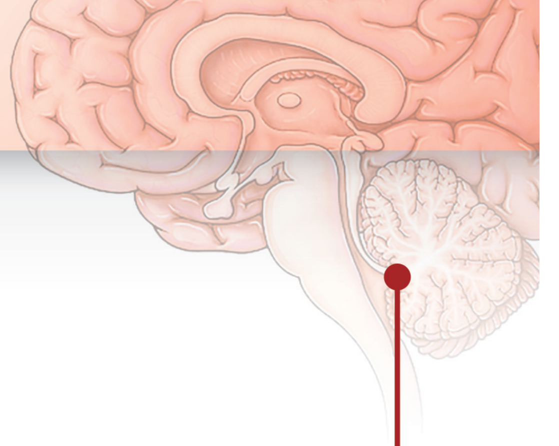


Chapter

5

Tracts of Spinal Cord

Competency

AN57.4: Enumerate ascending and descending tracts at mid-thoracic level of spinal cord.

- The tracts are defined as collection nerve fibers within the central nervous system, which have same origin, course, termination, and functions.
- *Synonyms*: Fasciculi, lemnisci (ribbon-like)

Classification of tracts

- The tracts of the spinal cord are classified into three types:
  1. Ascending
  2. Descending
  3. Intersegmental.

LOCATIONS OF TRACTS IN SPINAL CORD

- The tracts are located in the white matter of the spinal cord as follows (Flowchart 5.1):

  Anterior white column:
  - *Ascending tracts*: Anterior spinothalamic

Flowchart 5.1: Tracts of spinal cord

Tracts of spinal cord

	Anterior white column	***Lateral white column***	***Posterior white column***
Ascending tracts:	Anterior spinothalamic	Lateral spinothalamic Anterior spinocerebellar Posterior spinocerebellar Spinotectal	Tract of Goll Tract of Burdach
Descending tracts:	Anterior corticospinal Vestibulospinal Tectospinal Medial rubrospinal	Lateral corticospinal Rubrospinal Lateral reticulospinal Hypothalamospinal	Absent

  - *Descending tracts*: Anterior corticospinal, vestibulospinal, tectospinal, medial rubrospinal

  Lateral white column
  - *Ascending tracts*: Lateral spinothalamic, anterior spinocerebellar, posterior spinocerebellar, spinotectal
  - *Descending*: Lateral corticospinal, rubrospinal, lateral reticulospinal, hypothalamospinal

  Posterior white column
  - *Ascending tracts* (*only*): Tract of Goll (fasciculus gracilis), tract of Burdach (fasciculus cuneatus).

ASCENDING TRACTS

- Ascending tracts carry the sensory input to the central nervous system
- They carry the following sensations:
  1. Pain and temperature sensation
  2. Fine touch and conscious proprioception
  3. Unconscious proprioception.

Some Interesting Facts

- *Proprioception*: It is a sense of location and movement of the body part. It occurs at two levels:*Viva*
  1. *Conscious proprioception*: It is the ability to perceive and change the body position.*Viva*
  2. *Unconscious proprioception*: It helps to maintain the balance of the body during rest or movement as well as it helps in reflexes.*Viva*

General Arrangements of Sensory Pathway

- Sensory pathways connect sensory receptors with cerebral cortex.
- Each sensory pathway consists of multiple neurons which are called first order, second order, and third order neurons (Fig. 5.1).

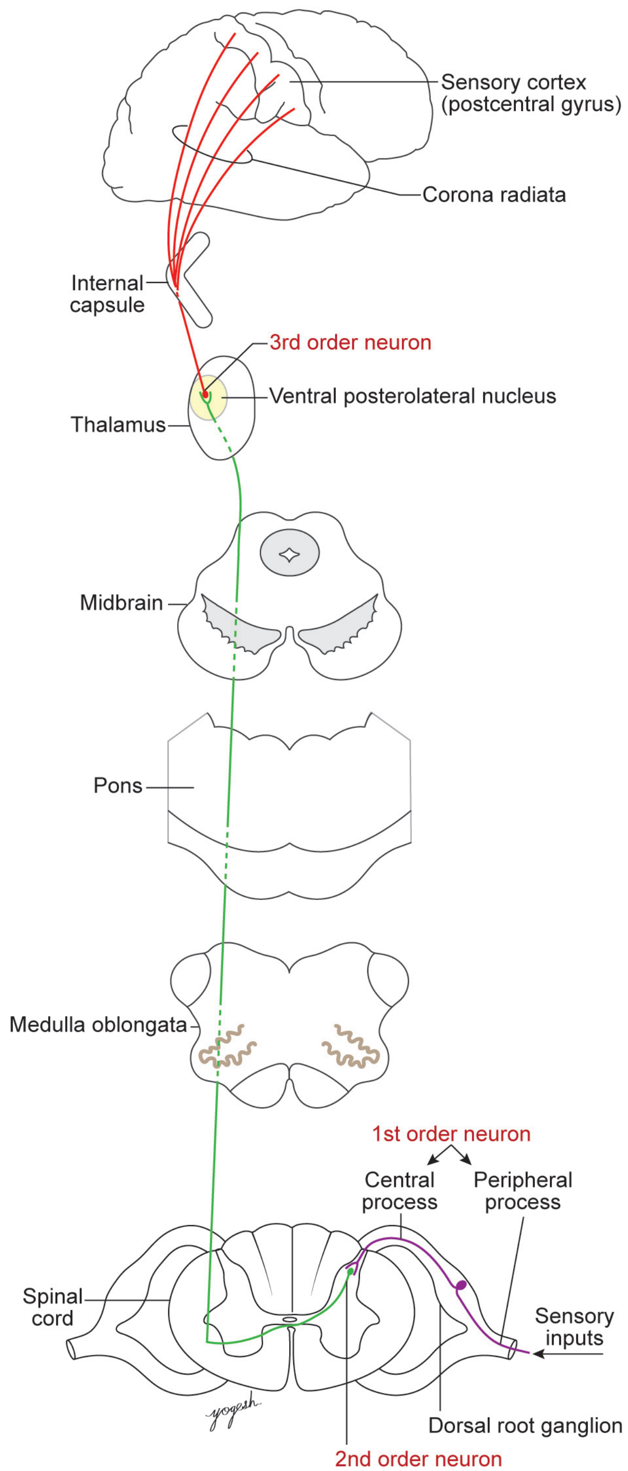


Fig. 5.1: General arrangements of sensory pathway

First order neurons

- These are located in dorsal root ganglia of spinal nerves and ganglia of cranial nerves. They are pseudounipolar neurons.
- These neurons have two processes:
  1. Peripheral process that carries signal from receptors.
  2. Central process that enters the central nervous system and transfers the signal to the second order neurons.

Second order neurons

- They are located within the gray matter of spinal cord and brainstem. Axons of most of the second order neurons cross to opposite side and then ascend upward.
- *Note*: Some of the primary order neurons transfer the signals to motor neurons (anterior horn cells) to generate the reflexes.

Third order neurons

- They are present in ventral posterolateral nucleus of thalamus. Their axons transfer the signals to sensory area of the cerebral cortex.

Lateral Spinothalamic Tract

Q. Describe the lateral spinothalamic tract or the tract carrying the pain and temperature sensations.

- *Functions*: Lateral spinothalamic tract carries pain and temperature sensations from opposite side of the body (Flowchart 5.1).*NEXT*
- *Receptors*:
  For pain: Free nerve endings
  For temperature:
  – End bulbs of Krause for cold
  – End bulbs of Ruffini for warmth.
- *Location in spinal cord*: Lateral white column.

Composition/pathway

- It consists of three order neurons: First order, second order, and third order neurons (Fig. 5.2).

First order neurons

- These are pseudounipolar neurons of the dorsal root ganglia of spinal cord that has
  a. *Peripheral processes* that carry pain and temperature sensations through the spinal nerve and its dorsal root.
  b. *Central processes* that enter the spinal cord through the lateral division of dorsal root of spinal nerve.

Flowchart 5.2: Lateral spinothalamic tract

Lateral spinothalamic tract

Location: Lateral white column

Functions

Pain and temperature sensations from opposite side of the body

Receptors

- Pain:
  Free nerve endings
- Cold:
  End bulbs of Krause
- Warmth:
  End bulbs of Ruffini

Pathway

First order neurons: Pseudounipolar neurons of dorsal root ganglion
- Peripheral processes receive stimuli
- Central processes relay in substantia gelatinosa of dorsal horn

Second order neurons: Cells of dorsal horn
- Their axons cross midline
- Ascend as lateral spinothalamic tract
- Ascend as spinal lemniscus in brainstem

Third order neurons:
- At VPL nucleus of thalamus
- Pass through internal capsule
- End at primary sensory cortex

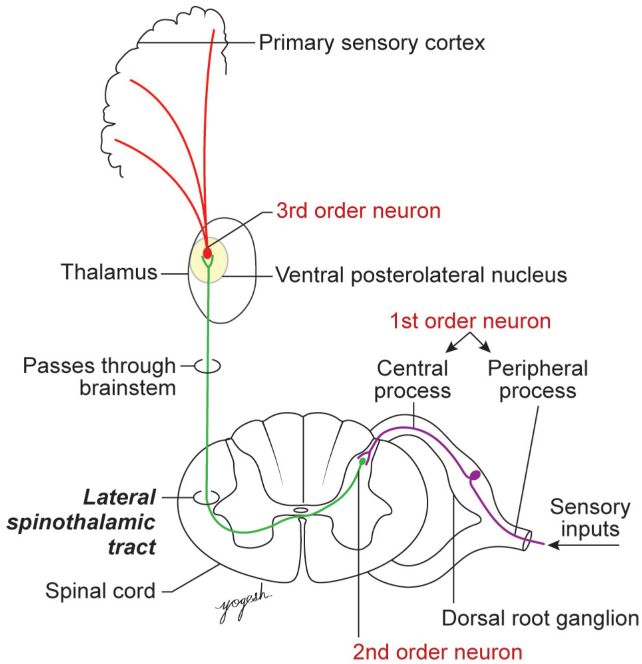


Fig. 5.2: Lateral spinothalamic tract

- These fibers ascend upward for one or two segments as *dorsolateral tract of Lissauer* (at the tip of dorsal horn).
- They relay in posterior horn by synapsing with neurons of *substantia gelatinosa*.

Seconds order neurons

- The cells of dorsal horn form the second order neurons. Their axon cross to the opposite side in anterior white commissure and ascends upward in the opposite white column as lateral spinothalamic tract. They ascend as *spinal lemniscus* in brainstem.
- They terminate in the ventral posterolateral nucleus (VPL) of thalamus.

Third order neurons

- These are neurons of ventral posterolateral nucleus (VPL) of thalamus. Their axons project to the *primary sensory cortex* of the cerebral hemisphere. These fibers pass through the posterior limb of the internal capsule.[MCQ]

Some Interesting Facts

- In the lateral spinothalamic tract, pain fibers are located anteriorly, while the temperature fibers are located posteriorly. The fibers are arranged superficial to deep as sacral, lumbar, thoracic, and cervical.
- The fibers of lateral spinothalamic tract form *spinal lemniscus* in the brainstem.
- Pain and perhaps temperature reach consciousness at thalamic level and emotional responses are elicited.
- Precise source, severity, quantity of pain and temperature stimuli, the cerebral cortex play an important role.

Clinical Integration

- *Unilateral lesion of lateral spinothalamic tract* → complete loss of pain and temperature sensations on the opposite side of the body.
- *Cordotomy for pain relief*: Cordotomy is a surgical procedure. In this procedure lateral spinothalamic tract is severed (incised) to relieve intractable pain. *Anatomical basis*: The fibers carrying pain lie on the lateral side in lateral spinothalamic tract (in lateral white column).
- *Syringomyelia*: In syringomyelia, crossing fibers of lateral spinothalamic tract are compressed that cause bilateral loss of pain and temperature sensation below the level of lesion.

Some Interesting Facts

Pathway for pain and temperature from head region:

- The pain and temperature sensations from the head region are carried by branches of *trigeminal nerve*.
- First order neurons of this pathway are located in *trigeminal ganglion*. Their peripheral process form the branches of trigeminal nerve. Their central processes enter the pons and runs downward as *spinal tract of trigeminal nerve*. Arrangements of fibers anterior to posterior: Ophthalmic fibers, maxillary fibers, and mandibular fibers.
- Second order neurons are located in the *nucleus of spinal tract of trigeminal nerve*. Their axons cross to the opposite side in the medulla oblongata and ascends upward as the *trigeminothalamic tract* in the brainstem up to thalamus.
- *Third order neurons* are located in ventral postero-medial (VPM) nucleus of thalamus. They send axons to *postcentral gyrus* of cerebral hemisphere.

Anterior Spinothalamic Tract

- *Functions*: It carries the following sensations from opposite side of the body (Flowchart 5.3)
  - light touch, tickle, itch
  - pressure.
- *Receptors*:
  - Merkel's disc, nerve ending at hair root, Meissner's corpuscles – for touch
  - Pacinian corpuscles – for pressure.
- *Location in spinal cord*: Anterior white column.

Pathway

- It consists of three order neurons: First, second, and third (Fig. 5.3).

First order neurons

- These are pseudounipolar neurons of the spinal cord that has
  a. *Peripheral processes* that carry the sensation through the spinal nerve and its dorsal root.

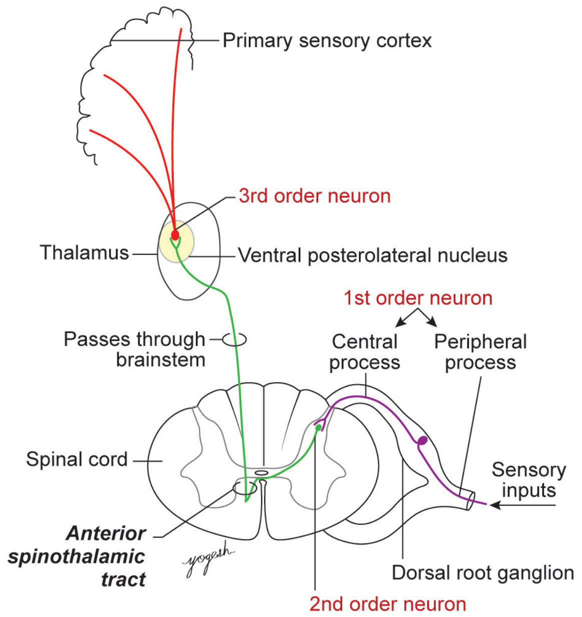


Fig. 5.3: Anterior spinothalamic tract

Flowchart 5.3: Anterior spinothalamic tract

Anterior spinothalamic tract

Location: Anterior white column

Functions

Carry light touch, tickle, itch, pressure sensations from opposite side of body

Receptors:

Touch: Merkel's disc, nerve endings at hair root, Meissner's corpuscles

- Pressure: Pacinian corpuscles

Pathway

First order neurons: Pseudounipolar neurons of dorsal root ganglion
- Peripheral processes carry impulses
- Central processes enter spinal cord

Second order neurons: Cells of dorsal horn
- Their axons cross midline
- Ascend as anterior spinothalamic tract
- Ascend as spinal lemniscus in brainstem

Third order neurons:
- At VPL nucleus of thalamus
- Pass through internal capsule
- End at primary sensory cortex

b. *Central processes* are highly myelinated. They enter the spinal cord through medial division of the dorsal root of spinal nerve. On entering the spinal cord, they ascend one to two segments in a dorsolateral tract of Lissauer. They relay at the cells of substantia gelatinosa.

Second order neurons

- They are located in the dorsal horn of spinal cord (in the substantia gelatinosa) their axons cross the midline in the anterior white commissure to reach the contralateral anterior white column.
- Then they ascend upward as anterior spinothalamic tract just in front of anterior horn. They ascend as *spinal lemniscus* in brainstem.
- These neurons relay in the ventral posterolateral nucleus (VPL) of the thalamus.

Third order neurons

- These are neurons of ventral posterolateral nucleus (VPL) of thalamus. Their axons project to the *primary sensory cortex* of the cerebral hemisphere. These fibers pass through the posterior limb of the internal capsule.[MCQ]

Clinical Integration

- *Lesion of anterior spinothalamic tract* → little or no loss of tactile, touch and pressure sensations as these are also transmitted by fasciculus gracillis and cuneatus.
- *Dissociation anesthesia*: It indicates the loss of pain and temperature sensations without affecting touch sensation.
  Anatomical basis: In syringomyelia, it affects the second order neurons that cross the midline. They are as follows:
  – Fibers of lateral spinothalamic tract – loss of pain and temperature sensations
  – Fibers of anterior spinothalamic tract – no or little loss of touch sensation as it is carried by uncrossed dorsal white column tract, fasciculus gracillis and cuneatus.

Some Interesting Facts

- *Jacket type anesthesia* for pain and temperature: In syringomyelia, there is compression of crossing fibers of lateral spinothalamic tract (carry pain and temperature) at the level of lesion. It causes loss of pain and temperature sensations at the level of lesion, but not above and below the lesion. This produces a jacket-type of anesthesia for pain and temperature.[Clinical fact]
- Receptors that transmit nociceptive (pain and discomfort) impulses consist of high-threshold free nerve endings. They ramify nerves on the external and internal surfaces of the body and viscera.
- Thinly myelinated (fast conducting) fibers carry sharp, short-term well-localized pain (such as pinprick).[MCQ]
- Nonmyelinated (type C) (slow conducting) fibers carry dull, persistent, poorly localized pain such as pain on stretching of the tendon.

Tract of Goll and Tract of Burdach

- *Synonym*: Fasciculus gracilis and fasciculus cuneatus.
- *Functions*: They carry the following sensations from opposite side of the body (Flowchart 5.4):[MCQ, NEXT, Viva]
  – Fine touch, two-point discrimination
  – Vibration
  – *Conscious proprioception*: Joint sense, stereognosis, conscious kinesthesia.
- *Location*: Posterior white column.

- *Two-point discrimination*: It involves differentiation of fine touch between adjacent two points. Usually, it is about 3 cm in hand and 0.6 cm for fingertips.
- *Stereognosis*: It is the ability to identify the object by touch with closed eyes.
- *Kinesthesia*: It is an awareness of the position of movement of body parts by sensory inputs from muscle and tendons.

Flowchart 5.4: Tract of Goll and Burdach

Tract of Goll and Burdach

Location: Posterior white column

Functions

From opposite side of body
- Fine touch
- Two-point discrimination
- Vibration
- Concious proprioception

Receptors
- Fine touch: Meissner's corpuscles
- Vibration and proprioception: Pacinian corpuscles, free nerve endings

Pathway

First order neurons: Pseudounipolar neurons of dorsal root ganglion
- Peripheral processes receive stimuli
- Central processes ascend in posterior white column as fasciculus gracilis and fasciculus cuneatus

Second order neurons:
Fasciculus gracilis → nucleus gracilis
Fasciculus cuneatus → nucleus cuneatus
↓
Axons cross as internal arcuate fibers in medulla → ascend as medial lemniscus

Third order neurons:
- At VPL nucleus of thalamus
- Pass through internal capsule
- End at primary sensory cortex

Receptors

- Meissner's corpuscles – for fine touch
- Pacinian corpuscles and free nerve endings – for vibration and proprioception.
- *Note*: Muscle spindles and Golgi tendon organ are responsible for unconscious proprioception.

Pathway

- It consists of three order neurons: First, second, and third (Fig. 5.4).

First order neurons

- These are pseudounipolar neurons of the spinal cord that has
  a. *Peripheral processes* that carry the sensation through the spinal nerve and its dorsal root.
  b. *Central processes* are thickly myelinated. They enter the spinal cord through median division of the spinal roots of spinal nerves.
- Then they ascend upward in the posterior column as follows:
  Fasciculus gracilis – fibers from coccygeal, sacral, lumbar, and lower thoracic regions form fasciculus gracilis.
  Fasciculus cuneatus – fibers from upper thoracic and cervical regions form fasciculus cuneatus.
- *Arrangements of fiber lateral to medial*: Cervical, thoracic, lumbar, and sacral fibers.
- Fasciculus gracilis terminates at the nucleus gracilis and fasciculus cuneatus at the nucleus cuneatus.

Some Interesting Facts

- Fasciculus gracilis lies medial to the fasciculus cuneatus in the posterior white column. They are separated from each other by posterointermediate sulcus and septum.

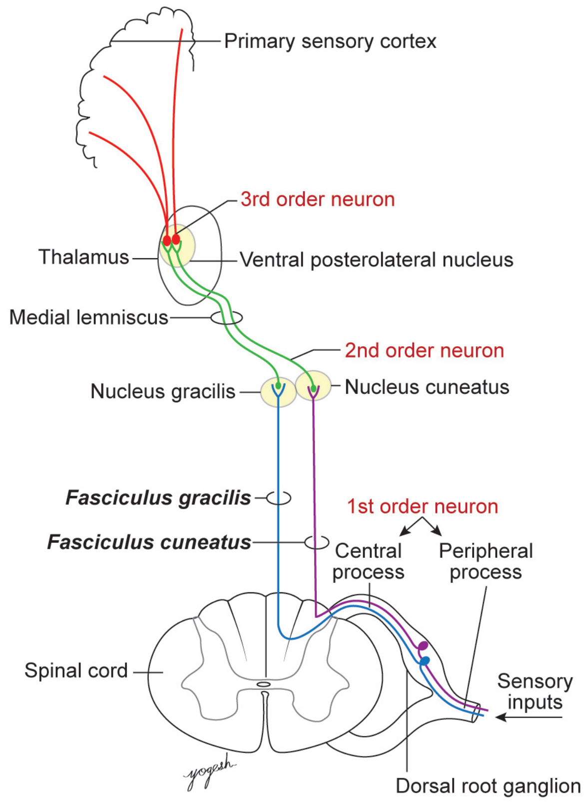


Fig. 5.4: Fasciculus gracilis and fasciculus cuneatus

Second order neurons

- The neurons of nuclei gracilis and cuneatus form second order neurons. Their axons curve ventromedially as *internal arcuate fibers* which decussate (cross) to the opposite side and ascend upward as *medial lemniscus*.
- These nuclei lie on the posterior aspect of medulla oblongata.
- Then medial lemniscus ascends in pons and midbrain to terminate in *ventral posterolateral nucleus of thalamus*.

Third order neurons

- They are located in VPL nucleus thalamus. Their axons ascend through the posterior limb of internal capsule and terminate in the sensory cortex of cerebral hemisphere.

Clinical Integration

- Unilateral lesion of posterior white column → results in loss of the discriminatory touch, sense of position, and vibration sensations below the level of lesion and on the side of lesion.
- *Tabes dorsalis*: In syphilis, the posterior white column undergoes degenerative changes (Fig. 5.5). These are called tabes dorsalis. It results in loss of position, vibration, and two-point discrimination sensations.
- *Romberg's sign*: In positive Romberg's sign, the patient falls if he stands with feet together and eyes closed. It may occur due to damage to tract of Goll and Burdach (loss of position sense).

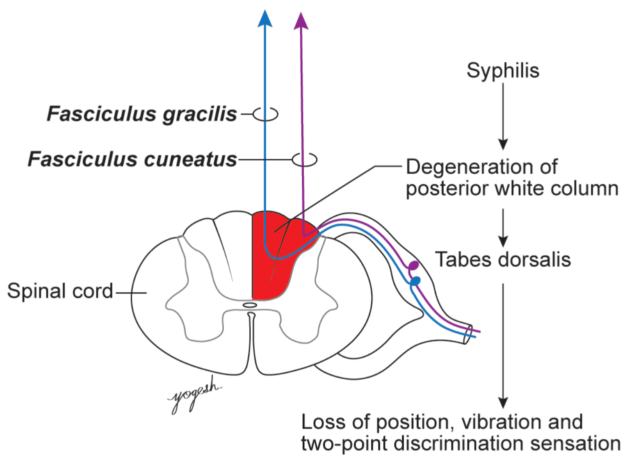


Fig. 5.5: Tabes dorsalis

Spinocerebellar Tracts

Functions

- Spinocerebellar tracts carry the unconscious proprioception to the cerebellum.
- They form afferent fibers of reflex arc involving cerebellum for maintenance of posture and coordination of movement.
- *Receptors*: Stretch receptor of muscle spindle and Golgi tendon organ for unconscious proprioception.

Pathway

- The spinocerebellar tract consists of two neurons arrangement.
  Note: Cerebral cortex receives impulses through three neurons arrangement pathway.
  The spinocerebellar tracts include (Table 5.1):
  1. Dorsal spinocerebellar tract
  2. Ventral spinocerebellar tract
  3. Cuneocerebellar tract
  4. Rostral spinocerebellar tract

Note: Many authors consider dorsal and ventral spinocerebellar tract together and they do not include cuneocerebellar tract and rostral spinocerebellar tract in this group.

Posterior (dorsal) spinocerebellar tract (Fig. 5.6)

- *First order neurons*: They are pseudounipolar neurons of dorsal root ganglion. Their central processes enter the spinal cord and relay in Clarke's column.
- *Second order neurons*: They are located *in nucleus dorsalis* (*Clarke's column*). Their axons pass to the dorsolateral part of lateral white column of same side and ascend as dorsal tract of spinocerebellar tract. They ascend to medulla oblongata where they enter *inferior cerebellar peduncle* and terminates in the ipsilateral cerebellar cortex (vermis).

Anterior (ventral) spinocerebellar tract (Fig. 5.6)

- *First order neurons*: The location and course of first order neurons are similar to dorsal spinocerebellar tract.
- *Second order neurons*: They are located in laminae V–VII of lumbosacral segments of spinal cord. Their

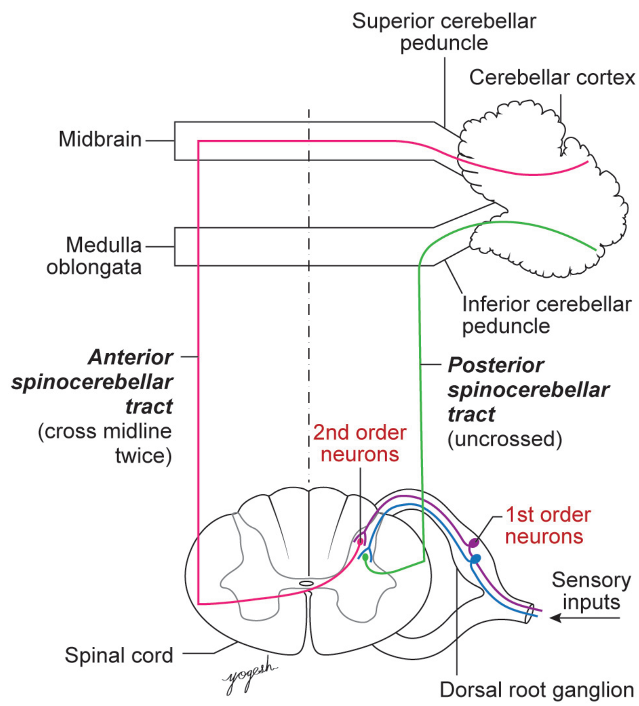


Fig. 5.6: Anterior and posterior spinocerebellar tracts

Table 5.1: Spinocerebellar tracts

Tract	*First order neuron*	*Second order neuron*	*Termination*	*Functions*
Dorsal or posterior spinocerebellar tract (C8 to L3)	Cells of dorsal root ganglion	Cells of dorsal nucleus (Clark's column)	Ipsilateral cerebellar vermis	• Proprioception from ipsilateral trunk and lower limb • Coordination of movements of lower limb • Maintenance of posture
Ventral or anterior spinocerebellar tract (C8–L3)	Cells of dorsal root ganglion	Dorsal horn cells	Ipsilateral cerebellar vermis	• Proprioception from ipsilateral trunk and lower limb • Same as above
Cuneocerebellar (C2 to T5)	Dorsal root ganglion	Accessory cuneate nucleus	Ipsilateral cerebellar vermis	Proprioception from ipsilateral neck and upper limb
Rostral spinocerebellar (C4–C8)	Dorsal root ganglion	Dorsal horn cells	Cerebellum	Proprioception from ipsilateral head and upper limb

axons mostly decussate (cross) and ascend as anterior or ventral spinocerebellar tracts in the anterolateral part of lateral white column. They ascend to midbrain and enter the cerebellum through *superior cerebellar peduncle*. They decussate in the cerebellum and terminate in the cerebellum cortex (vermis).

Cuneocerebellar tract

- *First order neuron*: They are located in the dorsal root ganglion. Their central processes enter the spinal cord at C2 to T5 level and ascend in fasciculus cuneatus in posterior white column. They terminate in internal or *accessory cuneate nucleus*. It is similar to nucleus dorsalis of Clarke which is present in the thoracic region.
- *Second order neurons*: They are located in the accessory cuneate nucleus. Their axons join the restiform body or *inferior cerebellar peduncle* and relay in the ipsilateral cerebral cortex.
- *Note*: Clarke's column is not present above C8 level, hence ventral and dorsal spinocerebellar tracts are replaced by cuneocerebellar tract which carries unconscious proprioception from the neck, upper limb and upper part of the trunk.

Rostral spinocerebellar tract

- *First order neurons*: These are the dorsal horn cells (C4–C8) that give information of unconscious proprioception of head and upper limb. Their central processes terminate in the lamina VII of dorsal horn.
- *Second order neurons*: They are located in *lamina VII of dorsal horn at C4 to C8 level*. Their axons ascend as rostral spinocerebellar tract along with ventral spinocerebellar tract. They enter the cerebellum mostly through *inferior cerebellar peduncle* (few through superior cerebellar peduncle) and terminate in cerebellar cortex.

Some Interesting Facts

- Both dorsal and ventral spinocerebellar tracts carry unconscious proprioception to the cerebellum. Their functional difference is as follows:[Clinical fact]
  - *Dorsal spinocerebellar tract* – coordination of fine movements of lower limb and individual lower limb muscle signals.
  - *Ventral spinocerebellar tract* – coordination of gross movements of lower limb as whole.
- The unconscious proprioception from heads, neck, upper limb, and upper part of trunk is conveyed to cerebellum through cuneocerebellar and rostral spinocerebellar tracts due to absence of Clarke's nucleus above C8 level.

Proprioception from head

- The conscious proprioception from the head is carried by *trigeminal nerve*.
- *First order neurons* are located in *mesencephalic nucleus of trigeminal nerve*.[MCQ] Their axon synapse with the neuron's *reticular formation* (second order neurons). The axons of these second order neurons ascend as *trigeminothalamic tract* and relay in ventral posterolateral (VPL) nucleus of thalamus (third order neurons). The axons of third order neurons reach cerebral hemisphere through internal capsule and terminate in the sensory cerebral cortex. Few fibers from mesencephalic nucleus of trigeminal nucleus go to insular cerebral cortex to convey unconscious proprioception.

DESCENDING TRACTS

- The descending tracts conduct the impulses from higher centers to the spinal cord. These tracts are listed in Table 5.2.

Corticospinal (Pyramidal) Tract

Q. Describe the corticospinal tract.

Functions

- Pyramidal tract is responsible for voluntary movement of body (Flowchart 5.5).
- Pyramidal tract is the major descending motor tract. Its fibers pass through the pyramid of medulla oblongata, hence called pyramidal tract.

Components

- It consists of two fibers:
  - *Corticospinal fibers* that terminate at the anterior horn cells of spinal cord
  - *Corticonuclear fibers* that terminate at the motor nuclei of cranial nerves in the brainstem.

Composition

- Pyramidal tract consists of two neurons: Upper and lower (Fig. 5.7).
- Upper motor neurons are located in motor area (area 4) and premotor area (area 6) of the cerebral cortex. *Motor area* lies in front of central sulcus (precentral gyrus). This area contains giant *pyramidal cells*.

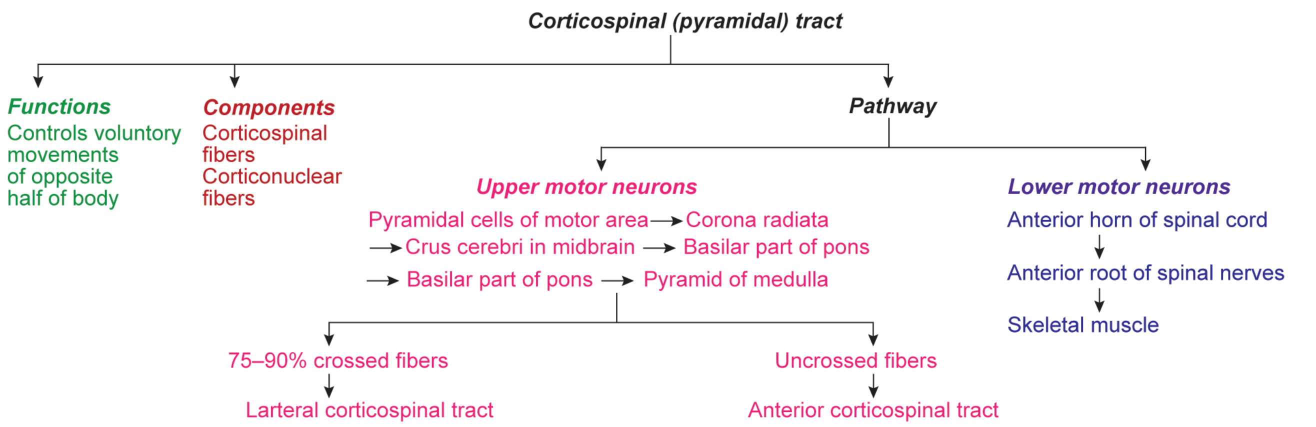
Some Interesting Facts

- Body is represented upside down in the motor cortex. Leg area is situated uppermost extending on to the medial surface of paracentral lobule. The leg area is followed by thigh, trunk, upper limb, face larynx, lips, jaw, tongue, and pharynx area.

Table 5.2: Descending tracts

Tract	*Location*	*Beginning (origin)*	*Target (termination)*	*Functions*
Lateral corticospinal tract (crossed)	Lateral white column	Upper motor neurons: Areas 4 and 6 of cerebral cortex	Lower motor neurons: Contralateral anterior horn cells	Execution of rapid, skilled voluntary movements especially hand and foot and lower limb
Anterior corticospinal tract (uncrossed)	Anterior white column	Upper motor neurons: Areas 4 and 6 of cerebral cortex	Lower motor neurons: Contralateral anterior horn cells	Voluntary movements of axial and upper limb muscles
Tectospinal tract	Anterior white column	Superior colliculus (midbrain)	• Contralateral anterior horn cells spinal cord • Motor nuclei of IIIrd, IVth and VIth cranial nerves	Coordination of eye and neck (head) movements
Rubrospinal	Lateral white column	Red nucleus (midbrain)	Contralateral interneurons of anterior horn	Involuntary movements of upper limb Controls muscle tone and synergy
Medial reticulospinal tract	Anterior white column	Reticular formation (pons)	Ipsilateral cells of anterior horn	Reflex movements of limb and trunk muscles (inhibitory influence)
Lateral reticulospinal tract	Lateral white column	Reticular formation (medulla oblongata)	Ipsilateral cells of anterior horn	Reflex movements of limb and trunk muscles (excitatory influence)
Vestibulospinal tract	Anterior white column	Vestibular nucleus	Ipsilateral cells of anterior horn cells of spinal cord (bilateral in cervical and upper thoracic region)	Unconscious maintenance of posture and balance Orientation of head

Flowchart 5.5: Corticospinal (pyramidal) tract



Pathway (Fig. 5.7, Flowchart 5.5)

Upper motor neurons

- The fibers of pyramidal tract originate from the large *pyramidal cells* (UMN) of the motor area. Their axons run in a fan-shaped manner as *corona radiata*. Then these fibers converge and pass through the genu and posterior limb of *internal capsule*.
- *In midbrain*: Then these fibers pass through the middle three-fifths of the *crus cerebri of midbrain*.
- *In pons*: These fibers are broken up into number of small bundles by pontine nuclei and transversely running *pontocerebellar fibers* in the basilar part of the pons.
- *In medulla oblongata*: These fibers converge to form a compact bundle that descends as *pyramid* on each side of the midline. In the lower part of the medulla oblongata, majority of the fibers (75–90%) cross to the opposite side in the *pyramidal decussation* and descends as *lateral corticospinal* (crossed tract) tract. Remaining fibers continue as *ventral corticospinal tract* [*Reference*: *Grey's Anatomy*, *42nd edn*].
- *In spinal cord*: The lateral corticospinal tract runs in the lateral white column and terminates on the

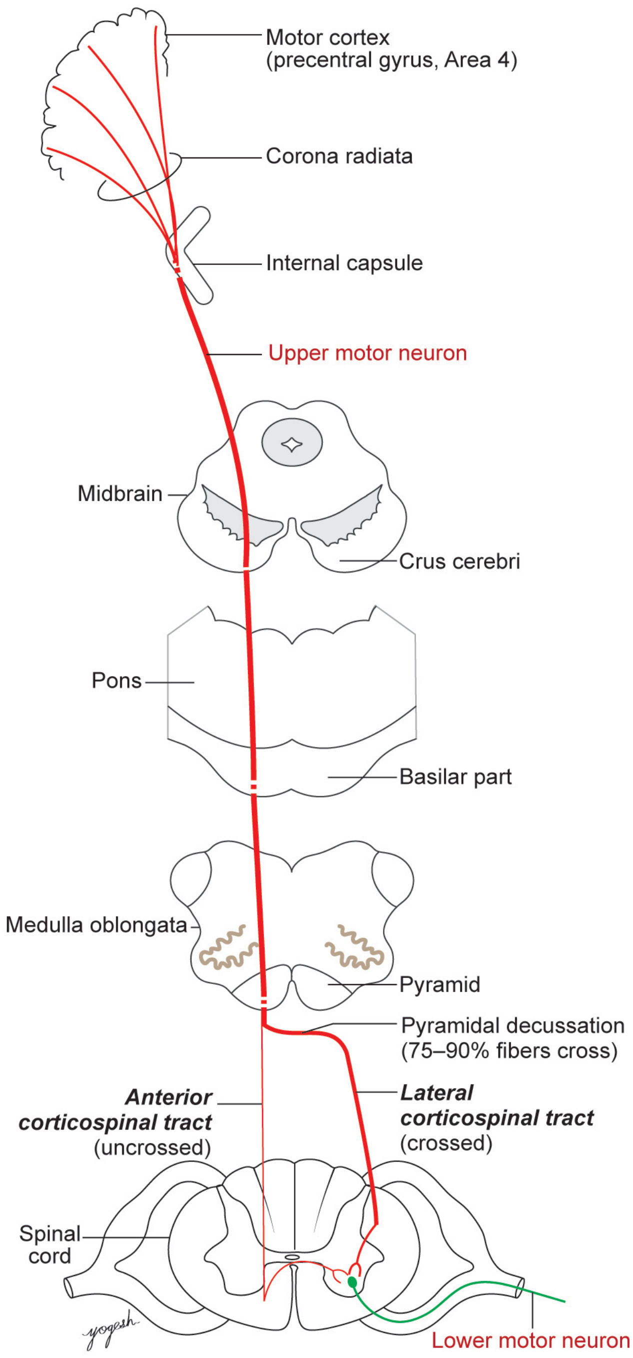


Fig. 5.7: Pyramidal tracts

anterior horn cells through interneurons. The ventral corticospinal tract runs in the anterior white column. Its fibers cross to the opposite side in the anterior white commissure of the spinal cord at the level of their termination.

Lower motor neurons

- They lie in the *anterior horn of spinal cord*. They receive the impulse from upper motor neurons through interneurons (only 5% upper motor neurons end directly on the lower motor neuron). Axons of lower motor neurons reach the skeletal muscle through the *anterior root of spinal nerves*. They produce contraction of skeletal muscles.

Some Interesting Facts

Arrangement of pyramidal tract fibers

- In internal capsule, the fibers are arranged before backward as head, upper limb, trunk, and lower limb. In the midbrain, the fiber are arranged medial to lateral as head, upper limb, trunk, and lower limb.
- *Corticonuclear fibers*: These fibers run on the medial side of corticospinal fibers in the brainstem. These fibers cross to the opposite side and terminate on the *motor nuclei of cranial nuclei* through interneurons. Some of the fibers terminate, unilaterally.
- *Pyramidal decussation*: It is present in the lower part of the medulla oblongata. It is crossing of 75–90% of corticospinal fiber.
- *Lateral corticospinal tract* controls rapid skilled voluntary movement of distal muscle of upper and lower limb, especially hand. Anterior corticospinal tract controls movements of axial and proximal limb muscles. About 55% of corticospinal fiber terminate at cervical level of spinal cord (mostly control upper limb movement) about 20% ends at thoracic and 25% at lumbar and sacral segments.
- *Motor nuclei of cranial nerves*: These include oculomotor nucleus, trochlear nucleus, motor nucleus of trigeminal nerve, abducent nucleus, motor nucleus of facial nerve, nucleus ambiguous, and hypoglossal nucleus.

Clinical Integration

Q. Write a short note on lower motor neuron paralysis.
Q. List the differences between upper and lower motor neuron paralysis.

Lesions of pyramidal tract

The lesions of pyramidal tract divided into two groups:
1. Lesions of upper motor neuron
2. Lesions of lower motor neuron.

Lesions of upper motor neuron

- The lesions cause upper motor neuron paralysis which results into hemiplegia and cranial nerve paralysis based on the location of the lesions as follows:
  a. *Lesion of motor cortex and internal capsule*: It results in contralateral hemiplegia and contralateral paralysis of lower face and tongue.
  b. *Lesion in midbrain*: It results in contralateral hemiplegia and ipsilateral ocular muscles paralysis supplied by III cranial nerve.
  c. *Lesion in pons*: It results in
     i. Raymond's syndrome – contralateral hemiplegia and ipsilateral paralysis of lateral rectus (supplied by cranial nerve VI)
     ii. Millard-Gubler syndrome – crossed facial paralysis
  d. *Lesion in medulla oblongata* → crossed hypoglossal paralysis
  e. *Lesion in spinal cord* → Brown-Séquard syndrome.

Features of upper motor lesions:[Viva]

- The lesions of upper motor neurons produce the following effects:
  1. *Spastic paralysis*: The lower neurons get hyper-stimulated by extrapyramidal fibers after losing control of pyramidal fibers. These hyperstimulated LMN cause hypertonia or spasticity of muscle and exaggerated tendon reflexes.[Viva]
  2. *Positive Babinski sign*: On scratching skin of the foot along the lateral aspect of the sole with a blunt object, the great toe undergoes dorsiflexion and other toes fan outward. This is called positive Babinski's sign.[Viva]
  3. Absence of abdominal and cremasteric reflex.[Viva]

Lesion of lower motor neurons

- It involves
  1. Lesions of motor nuclei of cranial nerve
  2. Lesions of anterior horn cells of spinal cord
  3. Lesions of ventral root or spinal nerves.
- It results in
  1. Flaccid type of muscle paralysis with loss of muscle tone
  2. Muscle wasting (atrophy)
  3. Loss of all reflexes
  4. Absence of Babinski's sign.
- The differences between upper and lower motor neuron paralysis are listed in Table 5.3.

Table 5.3: Differences between upper and lower motor neuron paralysis

Feature	*UMN lesion*	*LMN lesion*
Lesion	Above the anterior horn cells of spinal cord and cranial nerve nuclei	Lesion of anterior horn cells of spinal cord and cranial nerve nuclei
Paralysis	Spastic paralysis	Flaccid paralysis
Muscle tone	Increased	Decreased
Extent of paralysis	Widespread	Localized
Deep tendon reflexes	Increased	Absent
Superficial reflexes	Absent	Absent
Babinski's sign	Extensor (upgoing toe)	Normal or absent
Muscle wasting	Late	Usually present
Muscle clonus	Present	Absent

EXTRAPYRAMIDAL TRACTS

- *Extrapyramidal system* is a broad clinical term that is used for the connections of brain to the spinal cord other than corticospinal fibers. These connections influence all the motor activities and produce smooth, fine movements and balance of body (Fig. 5.8).
- *Note*: For understanding of extrapyramidal tract, always go through its function. These tracts are mediators (convey) for the signals of other parts of brain to the spinal cord.[Clinical fact]

Function

- Maintain body posture and balance
- Smoothen the motor activities (body movements)
- Perform unconscious body movement such as swinging of arms during walking.

Some Interesting Facts

Extrapyramidal centers[Viva]

- These are higher centers that give rise to extrapyramidal fibers. They are as follows:
  1. *Cortical area*: Frontal and parietal lobes
  2. *Subcortical areas*
     In cerebrum:
     – Basal nuclei: Caudate nucleus, putamen, globus pallidum, claustrum, amygdaloid body
     In diencephalon:
     – Subthalamic nuclei
     – Thalamus: Ventral anterior and central lateral nuclei
  3. *In midbrain*:
     – Red nucleus, reticular nuclei, substantia nigra, superior colliculus
  4. *In pons*:
     – Pontine nuclei, reticular nuclei
  5. *In medulla oblongata*:
     – Vestibular nuclei, olivary nuclei.
- The extrapyramidal fibers arise from cortical and subcortical area influence the activity at the anterior horn cell (lower motor neurons). The fibers from cortical centers form synapse with subcortical center which later send fibers to the spinal cord.
- Extrapyramidal pathway:
  Cortical centers → subcortical centers → spinal cord
- Phylogenetically, extrapyramidal system is older than pyramidal system.
- Extrapyramidal pathway is polysynaptic.

- *Spasticity*, is a muscle condition with abnormal increase in muscle tone or no stiffness with painful movement flaccidity, is a paralytic condition with muscle softness (flabbiness or lack of firmness).
- *Muscle clonus* is a rhythmic oscillating stretch reflex that is related to upper motor neuron lesion. *How to illicit*: Sudden downward pulling of patella → repetitive, rhythmical contraction and relaxation of quadriceps instead of single contraction as in normal individuals.

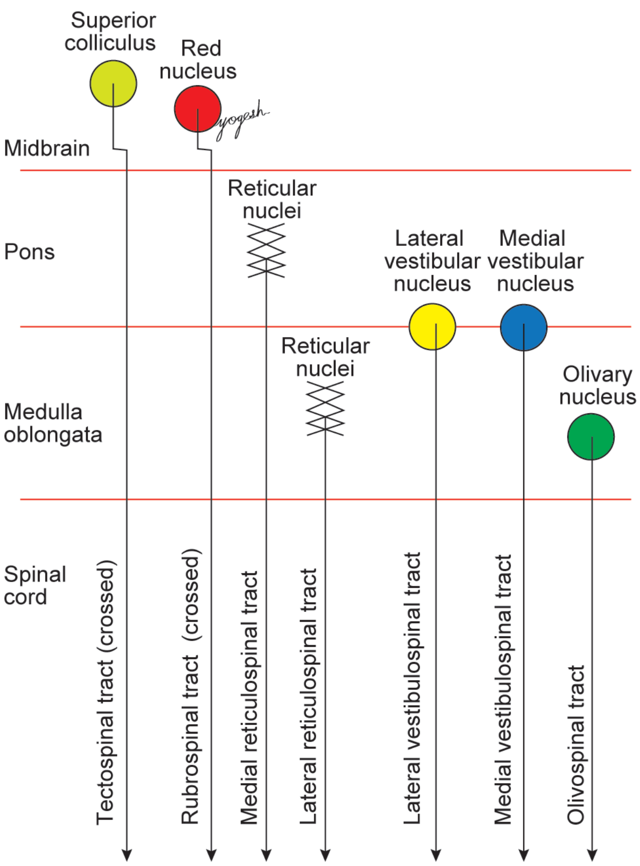


Fig. 5.8: Extrapyramidal tracts

Tectospinal Tract (Fig. 5.8)

Functions

- Tectospinal tract mediates reflex movements of the eyes, and the cervical and thoracic regions of trunk elicited by visual, auditory, and vestibular stimuli.
- *Physiological basis*

  Visual association areas (area 18, 19) → corticotectal tract → oculomotor nuclei and superior colliculus in midbrain → tectospinal tract → anterior horn cells of spinal cord.
- Thus, tectospinal tract conveys signal from visual association area to control the movement of eyes and upper part of the trunk.

Pathway

- *Location*: Anterior white column of spinal cord
- Tectospinal tract arises from the *superior colliculus* of midbrain. The fibers of tract cross (decussate) in the midbrain in between periaqueductal gray matter and red nucleus and form *dorsal tegmental decussation*. Then these fibers descend in the medial part of anterior white column of spinal cord.
- *Relay*: These fibers relay in interneurons of *anterior horn of spinal cord* (laminae VI to VIII). They extend only up to cervical and upper thoracic segments.[Viva]

Some Interesting Facts

- Tectospinal fibers stimulate the motor neurons supplying the contralateral muscle and inhibits the motor neurons supplying the ipsilateral muscle.

Rubrospinal Tract (Fig. 5.8)

Function

- Rubrospinal tract controls the movement of hand and digits by facilitating tone of flexor muscles and inhibiting tone of extensor muscles of upper limb.

Physiological basis

- Sensory motor cortex → corticorubral tract → red nucleus in midbrain → 1) rubrobulbar tract to motor nuclei of cranial nerves, 2) rubrospinal tract to anterior horn cells of spinal cord.
- Thus, rubrospinal tract conveys signals from sensory and motor cortex of cerebrum to control the movements of hand and digits.

Pathway (Fig. 5.8)

- *Location*: Lateral white column of spinal cord.
- Rubrospinal tract arises from red nucleus of midbrain. The fibers decussate in the midbrain as ventral tegmental decussation and descends as compact bundle in lateral white column of spinal cord.
- *Relay*: These fibers relay on the *anterior horn cells* of spinal cord laminae (laminae V–VII).

Some Interesting Facts

- Rubrospinal tract stimulates the neurons supplying contralateral upper limb flexor muscles and simultaneously inhibits extensor muscles, especially the distal muscle of upper limbs.

Reticulospinal Tract

Functions

- The reticulospinal tract influences the motor activity of axial and proximal limb muscles and helps in maintenance of posture and orientation of limbs.

Physiological basis

- Sensorimotor cortex → bilateral corticoreticular tracts → reticular formation in brainstem:
  1. Pontine reticular nuclei → medial or pontine reticulospinal tract
  2. Medullary reticular nuclei → lateral or medullary reticular tract → anterior horn cells of spinal cord.

Pathway (Fig. 5.8)

- *Location*: There are two reticulospinal tracts
  1. Medial reticulospinal tract descends in anterior white column.
  2. Lateral reticulospinal tract descends in lateral white column.
- *Medial reticulospinal tract* arises from *pontine reticular nuclei*. This tract descends ipsilaterally in the *anterior white column* of spinal cord thought out the entire length of spinal cord. It terminates on the *anterior horn cells* of spinal cord and stimulates extensor muscles and inhibits flexor muscles.
- *Lateral reticulospinal tract* arises from reticular nuclei of *medulla oblongata*. Its fibers run bilaterally in the *lateral white column* of spinal cord. It terminates on the *anterior horn cells* of spinal cord. It inhibits extensor muscles and stimulate flexor muscles. It also relays in *lateral horn cells* and increases heart rate, sweating, and pupillary dilatation.

Vestibulospinal Tract

Function

- Lateral vestibulospinal tract – maintains the posture and balance
- Medial vestibulospinal tract – mediates head movements while maintaining gaze fixation on an object.

Physiological basis

- *Vestibular nuclear complex* is located in the lower part of the floor of 4th ventricle at the level of ponto-medullary junction.
- Vestibular nuclei receive sensory inputs related to the movements and position of head from vestibular apparatus via the vestibular part of vestibulocochlear (VIII) nerve and also from the cerebellum.

Pathway (Fig. 5.8)

- *Lateral vestibulospinal tract* arises from the *lateral vestibular nucleus*. Its fibers run ipsilaterally in the anterior white column of spinal cord throughout entire length of spinal cord. These fibers stimulate axial (trunk) muscles, proximal limb extensor muscles, and inhibits limb flexor muscles.

  Thus, this tract maintains the posture by stimulating antigravity (limb extensor) muscles as well as mediates head and neck movements in response to vestibular sensory inputs.
- *Medial vestibulospinal tract* arises from the medial vestibular nucleus. Its fibers descend in
  a. Ipsilateral medial longitudinal bundle in brainstem
  b. Ipsilateral anterior white column in the spinal cord (up to upper thoracic segments).

  Its fibers terminate on the motor neurons of 3rd, 4th, 6th cranial nerve nuclei and on the anterior horn cells of spinal cord. Thus, they influence the cervical spinal cord → head movements while maintaining fixed gaze on an object.

Some Interesting Facts

- *Intersegmental tracts* are short ascending and descending tracts that are confined to the spinal cord. They interconnect the neurons of different segments levels and helps in intersegmental spinal reflexes.
- *Spinal reflexes*: These are automatic response to a stimulus without conscious thought. They include withdrawal reflex, stretch reflex, and Golgi tendon reflex.*Viva*
- Spinal reflexes are classified into two groups:
  1. Monosynaptic reflexes: For example: Stretch reflexes (tendon reflexes)
  2. Polysynaptic reflexes: For example: Withdrawal reflexes.

Box 5.1: Brown-Séquard syndrome

Q. Write a short note on Brown-Séquard syndrome.

Q. List the effects of hemisection of spinal cord.

- The hemisection of the spinal cord produces Brown-Séquard syndrome [*Charles-Édouard Brown-Séquard Mauritian Physiologist and Neurologist, 1817–1794*].

Clinical features

- The effects of hemisection of spinal cord are grouped as (Fig. 5.9):

  On the same side of section
  1. Ipsilateral upper motor neuron type of spastic paralysis below the level of lesion due to damage to lateral spinothalamic tract.

     If the lesion is in the upper cervical region of spinal cord → it produces hemiplegia (paralysis of both upper and lower limb of one side).

     If the lesion is in the thoracic segments → it produces monoplegia (paralysis of one lower limb)
  2. At the level of lesion, ipsilateral lower motor neuron type of paralysis (flaccid paralysis) due to damage to anterior horn cells and ventral root of spinal nerve.
  3. Ipsilateral loss of proprioception and vibration sensation, fine touch and two-point discrimination below the level of lesion due to damaged fasciculus gracilis and fasciculus cuneatus.
  4. Ipsilateral anesthesia of the affected segments.

  On the opposite side of section
  1. Contralateral loss of pain and temperature sensation below the level of lesion due to damaged lateral spinothalamic tract.

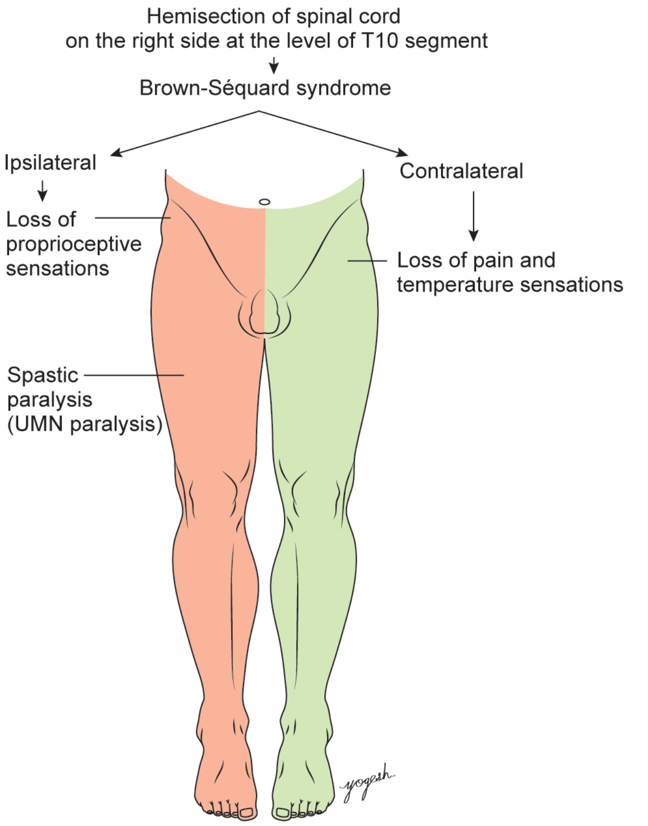


Fig. 5.9: Brown-Séquard syndrome (hemisection of spinal cord on the right side at the level of T10 segment)

Clinical Integration

Complete transaction of spinal cord

Q. Write a short note on spinal shock.

- In severe injury, there may be complete transaction of spinal cord. *Clinical features*
- The clinical features are grouped into two phases:
  - Stage of spinal shock for first three week
  - Stage of recovery after three weeks

Stage of spinal shock

- Immediately after complete transection of the spinal cord, the stage of spinal shock begins. It lasts for first three weeks of injury. It is characterized by
  1. Flaccid paralysis of all muscles
  2. Loss of all superficial and deep reflexes below the level of injury.
  3. Retention of urine due to loss of relaxation of internal sphincter of urinary bladder and flaccid paralysis of detrusor muscle.
  4. Retention of feces due to non-relaxation of external anal sphincter.
  5. Retention incontinence – that is urine will accumulate until the pressure is high enough to force the urine through the sphincter.

Recovery phase

- After the recovery from the shock, the muscle activity reappears. This phase is characterized by:
  1. Upper motor neuron, paralysis (spastic) will appear below the level of the lesion as follows:
     Lesion above C5 spinal segment → respiratory failure due to paralysis of phrenic nerve.
     Lesion between C2 to T1 → quadriplegia (paralysis of all 4 limbs).
     Lesion below T1 segments → paraplegia (paralysis of both lower limb).
  2. Automatic emptying of urinary bladder and bowel, that is, involuntary emptying at short interval after their sufficient distention.