Spinal Cord

INTRODUCTION

Situation and Extent

Spinal cord lies loosely in the **vertebral canal**. It extends from **foramen magnum** where it is continuous with medulla oblongata, above and up to the lower border of first lumbar vertebra below.

Coverings

Spinal cord is covered by sheaths called **meninges,** which are membranous in nature. Meninges are **dura mater, pia mater** and **arachnoid mater.** These coverings continue as coverings of brain. Meninges are responsible for protection and nourishment of the nervous tissues.

Shape and Length

Spinal cord is cylindrical in shape. Length of the spinal cord is about 45 cm in males and about 43 cm in females.

Enlargements

Spinal cord has two spindle-shaped swellings, namely **cervical** and **lumbar enlargements.** These two portions of spinal cord innervate upper and lower extremities respectively.

Conus Medullaris and Filum Terminale

Below the lumbar enlargement, spinal cord rapidly narrows to a cone-shaped termination called **conus medullaris.** A slender non-nervous filament called **filum terminale** extends from conus medullaris downward to the fundus of the dural sac at the level of second sacral vertebra.

Segments

Spinal cord is made up of 31 segments, which are listed in Box 143.1. In fact, spinal cord is a continuous structure. Appearance of the segment is by nerves arising from spinal cord, which are called spinal nerve.

Spinal Nerves

Segments of spinal cord correspond to 31 pairs of spinal nerves in a symmetrical manner. The spinal nerves are listed in Box 143.1.

BOX 143.1: Segments of spinal cord and spinal nerves

Spinal segments/Spinal nerves		
1. Cervical segments/Cervical spinal nerves	=	8
2. Thoracic segments/Thoracic spinal nerves	=	12
3. Lumbar segments/Lumbar spinal nerves	=	5
4. Sacral segments/Sacral spinal nerves	=	5
5. Coccygeal segment/Coccygeal spinal nerves	=	1
Total	=	31

Nerve Roots

Each spinal nerve is formed by an **anterior (ventral) root** and a **posterior (dorsal) root.** Both the roots on either side leave the spinal cord and pass through the corresponding **intervertebral foramina.** The first cervical spinal nerves pass through a foramen between occipital bone and first vertebra, which is called **atlas.** Cervical and thoracic roots are shorter whereas, the lumbar and sacral roots are longer. Long nerves descend in dural sac to reach their respective intervertebral foramina. This bundle of descending roots surrounding the filum terminale resembles the tail of horse. Hence, it is called cauda equina.

Fissure and Sulci

On the anterior surface of spinal cord, there is a deep furrow known as **anterior median fissure.** Depth of this fissure is about 3 mm. Lateral to the anterior median fissure on either side, there is a slight depression called the **anterolateral sulcus.** It denotes the exit of anterior nerve root. On the posterior aspect, there is a depression called **posterior median sulcus.** This sulcus is continuous with a thin glial partition called the **posterior median septum.** It extends inside the spinal cord for about 5 mm and reaches the gray matter.

On either side, lateral to posterior median sulcus, there is **posterior intermediate sulcus.** It is continuous with **posterior intermediate septum,** which extends for about 3 mm into the spinal cord. Lateral to the posterior intermediate sulcus, is the **posterolateral sulcus.** This denotes the entry of posterior nerve root.

Internal Structure of Spinal Cord

Neural substance of spinal cord is divided into inner gray matter and outer white matter (Fig. 143.1).

■ GRAY MATTER OF SPINAL CORD

Gray matter of spinal cord is the collection of nerve cell bodies, dendrites and parts of axons. It is placed centrally in the form of **wings of the butterfly** and it resembles the letter 'H'. Exactly in the center of gray matter, there is a canal called the **spinal canal.**

Ventral and the dorsal portions of each lateral half of gray matter are called ventral (anterior) and dorsal (posterior) gray horns respectively. In addition, the gray matter forms a small projection in between the anterior and posterior horns in all thoracic and first two lumbar segments. It is called the lateral gray horn. Part of the gray matter anterior to central canal is called the **anterior gray commissure** and part of gray matter posterior to the central canal is called **posterior gray commissure.**

Neurons in Gray Matter of Spinal Cord

Gray matter contains two types of multipolar neurons:

1. *Golgi type I neurons*

Golgi type I neurons have **long axons** and are usually found in anterior horns. Axons of these neurons form the long tracts of spinal cord.

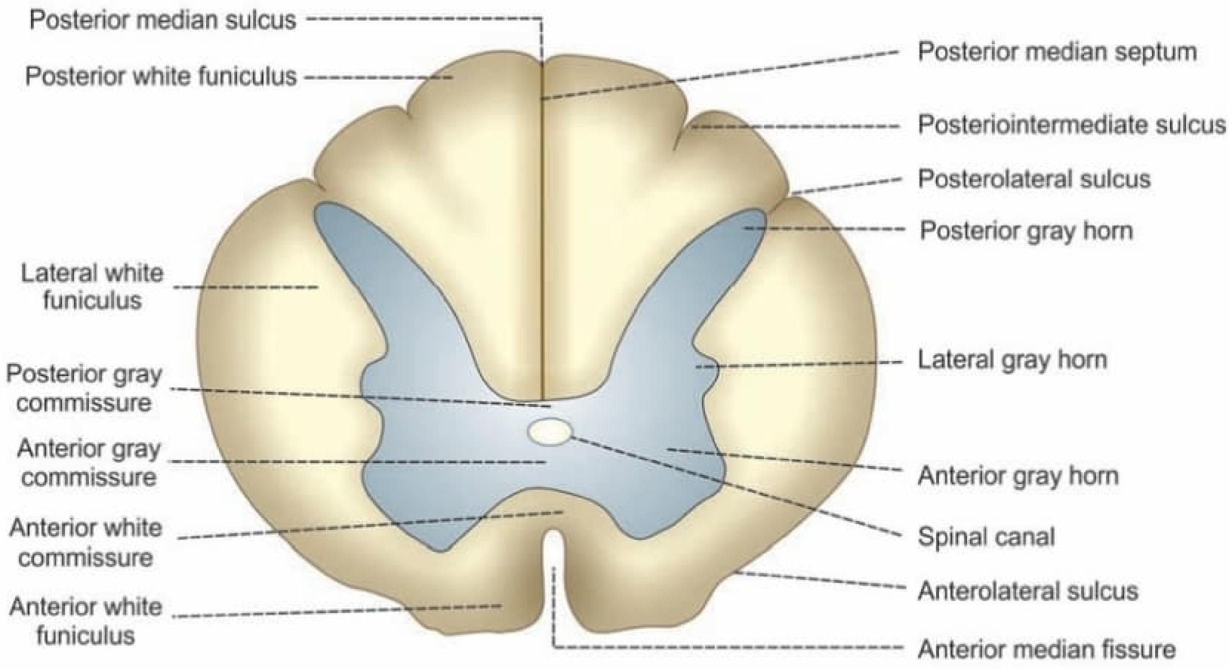

FIGURE 143.1: Section of spinal cord: thoracic se-

Golgi type II neurons

Golgi type II neurons have **short axons,** which are found mostly in posterior horns. Axons of these neurons pass towards the anterior horn of same side or opposite side.

Organization of Neurons in Gray Matter

Organization of neurons in the gray matter of spinal cord is described in two methods:

1. Nuclei or columns
2. Laminae or layers (Fig. 143.2).

■ NUCLEI

Clusters of neurons are present in the form of nuclei or cell columns in gray matter. Advantage of this method is that different nuclei are easily distinguished. Disadvantage is that some neurons like internuncial neurons, which are outside the distinct nuclei are not included.

Nuclei in Posterior Gray Horn

Posterior gray horn contains the nuclei of sensory neurons, which receive impulses from various receptors of the body through posterior nerve root fibers. There are four types of nuclei of sensory neurons:

1. *Marginal nucleus*

Marginal nucleus is also called **posteromarginal nucleus, marginal zone nucleus** or **border nucleus.** It covers the very tip of posterior gray horn and it is found in all levels of spinal cord.

2. *Substantia gelatinosa of Rolando*

Substantia gelatinosa of Rolando is a cap-like gelatinous material at the apex of posterior horn situated in all levels of spinal cord. It is formed by small neurons.

3. *Chief sensory nucleus or nucleus proprius*

Chief sensory nucleus is situated in the posterior gray horn ventral to substantia gelatinosa. It is a poorly defined cell column located in all segments of spinal cord.

4. *Dorsal nucleus of Clarke*

Clarke nucleus is also called **Clarke column of cells** and it is the collection of well-defined neurons. It occupies the basal portion of posterior horn. This nucleus is found in spinal segments between C8 and L3 only.

Nuclei in Lateral Gray Horn

Lateral gray horn has cluster of neurons called intermediolateral nucleus. The neurons of this nucleus give rise to sympathetic preganglionic fibers, which leave the spinal cord through the anterior nerve root. Intermediolateral nucleus extends between T1 and L2 segments of spinal cord.

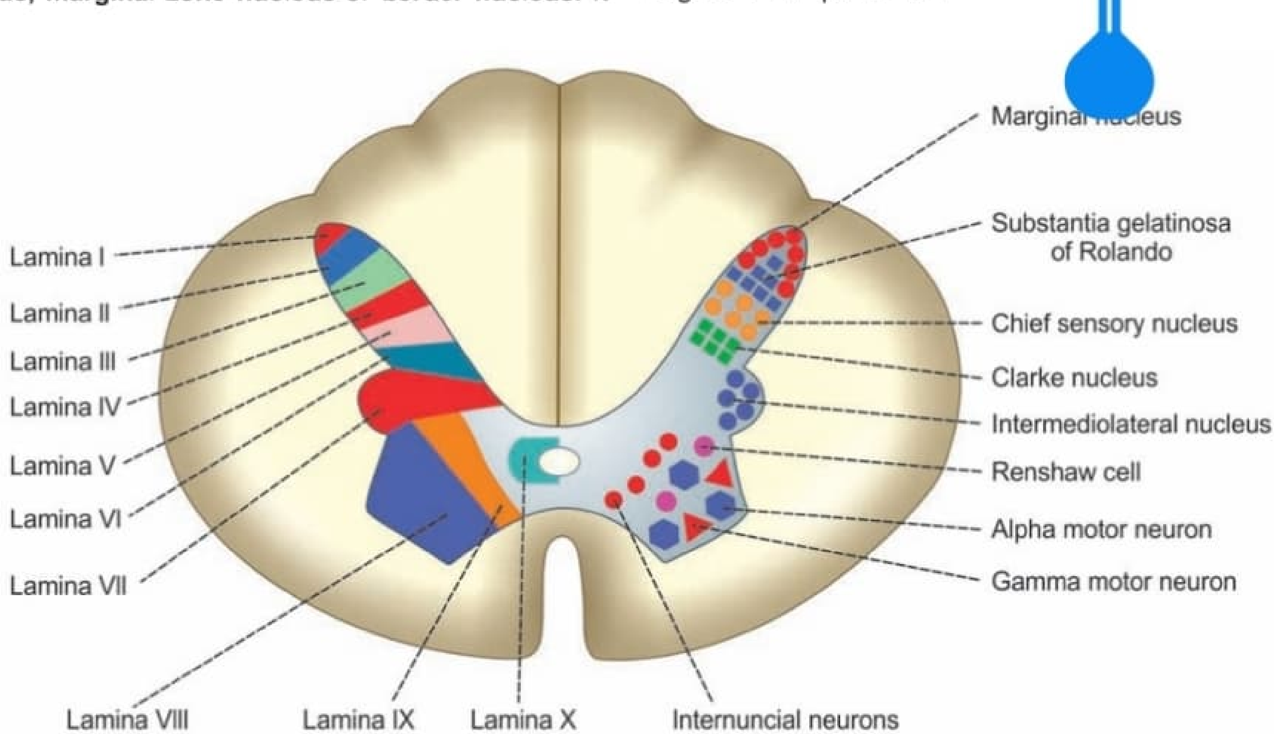

FIGURE 143.2: Neurons in gray horn of spinal cord: thoracic segment

Nuclei in Anterior Gray Horn

Anterior gray horn contains the nuclei of lower motor neurons, which are involved in motor function. These nuclei are present in almost all the levels of spinal cord. Three types of motor neurons are present in lower motor neuron nuclei:

1. *Alpha motor neurons*

Alpha motor neurons are large and multipolar cells. Axons of these neurons leave the spinal cord through the anterior root and end in groups of skeletal muscle fibers called **extrafusal fibers.**

2. *Gamma motor neurons*

Gamma motor neurons are smaller cells scattered among alpha motor neurons. These neurons send axons to **intrafusal fibers** of the muscle spindle.

3. *Renshaw cells*

These cells are also smaller in size. Renshaw cells are the **inhibitory neurons,** which play an important role in **synaptic inhibition** at the spinal cord (Chapter 140).

■ LAMINAE

Neurons of gray matter are distributed in laminae or layers. Each lamina consists of neurons of different size and shape. This cytoarchitectural lamination was identified in 1950 by **Brian Burke** and **Rexed.** He classified the neurons in 10 laminae based on his observation on sections of brain in a neonatal cat. Laminae are also called **Rexed laminae.**

Advantage of this method is that all the neurons of gray horn are included. Disadvantage is that it is difficult to distinguish the laminae from one another.

Laminae in Posterior Gray Horn

Laminae I to VI constitute the posterior gray horn. These laminae contain nuclei of sensory neurons, which are concerned with sensory functions.

Nuclei present in the laminae of posterior gray horn

Marginal nucleus	: Lamina I
Substantial gelatinosa of Rolando	: Laminae II and III
Chief sensory nucleus	: Laminae III, IV and V
Dorsal nucleus of Clarke	: Lamina VI

Lamina in Lateral Gray Horn

Lateral gray horn contains only one lamina, the lamina VII. It contains intermediolateral nucleus.

Laminae in Anterior Gray Horn

Laminae VIII and IX form the anterior gray horn. These laminae contain nuclei of motor neurons, which are concerned with motor functions.

Neurons present in the laminae of anterior gray horn

Motor internuncial neurons, which are also called interneurons	: Lamina VIII
Motor neurons	: Lamina IX

Lamina Around Central Canal

There is only one lamina around the center of the spinal canal, the lamina X. It contains neuroglia, which form the supporting tissue.

■ WHITE MATTER OF SPINAL CORD

White matter of spinal cord surrounds the gray matter. It is formed by the bundles of both myelinated and non-myelinated fibers, but predominantly the myelinated fibers. Anterior median fissure and posterior median septum divide the entire mass of white matter into two lateral halves. The band of white matter lying in front of anterior gray commissure is called **anterior white commissure** (Fig. 143.2).

Each half of the white matter is divided by the fibers of anterior and posterior nerve roots into three white columns or funiculi:

I. *Anterior or Ventral White Column*

Ventral white column lies between the anterior median fissure on one side and anterior nerve root and anterior gray horn on the other side. It is also called **anterior** or **ventral funiculus.**

II. *Lateral White Column*

Lateral white column is present between the anterior nerve root and anterior gray horn on one side and posterior nerve root and posterior gray horn on the other side. It is also called **lateral funiculus.**

III. *Posterior or Dorsal White Column*

Dorsal white column is situated between the posterior nerve root and posterior gray horn on one side and posterior median septum on the other side. It is also called **posterior or dorsal funiculus.**

■ TRACTS IN SPINAL CORD

TABLE 143.2: Ascending tracts of spinal cord

Situation	Tract	Origin	Course	Termination	Function
Anterior white column	1. Anterior spinothalamic tract	Chief sensory nucleus	Crossing in spinal cord Forms spinal lemniscus	Ventral posterolateral nucleus of thalamus	Crude touch sensation
Lateral white column	1. Lateral spinothalamic tract	Substantia gelatinosa	Crossing in spinal cord Forms spinal lemniscus	Ventral posterolateral nucleus of thalamus	Pain and temperature sensations
	2. Ventral spinocerebellar tract	Marginal nucleus	Crossing in spinal cord	Anterior lobe of cerebellum	Subconscious kinesthetic sensations
	3. Dorsal spinocerebellar tract	Clarke nucleus	Uncrossed fibers	Anterior lobe of cerebellum	Subconscious kinesthetic sensations
	4. Spinotectal tract	Chief sensory nucleus	Crossing in spinal cord	Superior colliculus	Spinovisual reflex
	5. Fasiculus dorsolateralis	Posterior nerve root ganglion	Component of lateral spinothalamic tract	Substantia gelatinosa	Pain and temperature sensations
	6. Spinoreticular tract	Intermediolateral cells	Crossed and uncrossed fibers	Reticular formation of brainstem	Consciousness and awareness
	7. Spino-olivary tract	Non-specific	Uncrossed fibers	Olivary nucleus	Proprioception
	8. Spinovestibular tract	Non-specific	Crossed and uncrossed fibers	Lateral vestibular nucleus	Proprioception
Posterior white column	1. Fasciculus gracilis	Posterior nerve root ganglia	Uncrossed fibers No synapse in spinal cord	Nucleus gracilis in medulla	Tactile sensation Tactile localization Tactile discrimination Vibratory sensation Conscious kinesthetic sensation Stereognosis
	2. Fasciculus cuneatus	Posterior nerve root ganglia	Uncrossed fibers No synapse in spinal cord	Nucleus cuneatus in medulla	

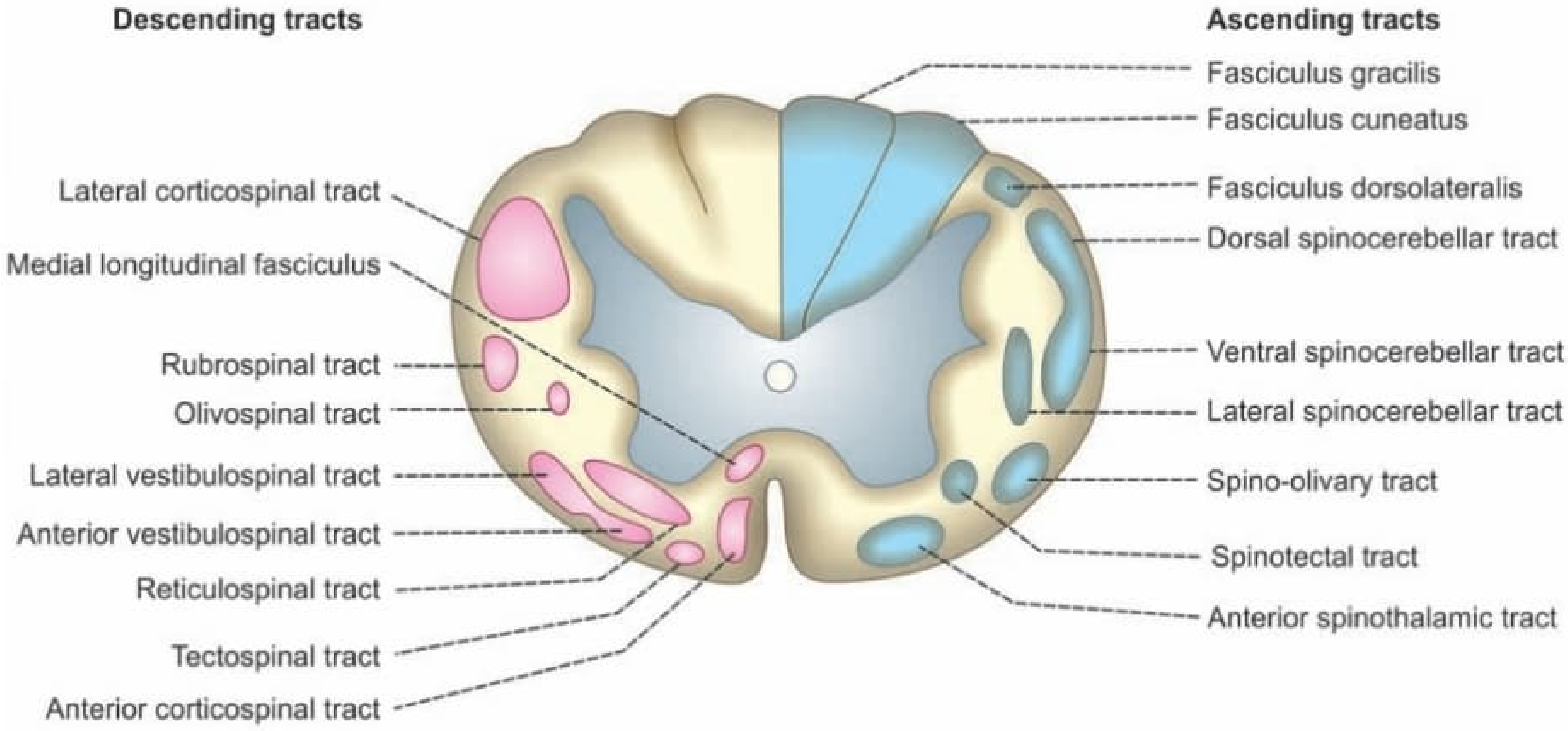

FIGURE 143.3: Tracts of spinal cord

TABLE 143.4: Descending tracts of spinal cord

	Tract	Situation	Origin	Course	Function
Pyramidal Tracts	1. Anterior corticospinal tract	Anterior white column	Betz cells and other cells of motor area	Uncrossed fibers	i. Control of voluntary movements ii. Form upper motor neurons
	2. Lateral corticospinal tract	Lateral white column	Betz cells and other cells of motor area	Crossed fibers	
Extrapyramidal tracts	1. Medial longitudinal fasciculus	Anterior white column	Vestibular nucleus Reticular formation Superior colliculus and cells of Cajal	Uncrossed fibers Extend up to uppercervical segments	i. Coordination of reflex ocular movements ii. Integration of movements of eyes and neck
	2. Anterior vestibulospinal tract	Anterior white column	Medial vestibular nucleus	Uncrossed fibers Extend up to upper thoracic segments	i. Maintenance of muscle tone and posture ii. Maintenance of position of head and body during acceleration
	3. Lateral vestibulospinal tract	Lateral white column	Lateral vestibular nucleus	Mostly uncrossed Extend to all segments	
	4. Reticulospinal tract	Lateral white fasciculus	Reticular formation of pons and medulla	Mostly uncrossed Extend up to thoracic segments	i. Coordination of voluntary and reflex movements ii. Control of muscle tone iii. Control of respiration and diameter of blood vessels
	5. Tectospinal tract	Anterior white column	Superior colliculus	Crossed fibers Extend up to lower cervical segments	Control of movement of head in response to visual and auditory impulses
	6. Rubrospinal tract	Lateral white column	Red nucleus	Crossed fibers Extend up to thoracic segments	Facilitatory influence on flexor muscle tone
	7. Olivospinal tract	Lateral white column	Inferior olivary nucleus	Mostly crossed Extent – not clear	Control of movements due to proprioception

Termination – fibers of all the tracts terminate in motor neurons situated in the anterior gray horn of spinal cord.

TABLE 143.6: Effects of hemisection (Brown-Séquard syndrome) of spinal cord

Level	Same side		Opposite side	
	Sensory changes	Motor changes	Sensory changes	Motor changes
Below the level of lesion	**Sensations lost** *Sensations carried by uncrossed tracts:* 1. Fine touch 2. Tactile localization 3. Tactile discrimination 4. Vibration sense 5. Conscious kinesthetic sensation 6. Stereognosis **Sensations retained** *Sensations carried by crossed tracts:* 1. Crude touch 2. Pain 3. Temperature	**Upper motor neuron lesion type** 1. Increased tone 2. Spastic paralysis 3. Loss of superficial reflexes 4. Exaggeration of deep reflexes 5. Babinski positive sign 6. Rigidity in the limbs 7. No muscular wastage	**Sensations lost** *Sensations carried by crossed tracts:* 1. Crude touch 2. Pain 3. Temperature **Sensations retained** *Sensations carried by uncrossed tracts:* 1. Fine touch 2. Tactile localization 3. Tactile discrimination 4. Vibration sense 5. Conscious kinesthetic sensation 6. Stereognosis	**No paralysis** *If it occurs:* 1. Very mild 2. Resembles upper motor neuron lesion type
At the level of lesion	**Complete anesthesia**	**Lower motor neuron lesion type** 1. Loss of muscle tone 2. Flaccid paralysis 3. Loss of all reflexes 4. Wastage of muscle 5. Loss of vasomotor tone	**Sensations lost** *Sensations carried by crossed tracts:* 1. Crude touch 2. Pain 3. Temperature **Sensations retained** *Sensations carried by uncrossed tracts:* 1. Fine touch 2. Tactile localization 3. Tactile discrimination 4. Vibration sense 5. Conscious kinesthetic sensation 6. Stereognosis	**No paralysis** *If it occurs:* 1. Very mild 2. Resembles lower motor neuron lesion type