6 Nervous Tissue

"It is the mind that makes the body rich"

Nervous tissue is the specialised tissue responsible for excitability and conduction of impulses. Nervous tissue comprises:

Neuron, i.e. nerve cells with its processes.

Neuroglia, the cellular connective tissue of the nervous system.

NEURON

Neuron is the structural and functional unit of nervous tissue.

Size: The size of a neuron varies from 4 to 20 microns. Motor neurons are larger than the sensory neurons.

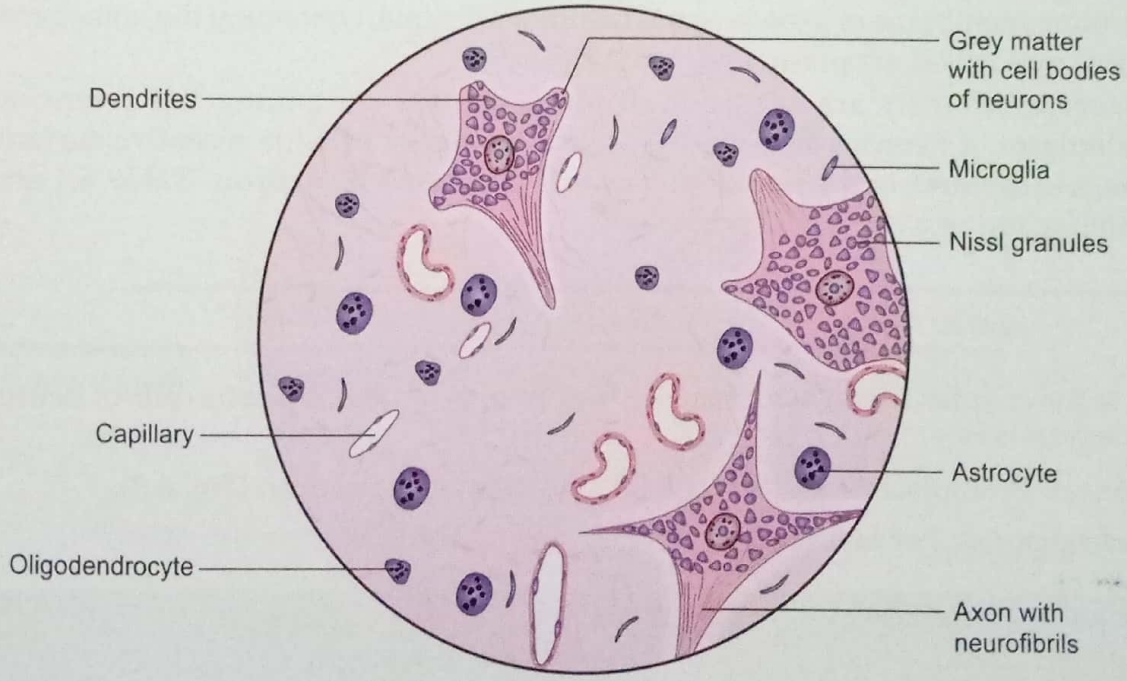
Nucleus: It is large, pale, vesicular and usually central in position. It has a fine chromatin network and a large prominent nucleolus. The *sex chromatin* in the females is often visible as being attached to the nuclear membrane.

Cytoplasm: The cytoplasm is basophilic and contains usual cell organelles like Golgi apparatus and mitochondria. But the *centrosome* is conspicuously absent in mature neuron showing its inability to divide. The cytoplasm of neuron contains two specialised organelles, e.g. Nissl granules and neurofibrils (Fig. 6.1).

Nissl granules are chromophilic bodies which give a granular appearance to the neurons. These are easily stained by toluidine blue and cresyl violet. Nissl granules are the rough endoplasmic reticulum, responsible for synthesis of proteins. These are usually present around the nucleus and in the dendrites, but are absent from the axon hillock (the part of neuron which gives origin to the axon) and axon. Nissl granules degenerate due to fatigue/injury to the neuron and the process is called *chromatolysis*. Neurons synthesise neurotransmitters and neurohormones.

Neurofibrils are thread like structures easily stained with silver impregnation techniques. They form a plexiform pattern in the cell body and are arranged in parallel manner in both the dendrites and axon of the neuron. The neurofibrils give support to the body and processes of the neuron.

PHOTOMICROGRAPH



FIGURE

FACTS TO REMEMBER

1. Multipolar neuron is large irregular cell with central nucleus
2. Has multiple dendrites, single axon
3. Also seen are the astrocyte, oligodendrocyte, microglia, capillaries

Fig. 6.1: *Grey matter of spinal cord. Stain: Haematoxylin-eosin, 400X*

Pigments as inclusions are also present in the neuron in the form of lipofuscin and melanin. These increase with age.

CLASSIFICATION

Depending upon the number of processes, the neurons are classified as:

i. Unipolar, e.g. mesencephalic nucleus of trigeminal or V cranial nerve.
ii. Pseudounipolar, e.g. dorsal root ganglia. A single process attached to the neuron divides into two; one is axon and other is dendrite.
iii. Bipolar, e.g. olfactory neuroepithelium, spiral ganglia of cochlea, vestibular ganglia and bipolar cells of retina. Axon and dendron arise from opposite poles of neuron.
iv. Multipolar, e.g. most of the neurons of cerebrum and cerebellum. One process is axon and rest of the processes are dendrites. Multipolar neuron may be pyramidal as in spinal cord (Fig. 6.1) and cerebrum or pear-shaped as in cerebellum.

CELL PROCESSES ARE AXON AND DENDRITES

a. *Axon*: Every neuron has only one long thin process or axon which arises from a special region or axon hillock, devoid of Nissl granules. It carries the impulse away from the cell body. The passage of impulse is always unidirectional, from dendrite: through cell body to the axon. This is known as "Law of forward conduction". The limiting membrane of axon is termed as the axolemma, containing the homogeneous substance called axoplasm and neurofibrils.
b. *Dendron/dendrites* are single/multiple processes containing the extension of cytoplasm of neurons with its cell organelles. These provide receptive surface for the neuron and carry impulses towards the soma of neuron. Table 6.1 shows comparison of axon and dendrites.

NEUROGLIA

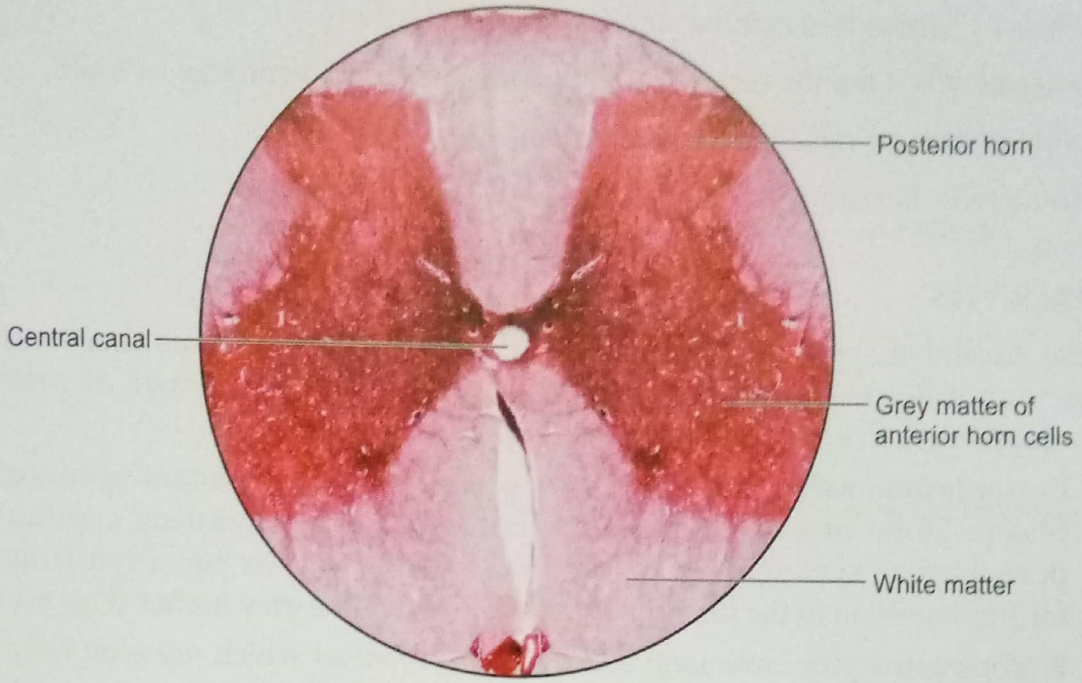
This is the cellular connective tissue of the nervous system. Various cells of neuroglia are:

Astrocytes: Protoplasmic and fibrous for nutrition of the neuron (Fig. 6.2).

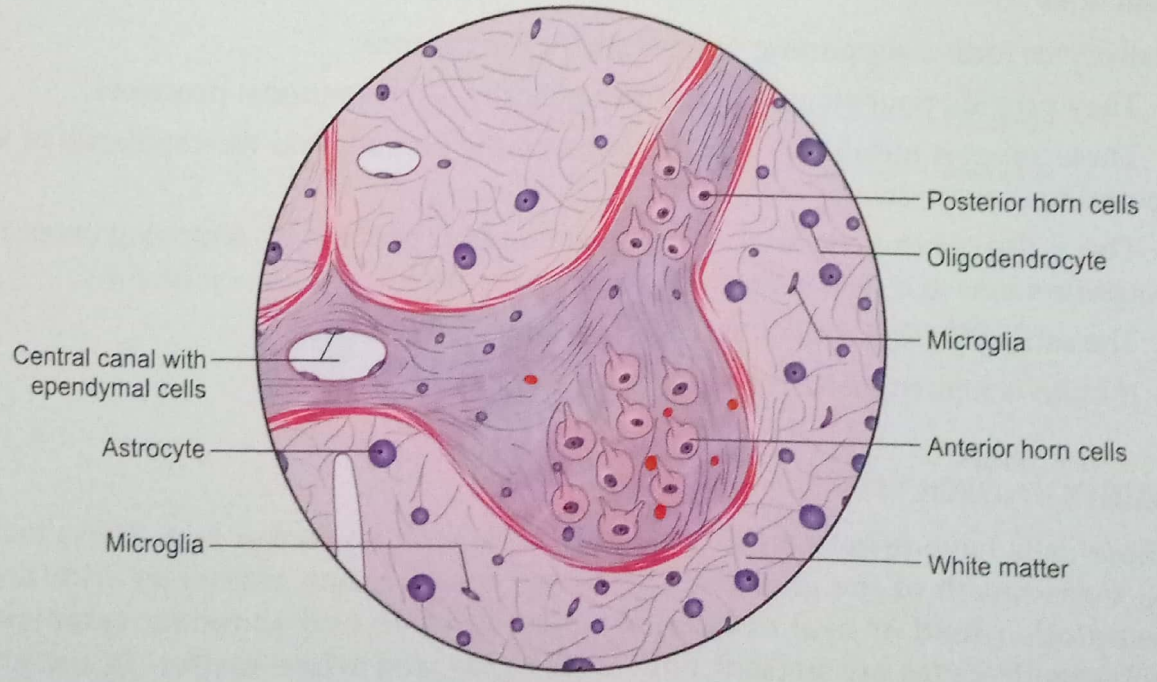
Oligodendrocytes: For laying down myelin sheath in CNS.

TABLE 6.1: Comparison of axon and dendrite

Axon	*Dendrites*
1. Only one axon is present in a neuron	Usually multiple in a neuron
2. Thin long process of uniform thickness and smooth surface	These are short multiple processes. Their thickness diminishes as these divide repeatedly. The branches are studded with spiny projections
3. The branches of axon are fewer and at right angles to the axon Golgi apparatus is present	The dendrites branch profusely and are given off at acute angles Golgi apparatus is absent
4. Axon contains neurofibrils and no Nissl granules	Dendrites contain both neurofibrils and Nissl granules
5. Forms the efferent component of the impulse	Forms the afferent component of the impulse



PHOTOMICROGRAPH



FIGURE

FACTS TO REMEMBER

1. Inner grey matter contains cell bodies of neurons
2. Outer white matter contains processes of neurons and neuroglial cells
3. Central canal lies in the grey commissure

Fig. 6.2: *Neuron and neuroglia: Spinal cord. Stain: Haematoxylin-eosin, 100X*

Microglia: Phagocytose cellular debris.

Ependymal cells: Line the central canal of spinal cord and ventricles of brain.

Satellite or capsular cells: Surround the neurons of the ganglia.

Schwann cells: Lay down myelin sheath on peripheral nerves.

ASTROCYTES

These are star-shaped cells with multiple processes. These cells are small with large vesicular indented nuclei, and cytoplasm drawn into number of processes. Development is from neural crest. These are of two types.

i. Protoplasmic astrocytes have thick processes with abundant granular cytoplasm. Some of the processes are attached to neighbouring capillaries by perivascular sucker feet. These sucker feet withdraw nutrition from them for transmission to the neuron. These are found in the grey matter (Figs 6.1 to 6.3).

ii. Fibrous astrocytes have long and straight processes which are seen only in the white matter.

Functions

Astrocytes form a supporting framework for the neurons.

They provide nourishment to the metabolically active neuronal processes.

These support metabolic exchange between the neurons and the capillaries of the central nervous system.

These also control chemical environment around neurons by removing excessive potassium ions and neurotransmitters like glutamate.

The astrocytes also contain glycogen and thus provide energy.

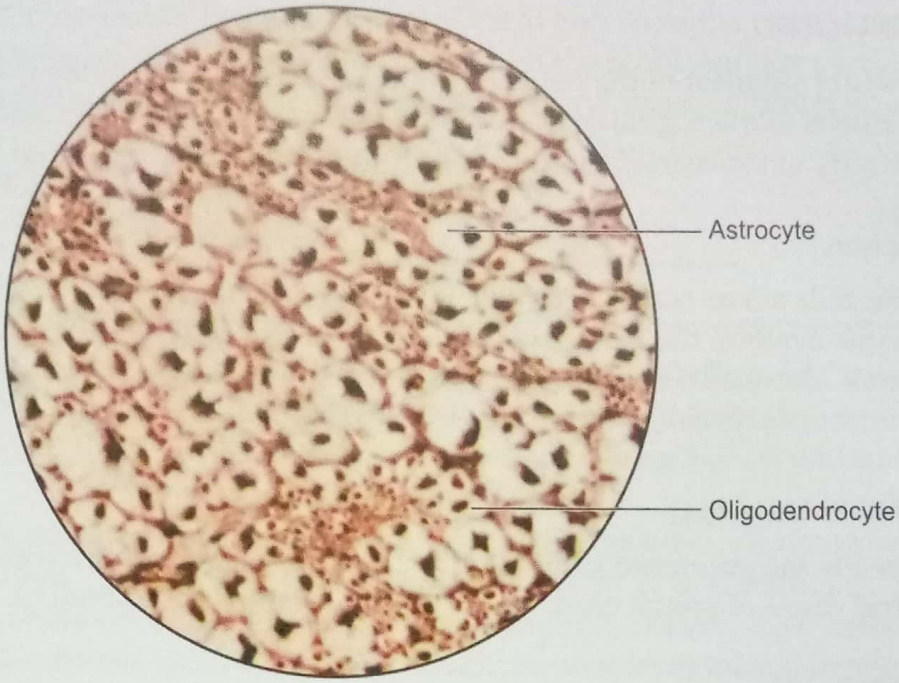
If brain is injured, these cells proliferate to form a scar.

OLIGODENDROCYTES

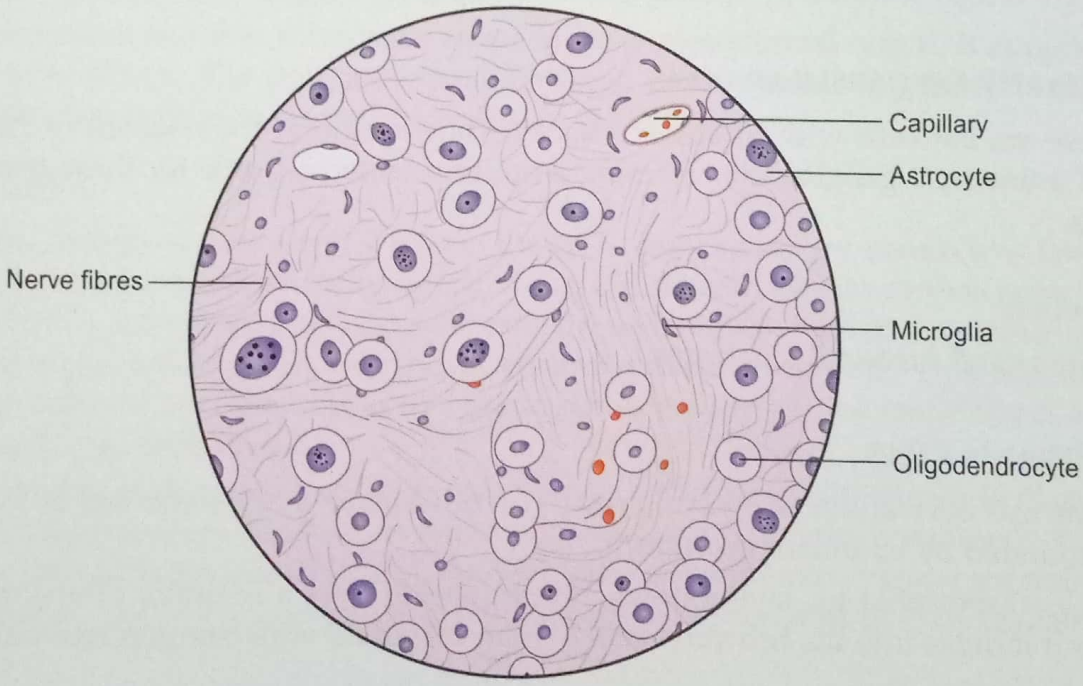
These cells have fewer and shorter processes, with no sucker feet. These make up three-fourth of the glial cells. These are smaller than astrocytes with deep basophilic round or oval nuclei, prominent nucleoli and abundant cytoplasm. Oligodendrocytes are present both in the grey and white matter. In the grey matter these are perineuronal in position. In the white matter these cells lie along the myelinated nerve fibre. These cells also develop from neural crest (Figs 6.2 and 6.3).

Function

The primary function of each cell is to lay down myelin sheath around the several axons within the central nervous system. Because of the myelin sheath formation these cells provide insulation and prevent formation of random synapses. Oligodendrocytes/oligodendroglia also support the neuronal network.



PHOTOMICROGRAPH



FIGURE

FACTS TO REMEMBER

1. Nerve fibres seen
2. Neuroglial cells, i.e. astrocytes, oligodendrocyte and microglial cells seen
3. Capillaries also seen

Fig. 6.3: *White matter of spinal cord. Stain: Haematoxylin-eosin, 100X*

MICROGLIA

These are smallest of the neuroglia and are present both in the grey and white matter. The nuclei of microglial cells are small, comma shaped, deeply stained and surrounded by scanty cytoplasm. They develop from mesoderm (Figs 6.1 to 6.3).

Function

These cells act as scavenger cells. In trauma or other destructive lesions of the central nervous system, the microglia show phagocytic activity. These form brains immune system. These also function as antigen-presenting cells. Also secrete cytokines which are immunoregulatory in function.

EPENDYMAL CELLS

These are tall columnar ciliated cells. These cells line the ventricles of the brain and the central canal of spinal cord. They develop from neural tube (Fig. 6.2).

Function

In the ventricles of brain the ependymal cells secrete cerebrospinal fluid. A small amount of CSF is also secreted by ependymal cells lining the central canal of spinal cord.

SATELLITE OR CAPSULAR CELLS

These are flat cells with prominent nuclei. They surround the neurons of the spinal and autonomic ganglia, thus forming a multinucleated capsule for these irreparable cells.

Function

Support and protect the neurons.

SCHWANN CELLS

These are derivatives of neural crest. The nucleus of a Schwann cell is flattened, surrounded by abundant cytoplasm.

It is responsible for laying down myelin sheath over a segment of a single axon after it indents into the Schwann cell. Myelin is stained with osmium tetroxide.

Function

These cells form myelin sheath in the peripheral nerves, thus protecting and insulating them. Due to the presence of myelin sheath the passage of impulse is faster as the rate of conduction is directly proportional to the thickness of the myelin.

Applied Aspect

- *Ependymomas:* Within the brain and spinal cord there are glial cells which support and protect the nerve cells. Tumor of these glial cells are called glioma. Ependymomas are rare type of glioma. These develop from the ependymal cells

which line the ventricles (fluid filled spaces in the brain) and from the central canal of the spinal cord. These can also be found in any parts of the brain, and are partially common in the cerebellum in children. They are the second most common spinal tumor.

- *Gliosis* is the diffuse proliferation of neuroglial cells.

NERVE FIBRES

A peripheral nerve fibre (Fig. 6.4) is an axon/dendron with its covering, i.e. myelin sheath and neurilemma. These fibres are myelinated. Each fibre consists of:

i. A central axon/axis cylinder with axoplasm and neurofibrils contained within the axolemma.
ii. Myelin sheath is composed of phospholipids, interrupted at intervals along with the length of the fibre. It is stained by osmic acid and not by H & E stain.
iii. Thin neurilemma sheath is present outside the myelin sheath. The cells of neurilemma are also known as Schwann cells, which are neuroectodermal in origin. At the points of interruption of myelin sheath the neurilemma comes into intimate contact with the axon and such areas are known as Nodes of Ranvier. The impulse jumps from one node to the next node.
iv. Endoneurium is a thin connective tissue layer of mesodermal origin. It supports the nerve fibres. The potential space between neurilemma and endoneurium contains tissue fluid for the nourishment of the nerve fibre.

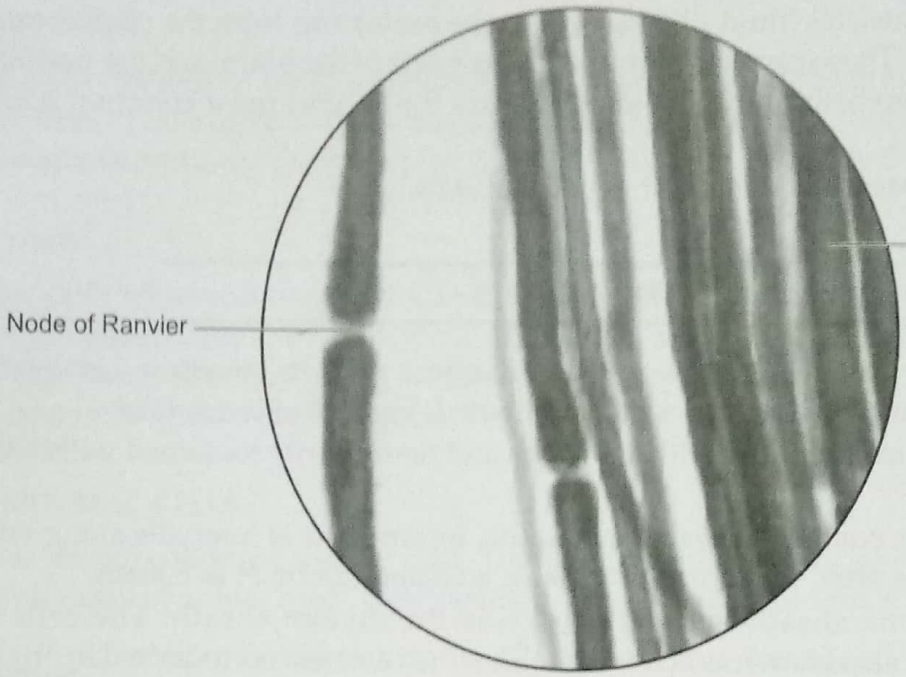
NERVE TRUNK

Transverse section of nerve trunk shows that it is surrounded by connective tissue sheath called *epineurium*. It sends in septa dividing the nerve trunk into various fascicles, each of which is surrounded by a dense sheath, the *perineurium*. From the perineurium, numerous septa extend to form a sheath enclosing each nerve fibre. This sheath is known as *endoneurium*. This connective tissue skeleton supports the nerve fibres and carries capillaries with them.

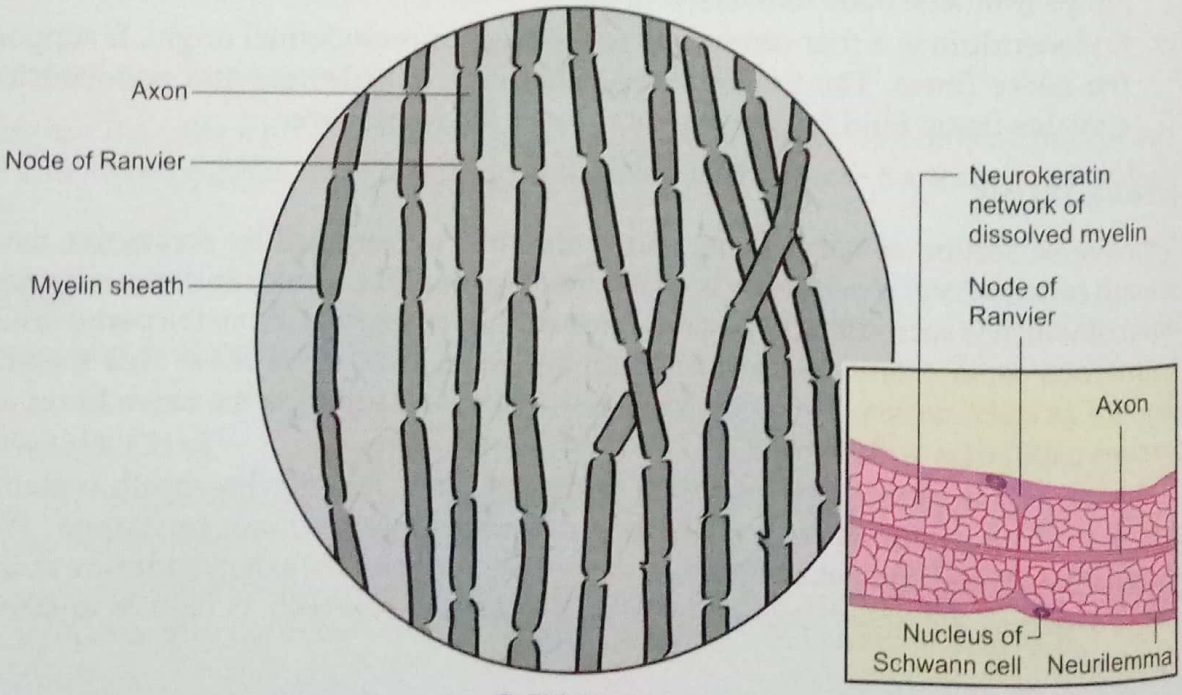
In transverse sections stained with osmic acid (Fig. 6.5) myelin sheath is stained black and neurilemma as well as axis cylinder (axon) remain unstained. With haematoxylin and eosin stain (Fig. 6.6), the neurilemma and the axis cylinder are stained pink, whereas the area occupied by myelin sheath is observed as halo or unstained space.

Applied Aspect

- *Bell's palsy* is the compression of a facial nerve in or just outside stylomastoid foramen due to inflammation and oedema of the nerve. This causes paralysis of facial muscles and loss of facial expression on the affected side.
- *Acute idiopathic inflammatory polyneuropathy (Guillain-Barré syndrome)* is a sudden, acute and progressive bilateral ascending paralysis which starts at the lower limb and then spreads to arms, trunks and cranial nerves. It is characterised by widespread inflammation with some demyelination of spinal, peripheral and cranial nerves and the spinal ganglia.



PHOTOMICROGRAPH



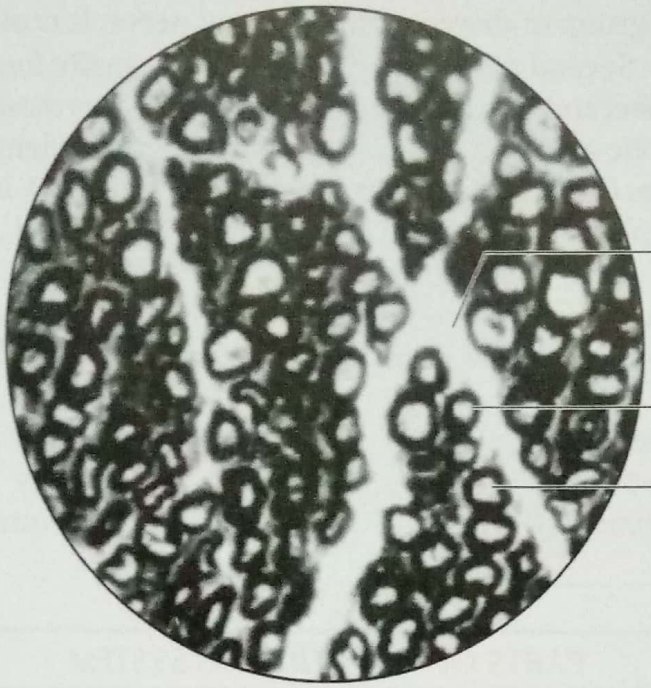
FIGURE

INSET
H and E stain

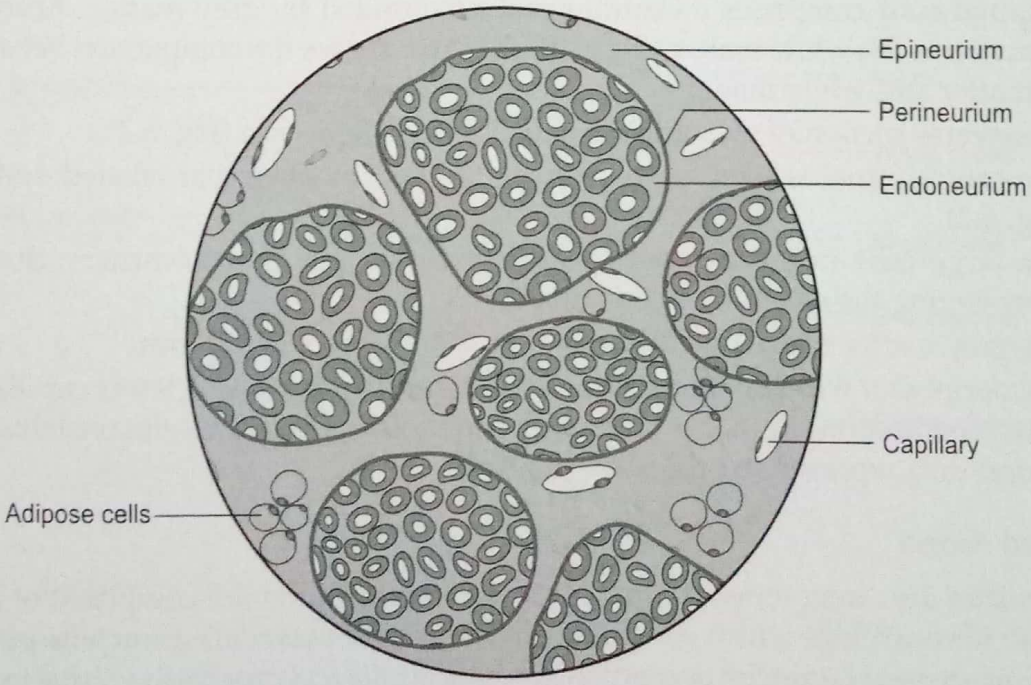
FACTS TO REMEMBER

1. Myelin sheath stained with osmic acid
2. Myelin sheath is interrupted by node of Ranvier
3. Inside the myelin sheath is the axon

Fig. 6.4: *Longitudinal section of myelinated nerve fibres: Stain: Osmic acid, 100X*



PHOTOMICROGRAPH



FIGURE

FACTS TO REMEMBER

1. Osmic acid preferentially stains the myelin sheath
2. Around each nerve fibre is endoneurium; around each nerve fasciculus is perineurium; and around the nerve is the epineurium
3. These support the nerve fibres

Fig. 6.5: *Transverse section of nerve trunk. Stain: Osmic acid, 100X*

- *Neuropathies* is a group of diseases of peripheral nerve. It is of two types:
  - *Polyneuropathy*: Several neurons are affected and usually long neurons like those supplying the feet and legs are affected first. This occurs mostly due to nutritional deficiencies (folic acid and vitamin B), metabolic disorders (diabetes mellitus), chronic diseases (renal and hepatic failure and carcinoma), infections (influenza, measles and typhoid fever) and toxic reactions (arsenic, lead, mercury and carbon tetrachloride)
  - *Mononeuropathy*: Usually one neuron is affected and most common cause is ischaemia due to pressure. The resultant dysfunction depends on site and degree of injury.
- *Traumatic neuroma* is a tumour like cluster formed by Schwann cells when the neurilemma of two cut ends is out of position or destroyed by the sprouted axons. It causes severe pain and mostly occurs due to some fractures or amputation of limb.

PARTS OF THE NERVOUS SYSTEM

SPINAL CORD

The spinal cord comprises a central canal surrounded by grey matter. Around this grey matter is the white matter (Fig. 6.2). Table 6.2 shows the comparison between the grey matter and white matter.

Transverse section of spinal cord stained with H & E stain (Fig. 6.2)

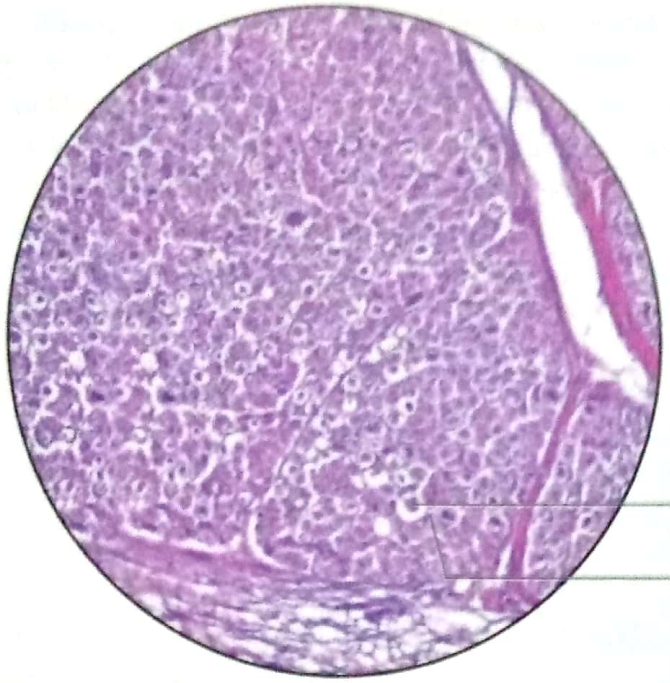
1. The central canal is seen as an oval cavity lined by columnar ciliated epithelium (Fig. 6.2).
2. The large cells in the anterior horn depict multiple angles/corners; the angles representing the origin of its processes.
   The grey matter reveals the neuroglial cells and lots of capillaries.
3. The peripheral white matter contains the fibres, neuroglia and fewer capillaries. In transverse sections the nerve fibres appear as hollow circles (myelin unstained) with central dots representing the axon (Fig. 6.6).

Applied Aspect

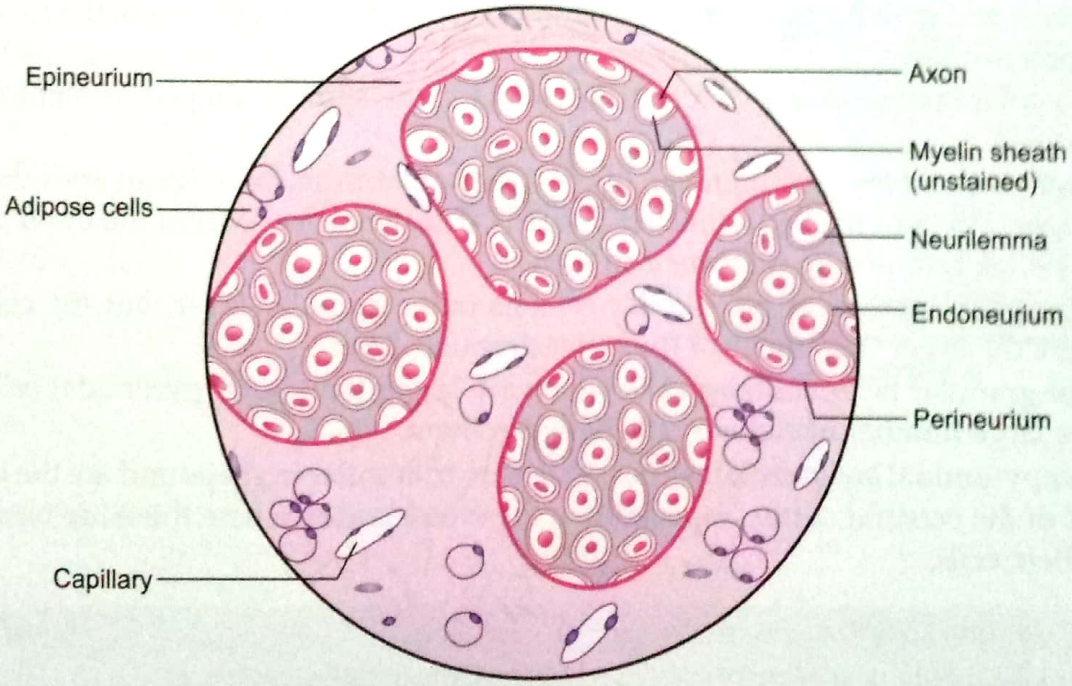
- *Herniated disc*: Intervertebral disc of the vertebral column are composed of a tough outer fibrocartilage which encases an elastic central mass called **nucleus pulposus**. During strenuous exercise or exertion in young adults and progressively due to skeletal

TABLE 6.2: Comparison of grey matter and white matter

Grey matter	*White matter*
1. Contains bodies of nerve cells	Bodies of nerve cells are absent
2. Has parts of dendrites and parts of the axon	Has most of the lengths of axon and dendrites
3. Contains protoplasmic astrocytes, oligodendroglia and microglia	Contains fibrous astrocytes, oligodendroglia and microglia
4. Has numerous capillaries	Has fewer capillaries



PHOTOMICROGRAPH



FIGURE

FACTS TO REMEMBER

1. The neurilemma is stained pink
2. The empty circle is the unstained myelin sheath
3. The inner structure is the stained axon

Fig. 6.6: *Transverse section of nerve trunk. Stain: Haematoxylin-eosin, 100X*

disease in older people there is herniation of nucleus pulposus into the vertebral canal. This may put pressure on the spinal nerve roots causing pain and numbness.

- *Syringomyelia* is the dilation of the central canal of the spinal cord. Dilation of central canal develops pressure which causes progressive damage to sensory and motor neurons. Early effects are insensibility to heat and pain (dissociated anaesthesia) and in long-term there is destruction of motor and sensory tracts leading to paralysis and loss of sensation and reflexes. This occurs most commonly in the cervical region and is associated with congenital abnormality of the distal end of the fourth ventricle.

GANGLIA

Collection of neurons outside the central nervous system is called ganglion. There are two types of ganglia, spinal and autonomic. These are compared in Table 6.3.

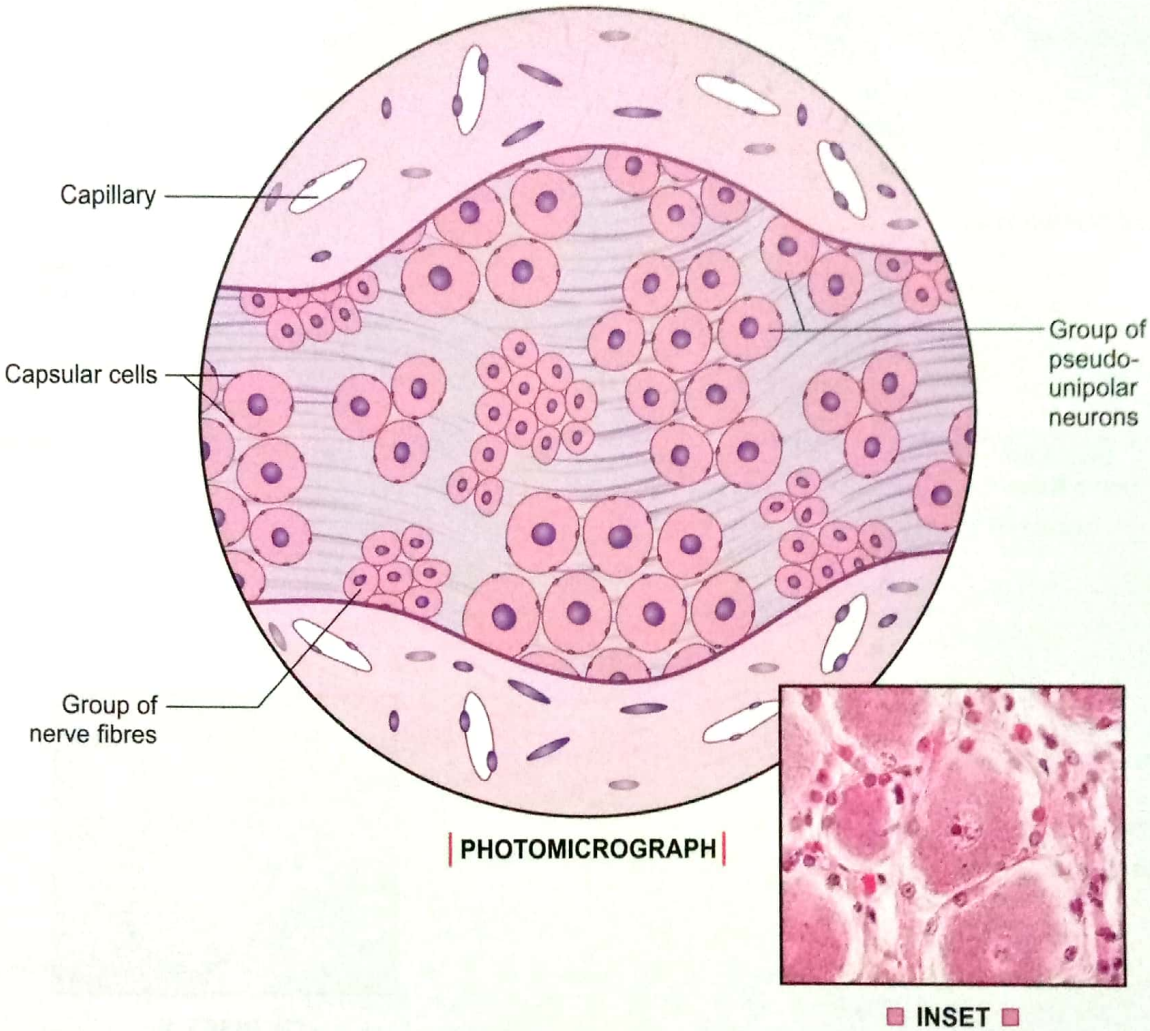
CEREBRUM

It is characterised by *heterotypical cortex*, i.e. histological structure differs in various regions of cerebral cortex. The outermost covering of the cerebral cortex is the pia mater which is the innermost meningeal layer. It carries capillaries to the grey matter. The cerebral cortex contains variety of cells. These are arranged in layers with one or more cell types predominant in each layer. The horizontal fibres are associated with each layer and give it a laminated appearance. From superficial to deep, the following six layers are seen:

1. Molecular layer consists of a few fibres and some spindle shaped or stellate cells (Fig. 6.9).
2. Outer granular layer contains small cells, triangular in shape, with an apex directed peripherally and the base directed inwards. The axons leave from the basal part of the cell. A few stellate cells are also seen.
3. Outer pyramidal layer has similar cells as outer granular layer, but the cells are distinctly larger than those of the outer granular layer.
4. Inner granular layer contains cells which are larger than outer pyramidal cells, but have large number of stellate cells between them.
5. Inner pyramidal layer contains cells which are triangular in shape and are the largest cells of the cerebral cortex, especially in the motor cortex where these are termed as the Betz cells.

TABLE 6.3: Comparison of the ganglia

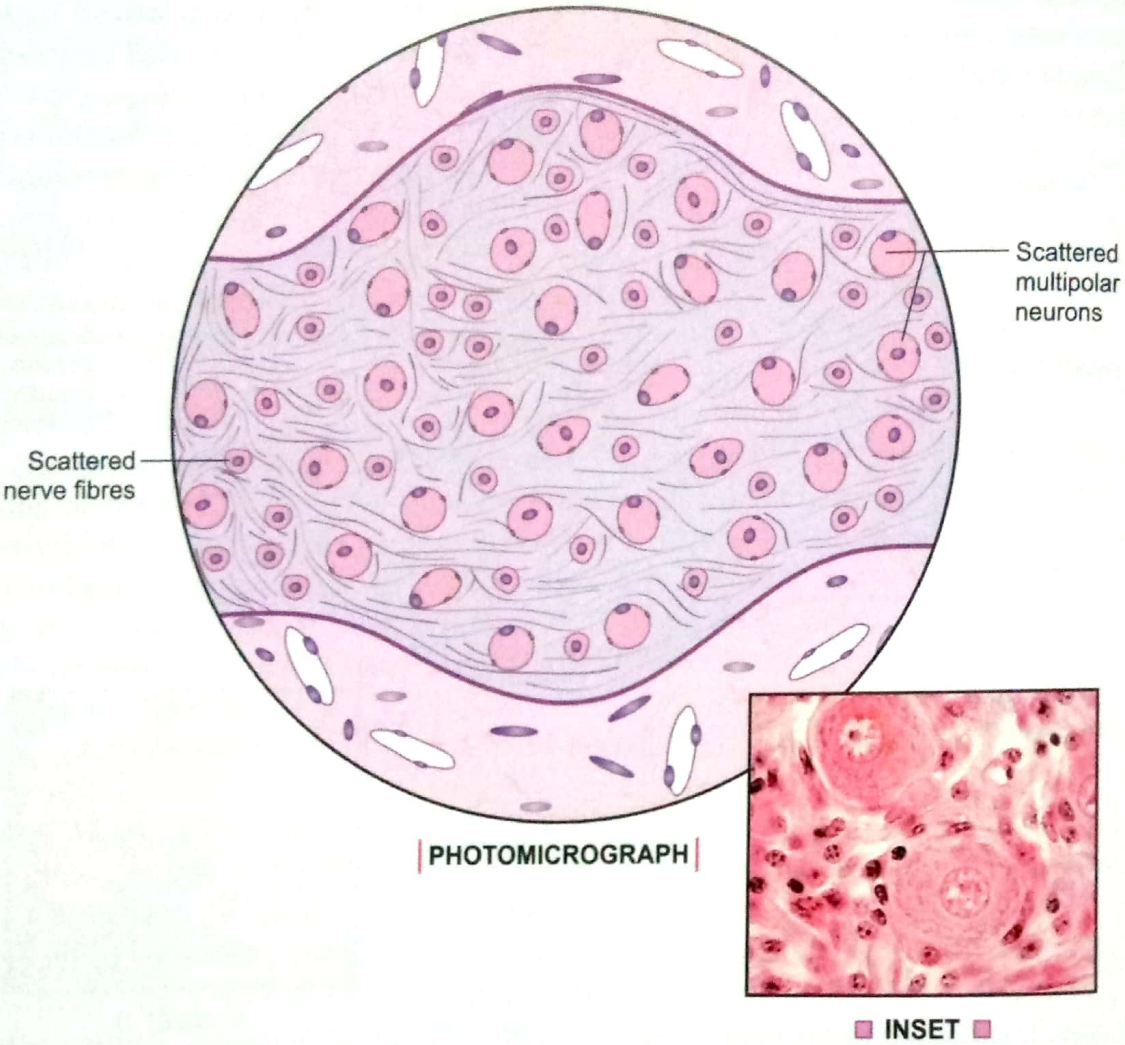
Dorsal root ganglion or sensory or Spinal ganglion (Fig. 6.7)	*Sympathetic ganglion or Autonomic ganglion* (Fig. 6.8)
1. Consists of pseudounipolar neurons	Consists of multipolar neurons
2. Has cell bodies of afferent neurons	Has cell bodies of efferent neurons
3. The cell body is large and rounded	The cell body is smaller and irregular
4. The nucleus is central with a prominent nucleolus	The nucleus is usually eccentric and has a prominent nucleolus
5. Around each neuron is a layer of flattened cells called capsular/satellite cells	Such capsular/satellite cells are a few in number
6. The neurons lie in groups separated by nerve fibres lying in groups	The neurons and nerve fibres lie scattered



FACTS TO REMEMBER

1. Pseudounipolar neurons
2. Cell body is large and rounded
3. Neurons in groups separated by nerve fibres in groups

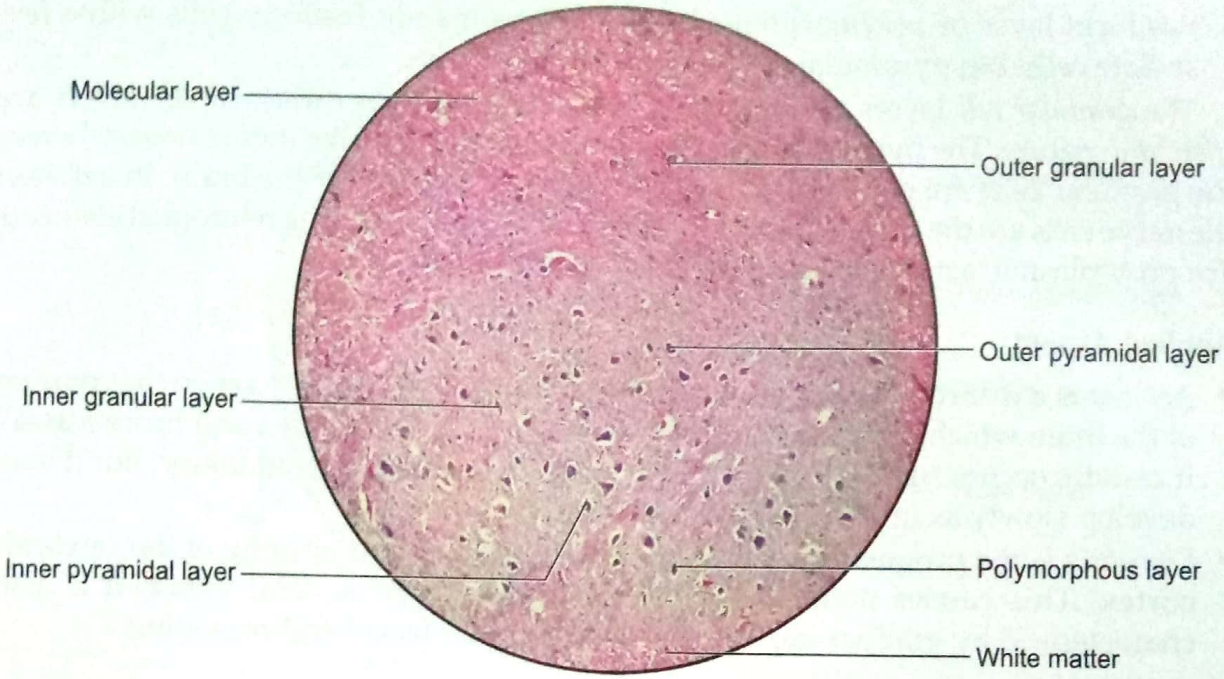
Fig. 6.7: *Spinal/sensory/dorsal root ganglion. Stain: Haematoxylin-eosin, 400X*



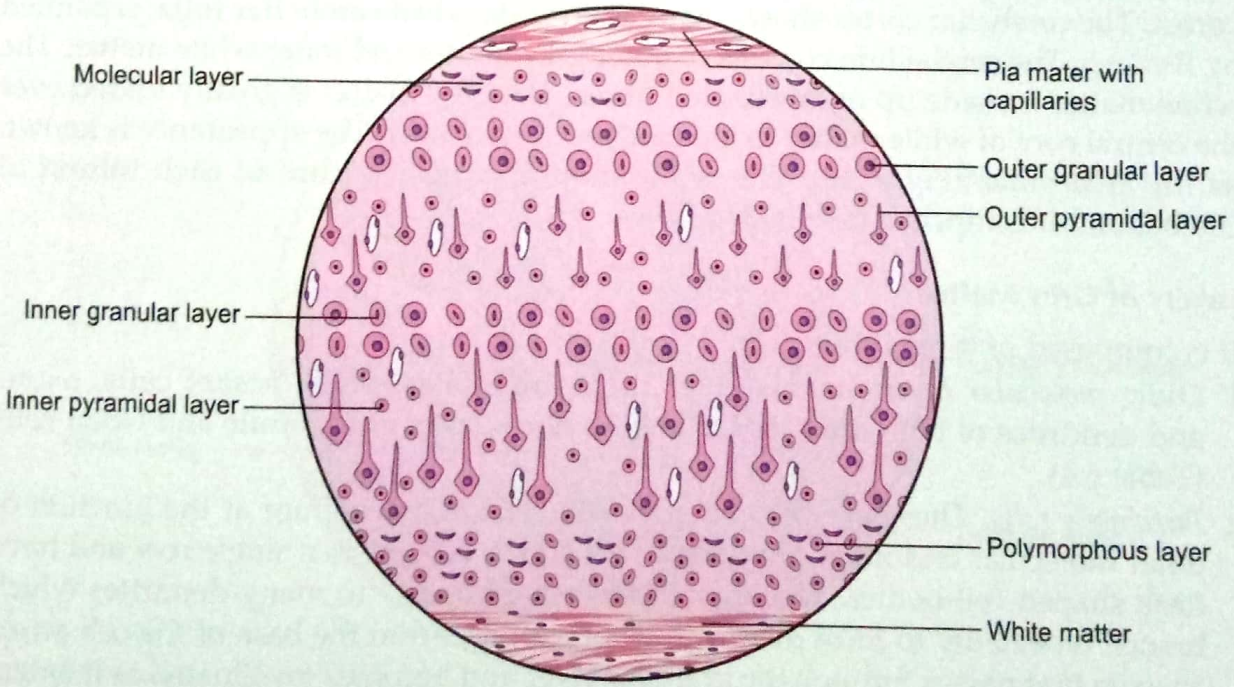
FACTS TO REMEMBER

1. Multipolar neurons
2. Cell body is small and irregular
3. Neurons and nerve fibres are scattered

Fig. 6.8: *Autonomic ganglion. Stain: Haematoxylin-eosin, 400X*



PHOTOMICROGRAPH



FIGURE

FACTS TO REMEMBER

1. Six layers of cells and fibres
2. Pyramidal cells more in motor cortex and granular cells more in sensory cortex
3. Numerous capillaries present

Fig. 6.9: *Grey matter of cerebrum. Stain: Haematoxylin-eosin, 400X*

6. Fusiform layer or polymorphous layer contains mainly fusiform cells with a few stellate cells. No pyramidal cells are seen in this layer.

The *granular cell* layers are *afferent* in connection and the *pyramidal* cell layers are *efferent* in nature. The pyramidal cells are more pronounced in the motor areas, whereas the granular cells are more conspicuous in the sensory areas of the brain. In between the nerve cells are the nerve fibres of these cells and capillaries. The neuroglial elements are protoplasmic astrocytes, oligodendroglia and microglia.

Applied Aspect

- *Aphasia* is a disorder of language (speech) that results from damage to that portion of the brain which are responsible for language (Wernicke's area and Broca's area). It usually occurs suddenly often as the result of a stroke or head injury. But it may develop slowly as in the case of a brain tumour.
- *Dementia* is the progressive, irreversible degeneration and atrophy of the cerebral cortex. This causes mental retardation usually over several years. It is also characterised by gradual impairment of memory, intellect and reasoning.

CEREBELLUM

The histological structure of entire cerebellum is similar and is called **homotypical cortex**. The cerebellar cortex shows many deep folds called **cerebellar folia**, separated by fissures. The cerebellum consists of outer grey matter and inner white matter. The white matter is made up of myelinated fibres. The grey matter is greatly folded over the central core of white matter to increase the surface area. The appearance is known as the *arbor vitae* (Fig. 6.10). The white matter forms the core of each folium of cerebellum. It comprises myelinated fibres.

Layers of Grey Matter

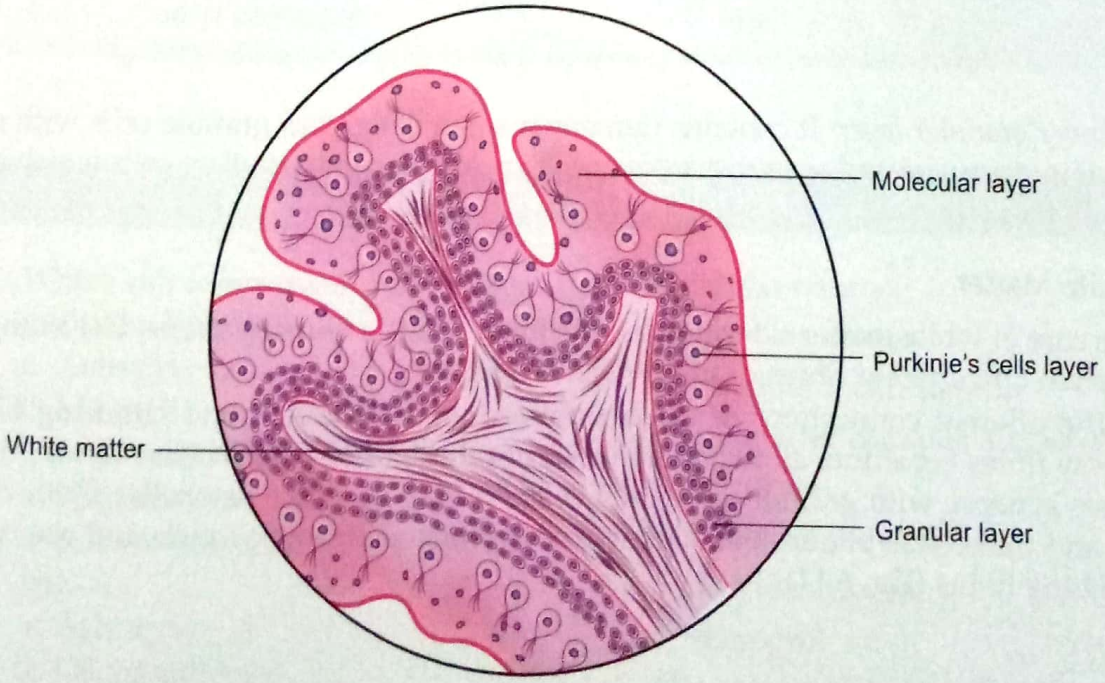
It is composed of three layers:

1. *Outer molecular layer*: In this layer there are stellate cells, basket cells, axons and dendrites of both cell types, climbing fibres, axons of granule and Golgi cells (Table 6.4).
2. *Purkinje's cells*: These are the characteristic cells of cerebellum at the junction of outer molecular and inner granular layers. These cells lie in a single row and have flask shaped cell bodies. The apex of the cell gives rise to many dendrites which branch repeatedly to form dendritic arborisations. From the base of the cell arises an axon that passes through the granular layer and becomes myelinated as it enters the white matter (Table 6.5).

TABLE 6.4: Showing types of neurons in cerebellum

Layers	*Neurons*	*Population*
Outer molecular layer	Stellate cells, Basket cells	Sparse cells in this zone
Purkinje's cell layer	Purkinje's cells are characteristic cerebellar neurons	In single layer at the junction of molecular and granular layers
Granular cell layer	Granule cell, Golgi cell	Densely populated zone

PHOTOMICROGRAPH



FIGURE

FACTS TO REMEMBER

1. Outer molecular layer and inner granular layer
2. Purkinje's cells at the junction
3. Uniform structure

Fig. 6.10: *Structure of cerebellum cortex. Stain: Haematoxylin-eosin, 100X*

TABLE 6.5: Depicting connections of various neurons

Neuron and its placement	*Course of dendrites*	*Course of axon*
Purkinje's cells at the junction of molecular and granular layers (Fig. 6.11)	Lie in molecular layer and subdivide to form a dendritic tree. The dendrites of each Purkinje's cell lie in plane parallel to each other	Travels through the granular layer to enter the nuclei in the white matter
Granule cells in deep part of granular layer	4–6 short dendrites which synapse with **mossy** fibres in granular layer	Axon passes upwards in the molecular layer (neuron lying upside down); divides into two subdivisions which run in opposite directions (T-shaped). These subdivisions of axon are termed as parallel fibres and synapse with dendrites of Purkinje's cell
Outer stellate cell confined to the molecular layer	Synapse with parallel fibres (axons of granule cells)	Synapses with dendrites of Purkinje's cell
Basket cells in deeper part of molecular layer	Ramify in molecular layer synapsing with parallel fibres (axons of granule cells)	Form baskets around the cell bodies of Purkinje's cell
Golgi cells in superficial part of granular layer	Synapses with axons of granule cells (parallel fibres) in molecular layer	Ends in relation to dendrites of granule cells to form the glomeruli in granular layer

3. *Inner granular layer*: It contains numerous small Golgi and granule cells with dark staining nuclei and scanty cytoplasm. There are also large stellate cells which have more cytoplasm.

White Matter

The core of white matter is formed by myelinated nerve fibres or axons. The axons are afferent and efferent fibres of the cerebellar cortex.

The afferent connections of cerebellum are through **mossy** and **climbing** fibres. Mossy fibres constitute all the afferents except those of olivo-cerebellar fibres. Mossy fibres synapse with granule and Golgi cells (Table 6.5). Olivo-cerebellar fibres climb up and make synaptic connections with dendrites of Purkinje's cells and are called climbing fibres (Fig. 6.11).

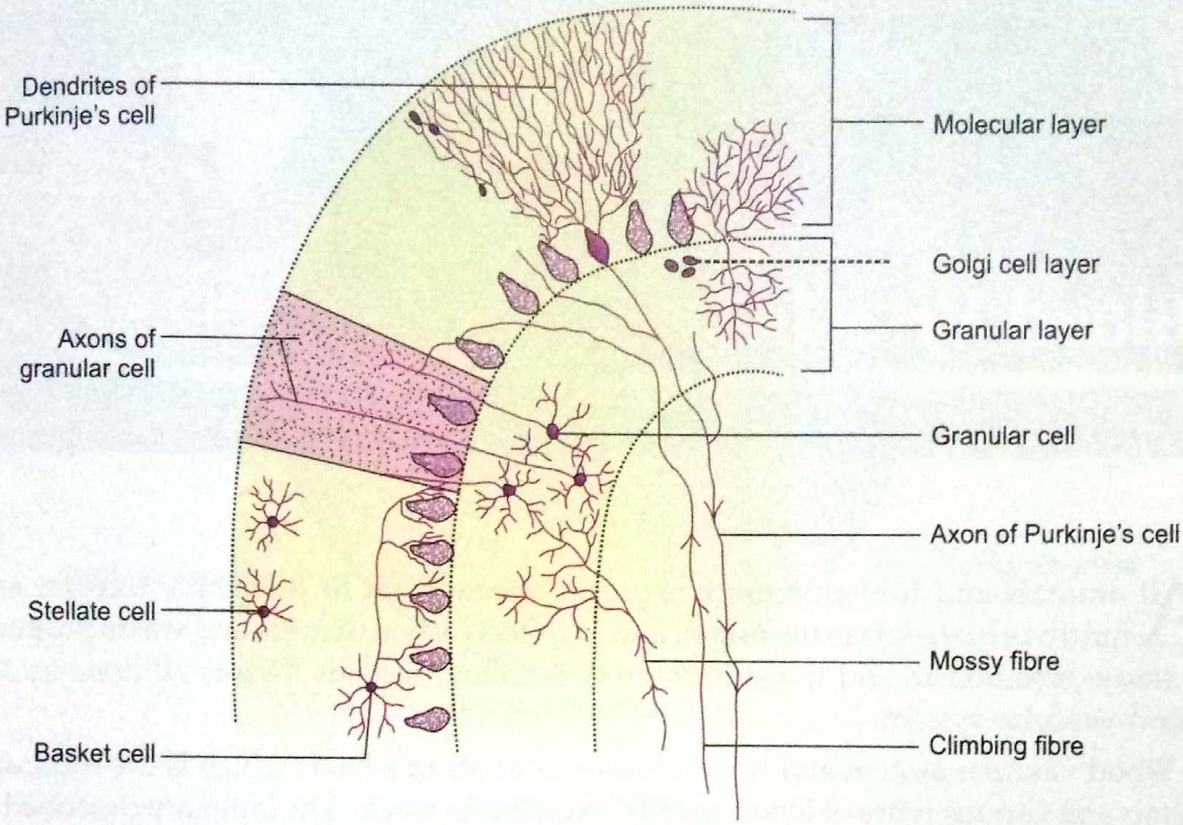


Fig. 6.11: *Schematic figure to show layers and fibres of cerebellar cortex*

MULTIPLE CHOICE QUESTIONS

1. Which cell forms myelin sheath on peripheral nerves?
a. Astrocyte
b. Microglia
c. Schwann's cell
d. Oligodendrocyte

2. Myelin sheath in CNS is laid down by:
a. Astrocyte
b. Oligodendrocyte
c. Schwann's cell
d. Ependymal cell

3. Spinal/sensory ganglion contains the following type of neuron:
a. Multipolar neuron
b. Bipolar neuron
c. Unipolar neuron
d. Pseudounipolar neuron

4. White matter contains all *except*:
a. Astrocyte
b. Neuronal cell body
c. Oligodendrocyte
d. Microglia

5. All are layers of cerebellum *except*:
a. Molecular layer
b. Purkinje's cell layer
c. Granular layer
d. Betz cell layer

ANSWERS

1. c 2. b 3. d 4. b
5. d