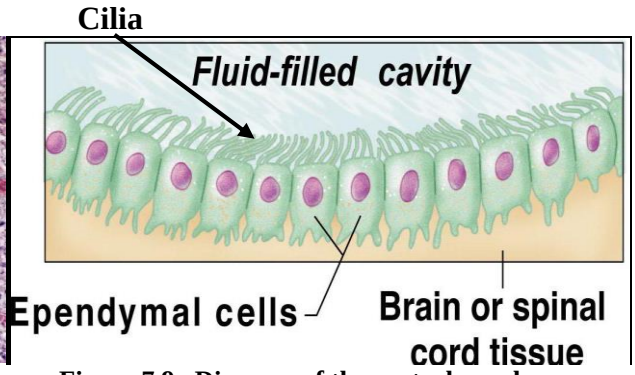

Figure 7.9. Diagram of the central canal of the spinal cord.

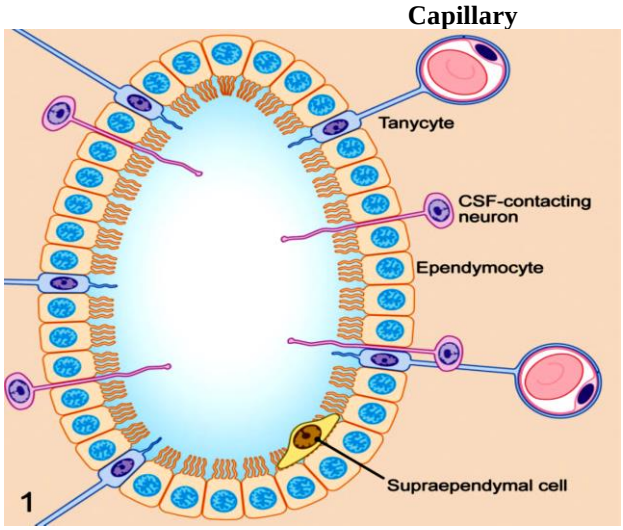

Figure 7.10. Diagram of choroid plexus.

The basal part of some ependymal cells have a long process that extends deep into subjacent neural tissue. These modified ependymal cells also known as tanycytes there are in brain ventricles where they produce the cerebrospinal fluid and play a role in transferring chemical substances from cerebrospinal fluid to the capillary plexus. Tanycytes and associated capillary loops are called the choroid plexus [13].

Astrocytes

There are 2 types of astrocytes:

1) Protoplasmic;

2) Fibrous.

Protoplasmic astrocytes have numerous thick, shot and more branched processes. They are more prevalent in gray matter of the brain.

Fibrous astrocytes have long, slender, less branched processes. They are more prevalent in white matter of the brain.

Astrocytes provide the nutrition and support for the neurons in CNS. These cells are also often attached to blood vessels by their processes expanded endings called pedicles or "perivascular feet" to produce blood brain barrier [13].

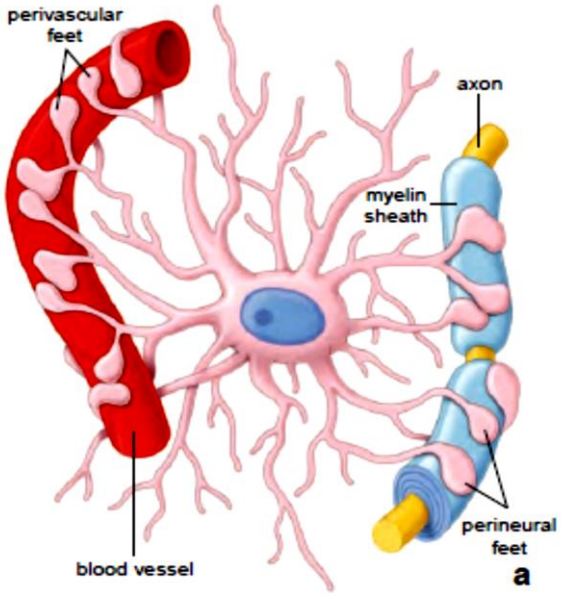

Figure 7.11. Diagram of protoplasmic astrocyte [13].

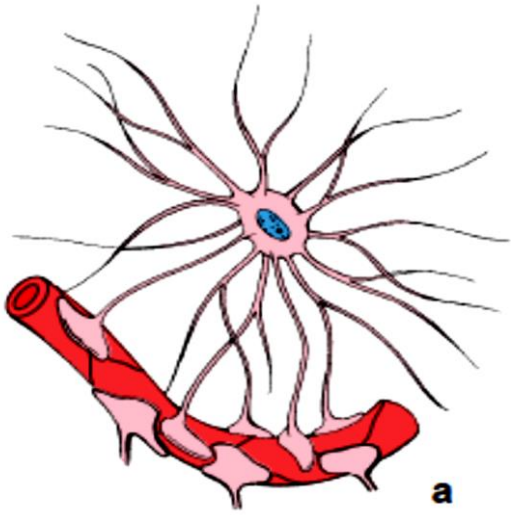

Figure 7.12. Diagram of fibrous astrocyte [13].

Oligodendrocytes

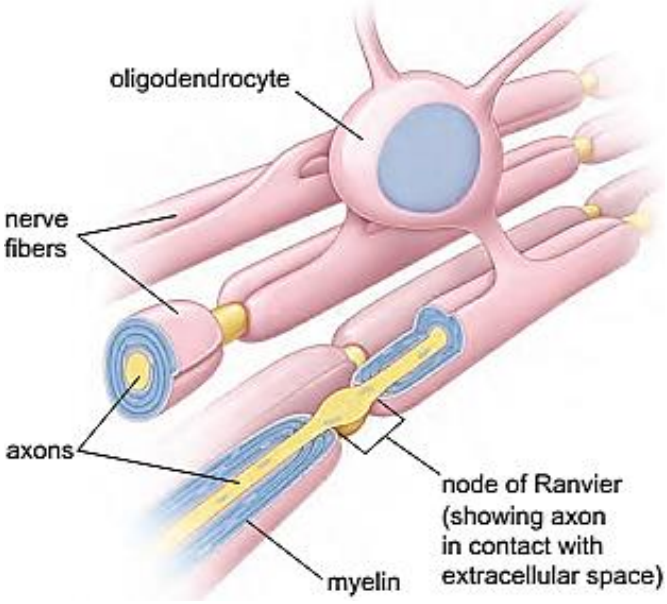

Figure 7.13. Diagram of oligodendrocyte [13].

Oligodendrocytes are found both in gray and white matter of the central nervous tissue. The oligodendrocytes are the cell responsible for producing CNS myelin. Cytoplasmic processes from the oligodendrocyte cell body form flattened cytoplasmic sheaths that wrap around each of the axons.

The oligodendrocytes are analogous to the Schwann cells of peripheral nerves. But unlike Schwann cells, oligodendrocytes can participate in the myelination of more than one axon [13].

Satellite cells

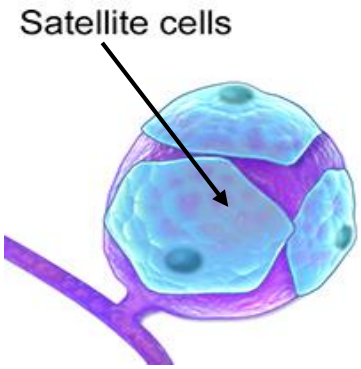

Figure 7.14. Diagram of satellite cells.

Satellite cells are small cuboidal cells surrounding the neuronal cell bodies of ganglia. Functionally they provide structural and metabolic support the neuronal bodies in the ganglion [14].

Schwann cells

The main function of Schwann cells is to produce both myelinated and unmyelinated nerve fibers in peripheral nervous system. In addition, Schwann cells aid in cleaning up peripheral nervous tissue debris and regulate the growth of peripheral nervous tissue axons.

Question 4. Formation and structure of unmyelinated nerve fibers.

There are two types of nerve fibers - myelinated and unmyelinated.

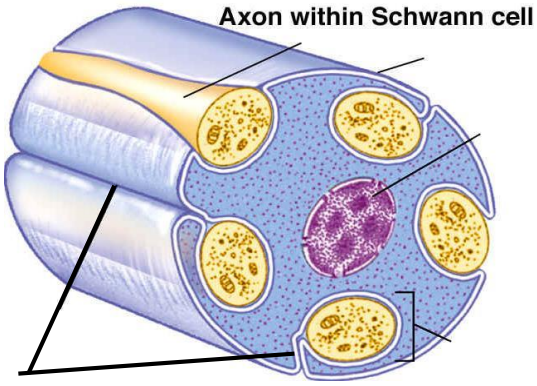

Figure 7.15. Diagram of unmyelinated nerve fiber.

The unmyelinated nerve fiber is produced by invading of one or several neuronal processes into the cytoplasm of Schwann cell. At this the axons engulfed by the Schwann cell cytoplasm. When the axon is completely enclosed by the Schwann cell membrane, the closed membrane lips called mesaxon, is created [13].

Unmyelinated nerve fiber (slide)

Stain: hematoxylin-eosin

Using this illustration you must perform the exercise 8 of album (topic "Nervous tissue")

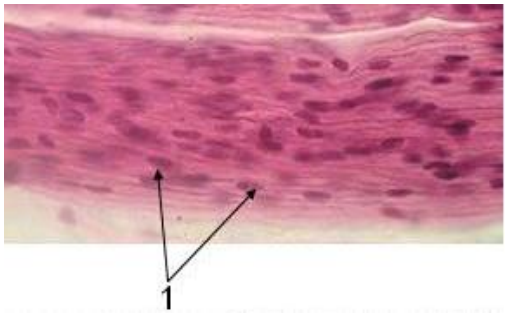

Figure 7.16. Photomicrograph of unmyelinated nerve fibers.

1. Nuclei of Schwann cell

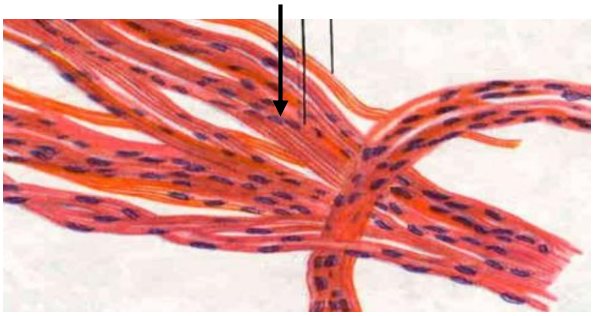

Figure 7.17. Diagram of unmyelinated nerve fibers [15].

Question 5. Formation and structure of myelinated nerve fibers.

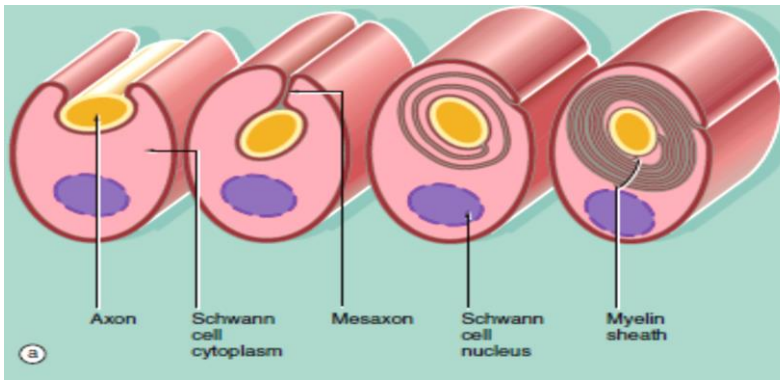

Figure 7.18. Diagram of myelinated nerve fiber formation [14].

Myelinated nerve fiber starts to produce by invading of one neuronal axon into cytoplasm of the Schwann cell lying near. When the axon is completely enclosed by the Schwann cell membrane, the mesaxon is created. After the mesaxon becomes elongated and spirally wraps around axon to produce inner a lipid-rich layer, called the myelin sheath. Thus, myelin sheath corresponds to the plasma membrane of Schwann cell.

External to, myelin sheath there is a thin outer Schwann sheath or neurilemma in myelinated nerve fiber. Schwann sheath corresponds to the displaced thin cytoplasm with organelles and nucleus of the Schwann cell [13].

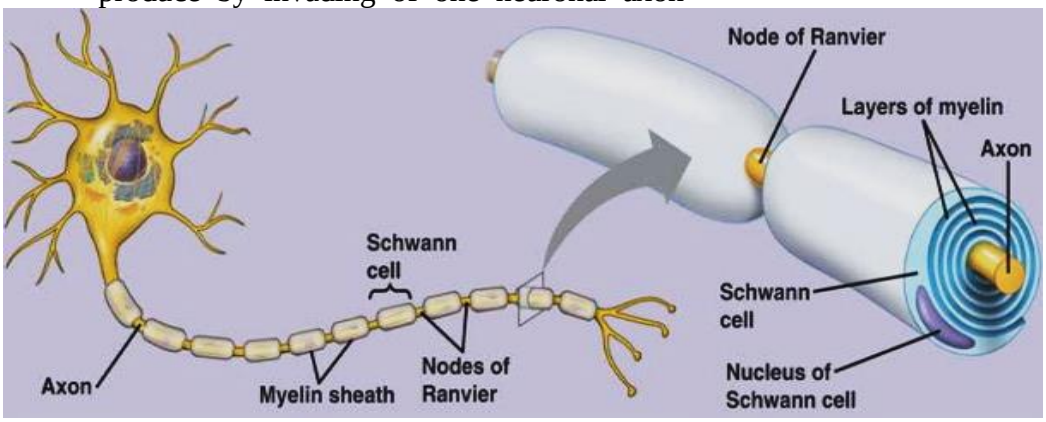

Figure 7.19. Diagram of myelinated nerve fiber [2].

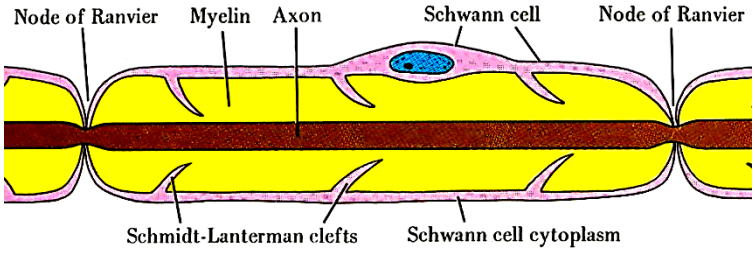

Figure 7.20. Diagram of myelinated nerve fiber [12].

Each process of neuron is related to a large number of Schwann cells over its length. One Schwann cell provides the myelin sheath for a short segment of the axon. At the junction of two segments, there is a short gap in the myelin sheath called a node of Ranvier. Thus, the node of Ranvier is the place between neighboring Schwann cells where myelin sheath is interrupted.

Myelin of each axon segment is interrupted by oblique cone shaped clefts called Schmidt-Lanterman clefts. Schmidt-Lanterman cleft is helical cytoplasmic tunnels from the outside of the sheath to the inside. Thus, Schmidt-Lanterman clefts correspond to the Schwann cell cytoplasm between mesaxon lamellae. Schmidt-Lanterman clefts are pathway for conduction of the metabolites to the myelin sheath and axon.

Schwann cells are necessary for the life and function of the neurons processes. Myelin provides the insulation and increase of speed of nerve impulse conducting.

In myelinated axons, the nerve impulse jumps as "current flow" from one node of Ranvier to the next. This process is designated as saltatory conduction; it is more rapid than a continuous wave of depolarization.

Myelin nerve fibers belong to the somatic nerves. Unmyelmated nerve fibers are characteristically for autonomic nervous system and innervate viscera [13].

Myelinated nerve fiber (slide)

Stain: osmic acid

Using this illustration you must perform the exercise 10 of album (topic "Nervous tissue")

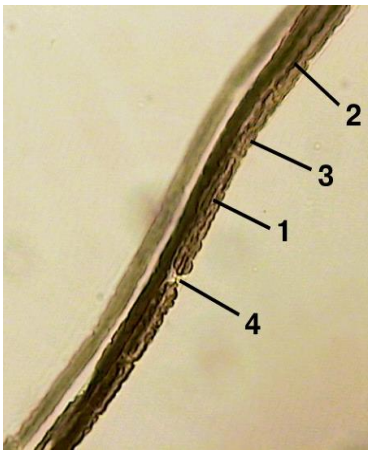

Figure 7.21. Photomicrograph of myelinated nerve fibers.

Figure 7.22. Diagram of myelinated nerve fibers [18].

1. Axon
2. Myelin
3. Neurolemma (nucleus and cytoplasm of Schwann cell)
4. Node of Ranvier

Question 6. Relationship between neurons, glia and blood vessels. Blood-brain and blood-cerebrospinal fluid barriers.

Communications between some glial cells with walls of capillaries leads to formation of barriers in nervous system. Two principle barriers create in nervous system:

1) Blood-brain barrier;
2) Blood-cerebrospinal fluid barrier (hemato-liquor barrier)

Blood-brain barrier

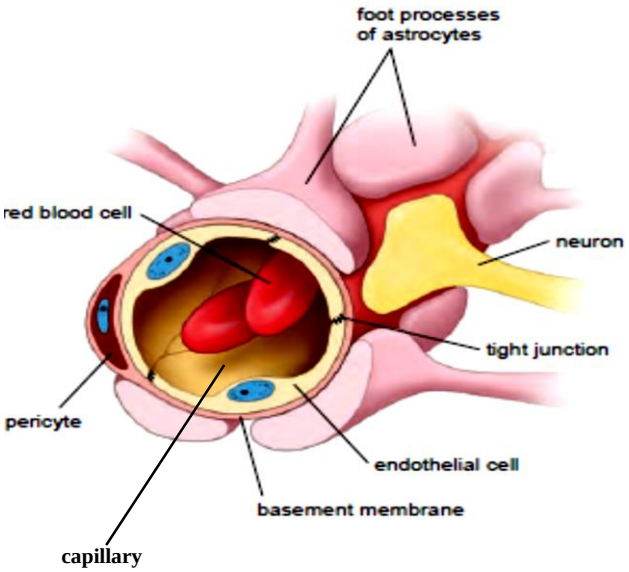

Figure 7.23. Diagram of myelinated blood-brain barrier [13].

Blood-brain barrier is barrier between brain tissue and blood circulation. It consists of 3 components:

1) Endothelium (simple squamous epithelium) lining capillaries inside;
2) Endothelial basement membrane;
3) Astrocytes pedicles (foot processes).

Main function of blood-brain barrier is the protection of CNS neurons against different noxious substances [13].

Blood-cerebrospinal fluid barrier

Blood-cerebrospinal fluid barrier is barrier between cerebrospinal fluid and blood circulation. It consists of 3 components:

1) Endothelium;
2) Endothelial basement membrane;
3) Ependymal cells.

Blood-cerebrospinal fluid barrier restricts the passage of substances from the blood into the liquor. Blood-cerebrospinal fluid barrier is more permeable then blood-brain barrier.

Question 7. Structure and classification of synapses.

Synapses are specialized junctions between neurons that facilitate the transmission of nerve impulses from one to another neuron. Synapses also occur between axons and effector (target) cells, such as muscle and gland cells.

According to the mechanism of conduction of the nerve impulses, the synapses are classified as chemical or electrical.

Electrical synapse

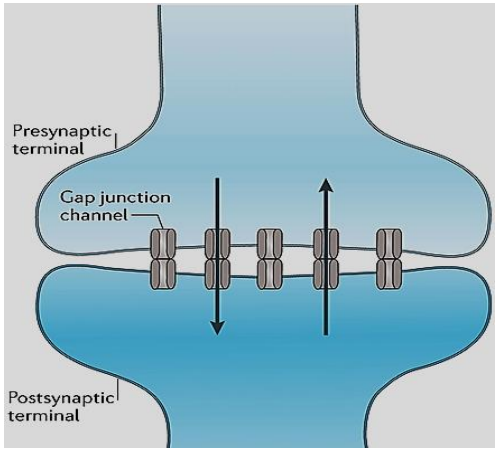

Figure 7.24. Diagram of electrical synapse.

Electrical synapses are common in invertebrates. Electrical synapses contain gap junctions between closely apply plasma membranes of neurons that permit movement of ions between cells and the direct spread of electrical current from one cell to another on both directions [13].

Chemical synapse

In chemical synapses, the conduction of impulses is achieved by the release of chemical substances called neurotransmitters from the presynaptic part of neuron. Neurotransmitters then diffuse across the narrow intercellular space or synaptic cleft, which separates the presynaptic part of neuron from the postsynaptic part of neuron or target cell. A chemical synapse transmits an impulse only in one direction.

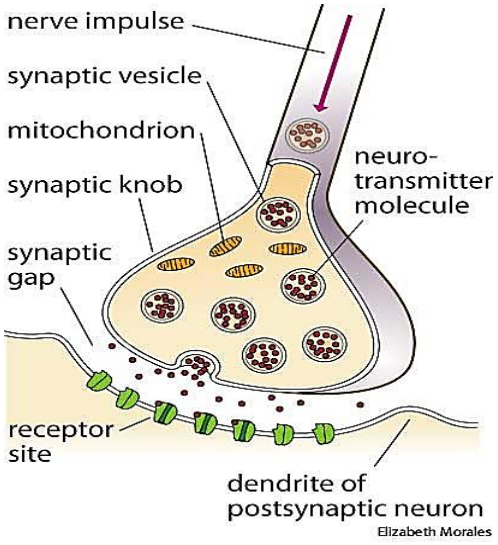

Figure 7.25. Diagram of chemical synapse.

The chemical synapse consists of 3 parts:
1) presynaptic part;
2) synaptic cleft;
3) postsynaptic part.

A presynaptic part called also synaptic knob or bouton is the end of the neuron process from which neurotransmitters are released. The presynaptic part is characterized by the presence of numerous mitochondria and membrane-bound synaptic vesicles containing neurotransmitters.

The synaptic cleft is the 20 to 30 nm space that separates the presynaptic neuron from the postsynaptic neuron or target cell, which the neurotransmitter must cross.

The postsynaptic part contains receptors on its postsynaptic membrane with which the neurotransmitters interact [9].

Synaptic transmission

1) When an impulse reaches the presynaptic part, calcium enters the presynaptic part.
2) The action of the calcium causes the synaptic vesicles to migrate to, and fuse with the presynaptic membrane and then discharge the neurotransmitters into the synaptic cleft by exocytosis.
3) After the neurotransmitters diffuse across the synaptic cleft and bind to receptors in the postsynaptic membrane.
4) The transmitter-receptor reaction causes channels to open in the postsynaptic membrane, which allow ions to pass, depolarizing the postsynaptic membrane and thereby generating a nerve impulse [1].

Morphological classification of synapses

Synapses between neurons morphologically may be classified as:

1) axodendritic, occurring between axons and dendrites;
2) axosomatic, occurring between axons and the cell body;
3) axoaxonic, occurring between axons and axons [9].

Functional classification of synapses

Functionally synapses may be:

1) **Excitatory:**
   a) cholinergic, when neurons use neurotransmitter acetylcholine;
   b) catecholaminergic, when neurons use epinephrine, norepinephrine, dopamine;
   c) serotonergic, when neurons use serotonin.
2) **Inhibitory,** when neurons use neurotransmitter γ-aminobutyric acid (GABA) or glycine [13].

Question 8. Efferent nerve endings: classification and structure.

Efferent or motor nerve endings are endings of motor neurons axons. There are two principle types of motor nerve endings in nervous tissue: motor end plates and varicosities.

Motor end plate

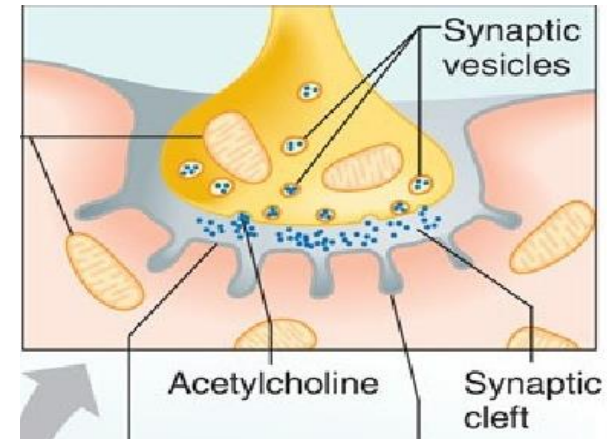

Figure 7.26. Diagram of motor end plate

Motor end plates are terminal branches of the somatic nervous system motor neurons axons on the muscle fibers. The cell bodies of these neurons lye in the spinal cord or brainstem. Thus, the motor end plate is typical neuromuscular junction including the same to synapses parts:

1) presynaptic part;
2) synaptic cleft;
3) postsynaptic part.

The axon ending is a typical presynaptic structure of motor end plate containing numerous mitochondria and synaptic vesicles with neurotransmitter acetylcholine.

Postsynaptic part of motor end plate is represented by the muscle fiber plasma membrane that underlies the synaptic cleft. Plasma membrane or sarcolemma of motor end plate has many deep junctional folds (subneural folds) containing cholinergic receptors for acetylcholine. Release of acetylcholine into the synaptic cleft initiates depolarization of the plasma membrane, which leads to muscle fiber contraction [13].

Varicosities

Varicosities are bulges of the vegetative nervous system motor neurons axons on the smooth muscle cells.

Varicosities contain membrane limited vesicles with neurotransmitters [3].

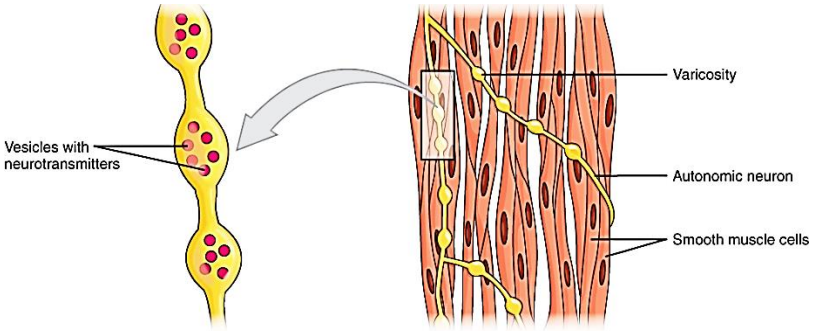

Figure 7.27. Diagram of varicosities.

Question 9. Afferent nerve endings: classification and structure.

Afferent or sensory receptors are endings located at the distal tips of the peripheral processes of sensory neurons that receive irritation from viscera (interoreceptors), from muscles and tendons (proprioreceptors) or outside the body (exteroreceptors).

Sensory nerve endings morphologically are classified into:

1. Nonencapsulated;
2. Encapsulated [13].

Nonencapsulated sensory nerve endings

Nonencapsulated sensory nerve endings also are called free nerve endings because they lack a connective tissue or Schwann cell environment. This type of endings is the simplest type presenting by terminal branches of the sensory neurons processes. They situate in epithelium, connective tissue and in close association with hair follicles and receive temperature, mechanical and pain stimuli [13].

Encapsulated sensory nerve endings

Encapsulated nerve endings are represented by terminal branch of the sensory neurons process surrounding with glial cells and sometimes enclosed in a connective tissue capsule. They are:

a) Pacinian corpuscles;
b) Muscle spindles;
c) Meissner's corpuscles;
d) Ruffini's corpuscles;
e) Krause's end bulb.

Pacinian corpuscle

Skin dermis

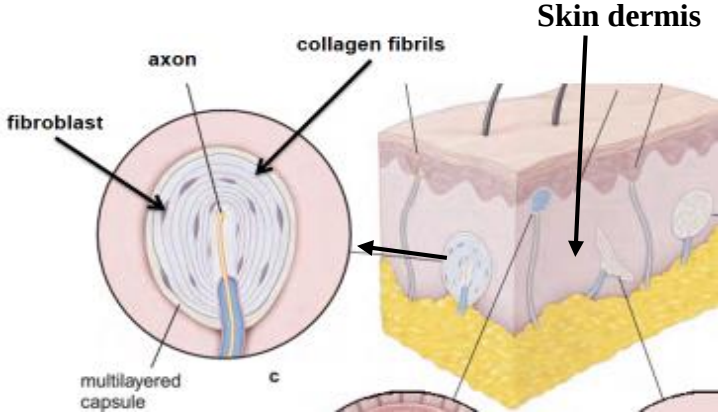

Figure 7.28. Diagram of Pacinian corpuscle [13].

Pacinian corpuscles are deep pressure receptors for mechanical and vibratory pressure. They are large ovoid structure found in the deeper dermis and hypodermis of skin and connective tissue of inner organs.

Pacinian corpuscle is composed of 2 parts:

1) inner core (bulb), which consists of an unmyelinated portion of the axon surrounding by the tightly packed, flattened Schwann cells;

2) outer core (bulb) which consists of a connective tissue capsule presenting by concentric collagen fibrils and fibroblastlike cells [13].

Pacinian corpuscle (slide)

Stain: hematoxylin-eosin

Using this illustration you must perform the exercise 16 of album (topic "Nervous tissue")

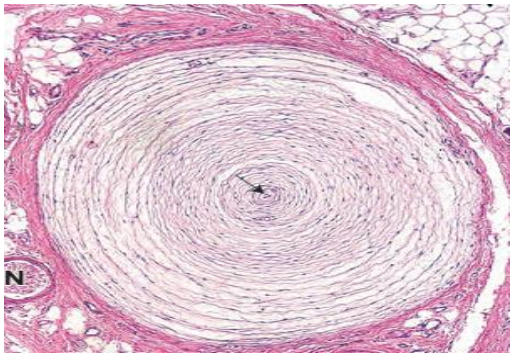

Figure 7.29. Photomicrograph of Pacinian corpuscle [13].

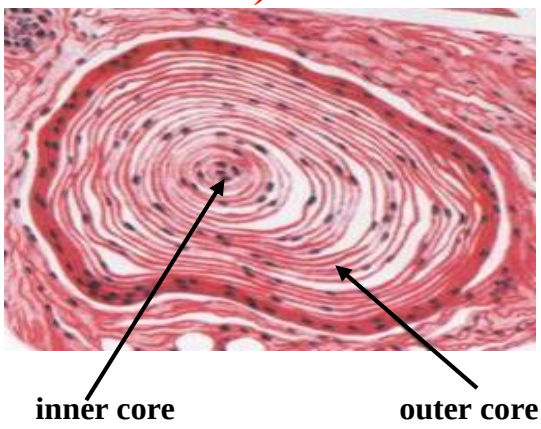

Figure 7.30. Diagram of Pacinian corpuscle [15].

Question 10. Regeneration of the nervous tissue.

Neurons do not divide by mitosis after their damage.

In contrast to the peripheral nervous system (PNS), in which injured axons rapidly regenerate, axons severed in the central nervous system (CNS) usually cannot regenerate.