■ ASCENDING TRACTS OF SPINAL CORD

Ascending tracts of spinal cord carry the impulses of various sensations to the brain.

Pathway for each sensation is formed by two or three groups of neurons, which are:

1. First order neurons
2. Second order neurons
3. Third order neurons.

First Order Neurons

First order neurons receive sensory impulses from the receptors and send them to sensory neurons present in the posterior gray horn of spinal cord through their fibers. Nerve cell bodies of these neurons are located in the **posterior nerve root ganglion.**

Second Order Neurons

Second order neurons are the sensory neurons present in the posterior gray horn. Fibers from these neurons form the ascending tracts of spinal cord. These fibers carry sensory impulses from spinal cord to different brain areas below cerebral cortex **(subcortical areas)** such as thalamus.

All the ascending tracts are formed by fibers of second order neurons of the sensory pathways except the ascending tracts in the posterior white funiculus, which are formed by the fibers of first order neurons.

Third Order Neurons

Third order neurons are in the **subcortical areas.** Fibers of these neurons carry the sensory impulses from subcortical areas to cerebral cortex.

Ascending tracts situated in different white funiculi are listed in Table 143.1 and their features are given in Table 143.2.

■ 1. ANTERIOR SPINOTHALAMIC TRACT

Anterior spinothalamic tract is formed by the fibers of second order neurons of the pathway for **crude touch sensation** (Figs. 143.3 and 143.4).

Situation

Anterior spinothalamic tract is situated in **anterior white funiculus** near the periphery.

Origin

Fibers of anterior spinothalamic tract arise from the neurons of **chief sensory nucleus** of posterior gray horn, which form the **second order neurons** of the crude touch pathway. First order neurons are situated in the posterior nerve root ganglia. These neurons receive the impulses of crude touch sensation from the pressure receptors. Axons of the first order neurons reach the chief sensory nucleus through the posterior nerve root.

Course

Anterior spinothalamic tract contains **crossed fibers.** After taking origin, these fibers cross obliquely in the anterior white commissure and enter the anterior white column of opposite side. Here, the fibers ascend through other segments of spinal cord and brainstem (medulla, pons and midbrain) and reach thalamus.

TABLE 143.1: List of ascending tracts of spinal cord

White column	Tract
Anterior white column	1. Anterior spinothalamic tract
Lateral white column	1. Lateral spinothalamic tract 2. Ventral spinocerebellar tract 3. Dorsal spinocerebellar tract 4. Spinotectal tract 5. Fasiculus dorsolateralis 6. Spinoreticular tract 7. Spino-olivary tract 8. Spinovestibular tract
Posterior white column	1. Fasciculus gracilis 2. Fasciculus cuneatus 3. Comma tract of Schultze

Few fibers of this tract ascend in posterior gray horn for 2 or 3 segments in the same side and then cross over to the anterior white column of opposite side.

While ascending through brainstem, the number of fibers is considerably reduced since some of the fibers form the collaterals and reach the reticular formation of brainstem.

Termination

Fibers of anterior spinothalamic tract terminate in the **ventral posterolateral nucleus** of **thalamus.** Neurons of this thalamic nucleus form third order neurons of the pathway. Fibers from thalamic nucleus carry the impulses to somesthetic area (sensory cortex) of cerebral cortex.

Function

Anterior spinothalamic tract carries impulses of **crude touch** (protopathic) sensation.

Effect of Lesion

Bilateral lesion of this tract leads to loss of crude touch sensation and loss of sensations like itching and tickling. Unilateral lesion of this tract causes **loss of crude touch** sensation in opposite side below the level of lesion (because fibers of this tract cross to the opposite side in spinal cord).

■ 2. LATERAL SPINOTHALAMIC TRACT

Lateral spinothalamic tract is formed by the fibers from second order neurons of the pathway for the sensations of **pain** and **temperature** (Fig. 143.4).

Situation

Lateral spinothalamic tract is situated in the **lateral column** towards medial side, i.e. near the gray matter.

Origin

Fibers of lateral spinothalamic tract take origin from two sources:

i. Marginal nucleus
ii. Substantia gelatinosa of Rolando.

Course

Lateral spinothalamic tract has **crossed fibers.** Axons from **marginal nucleus** and **substantia gelatinosa** of **Rolando** cross to the opposite side and reach the lateral column of same segment. Few fibers may ascend one or two segments, then cross to the opposite side and then ascend in the lateral column.

All the fibers pass through medulla, pons and mid-brain and reach thalamus along with fibers of anterior spinothalamic tract. Some of the fibers of lateral spino-thalamic tract form collaterals and reach the reticular formation of brainstem.

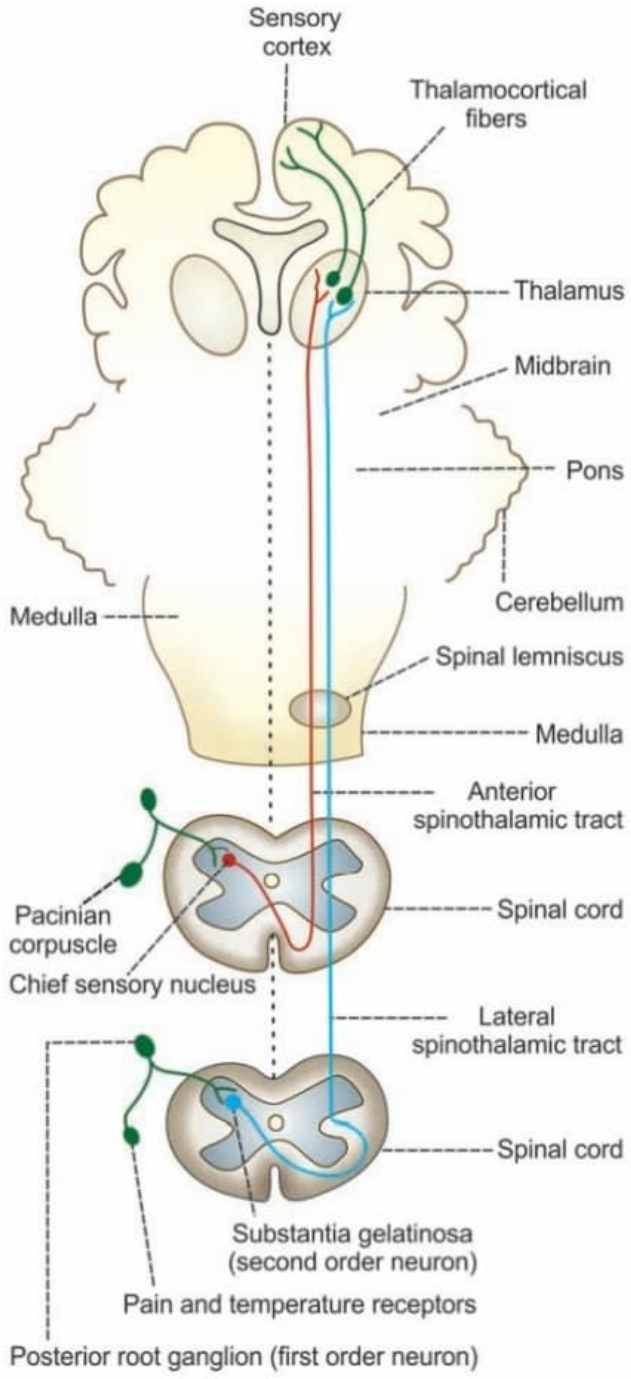

FIGURE 143.4: Spinothalamic tracts and pathways for crude touch, pain and temperature sensations. Anterior spinothalamic tract (red) carries crude touch sensation. Lateral spinothalamic tract (blue) carries pain and temperature sensations.

Fibers of lateral spinothalamic tract form **spinal lemniscus** along with the fibers of anterior spinothalamic tract at the lower part of medulla.

Termination

Fibers of lateral spinothalamic tract terminate in the **ventral posterolateral nucleus** of **thalamus** along with anterior spinothalamic tract fibers. From here, third order neuron fibers run to somesthetic area (sensory cortex) of cerebral cortex.

Function

Fibers of lateral spinothalamic tract carry impulses of **pain** and **temperature** sensations. Fibers arising from this marginal nucleus transmit impulses of fast pain sensation. Fibers arising from substantia gelatinosa of Rolando transmit impulses of slow pain and temperature sensations. Refer Chapter 145 for details of pain fibers.

Effect of Lesion

Bilateral lesion of this tract leads to total loss of pain and temperature sensations on both sides below the level of lesion. Unilateral lesion or sectioning of the lateral spinothalamic tract causes loss of pain **(analgesia)** and temperature **(thermoanesthesia)** below the level of lesion in the opposite side.

■ 3. VENTRAL SPINOCEREBELLAR TRACT

Ventral spinocerebellar tract is also known as **Gower tract, indirect spinocerebellar tract** or **anterior spinocerebellar tract.** It is constituted by the fibers of second order neurons of the pathway for **subconscious kinesthetic sensation** (Fig. 143.5).

Situation

This tract is situated in **lateral white column** of the spinal cord along the lateral periphery.

Origin

Fibers of this tract arise from the **marginal nucleus** in posterior gray horn. Neurons of marginal nucleus form the second order neurons. Fibers from these neurons make their first appearance in **lower lumbar segments** of spinal cord.

First order neurons are in the posterior root ganglia and receive the impulses of proprioception from the proprioceptors in muscle, tendon and joints. Fibers from neurons of posterior root ganglia reach the marginal cells through posterior nerve root.

Course

Ventral spinocerebellar tract contains both **crossed** and **uncrossed fibers.** Majority of the fibers from the marginal nucleus cross the midline and ascend in lateral white column of opposite side. Some fibers ascend in the lateral white column of the same side also. These nerve fibers ascend through other spinal segments, medulla, pons and midbrain.

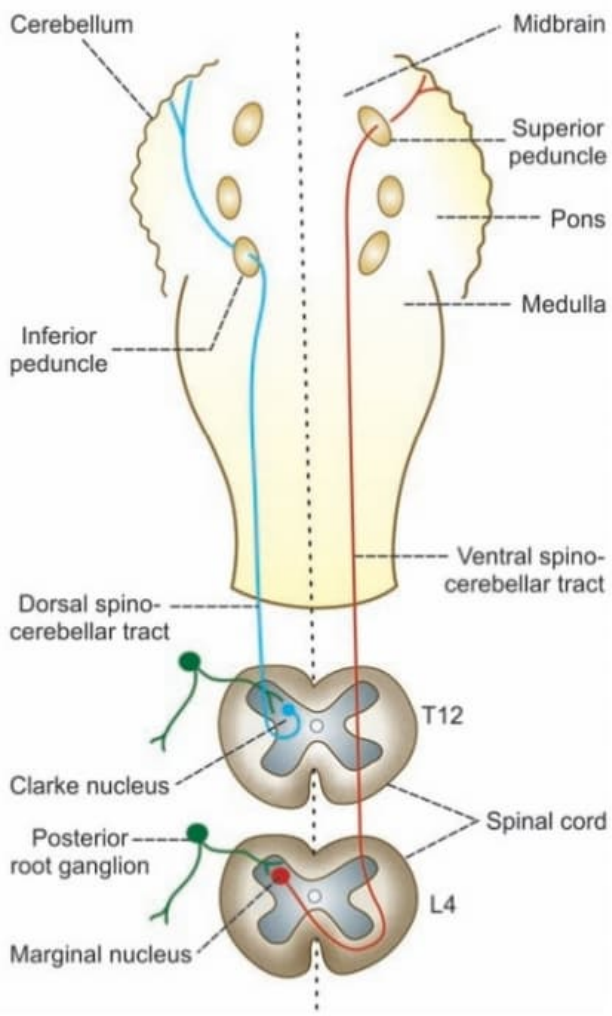

FIGURE 143.5: Spinocerebellar tracts and pathway for subconscious kinesthetic sensation

Finally, the fibers reach the cerebellum through the superior cerebellar peduncle.

Termination

These fibers terminate in the cortex of anterior lobe of **cerebellum.**

Function

Ventral spinocerebellar tract carries the impulses of **subconscious kinesthetic sensation** (proprioceptive impulses from muscles, tendons and joints). Impulses of subconscious kinesthetic sensation are also called **non-sensory impulses.**

Effect of Lesion

Lesion of this tract leads to loss of subconscious kinesthetic sensation in the opposite side.

■ 4. DORSAL SPINOCEREBELLAR TRACT

Dorsal spinocerebellar tract is otherwise called **Flechsig tract, direct spinocerebellar tract** or **posterior spinocerebellar tract.** Like the ventral spinocerebellar tract, this tract is also constituted by the second order neuron fibers of the pathway for subconscious kinesthetic sensation. The first order neurons are in the posterior nerve root ganglia. But, the fibers of this tract are uncrossed (Fig. 143.5).

Situation

Dorsal spinocerebellar tract is situated in the **lateral column** along the posterolateral periphery of spinal cord. It is situated posterior to ventral cerebellar tract and anterior to the entry of posterior nerve root.

Origin

Fibers of this tract originate from the **dorsal nucleus of Clarke** situated in the posterior gray matter of the spinal cord. First appearance of the fibers is in **upper lumbar segments.** From lower lumbar and sacral segments, the impulses are carried upwards by dorsal nerve roots to upper lumbar segments.

Course

Flechsig tract is formed by **uncrossed fibers.** Axons from neurons in dorsal nucleus of Clarke (second order neurons) reach lateral column of same side. Then, these fibers ascend through other spinal segments and reach medulla oblongata. From here, the fibers reach cerebellum through inferior cerebellar peduncle.

Termination

Fibers of this tract end in the cortex of anterior lobe of **cerebellum** along with ventral spinocerebellar tract fibers.

Function

Along with ventral spinocerebellar tract, the dorsal spinocerebellar tract carries the impulses of **subconscious kinesthetic sensation,** which are known as **non-sensory impulses.**

Effect of Lesion

Unilateral loss of the subconscious kinesthetic sensation occurs in lesion of this tract on the same side, as this tract has uncrossed fibers.

■ 5. SPINOTECTAL TRACT

Spinotectal tract is considered as a component of anterior spinothalamic tract. It is constituted by the fibers of second order neurons.

Situation

Spinotectal tract occupies the lateral side of **lateral white column,** anterior to lateral spinothalamic tract. It is bound anteriorly by anterior nerve root.

Origin

Fibers of this tract originate from the **chief sensory nucleus** (like anterior spinothalamic tract). First appearance of the fibers is in upper lumbar segments. This tract is very prominent in the cervical segments.

Course

Spinotectal tract contains **crossed fibers.** After taking origin, the fibers cross to opposite side through anterior white commissure to the lateral column. Then, these fibers ascend to the midbrain along with anterior spinothalamic tract.

Termination

Fibers of spinotectal tract end in the **superior colliculus** of tectum in midbrain.

Function

Spinotectal tract is concerned with **spinovisual reflex.**

■ 6. FASCICULUS DORSOLATERALIS

Fasciculus dorsolateralis is otherwise called **tract of Lissauer.** It is considered as a component of lateral spinothalamic tract. And, it is constituted by the fibers of first order neurons.

Situation

Lissauer tract is situated in the **lateral white column** between the periphery of spinal cord and tip of posterior gray horn.

Origin

Lissauer tract is formed by fibers arising from the **cells of posterior root ganglia** and enters the spinal cord through lateral division of posterior nerve root.

Course

Lissauer tract contains **uncrossed fibers.** After entering spinal cord, the fibers pass upwards or downwards for few segments on the same side and synapse with cells of substantia gelatinosa of Rolando. Axons from these cells (second order neurons) join the lateral spinothalamic tract.

Function

Fibers of the dorsolateral fasciculus carry impulses of **pain** and **thermal sensations.**

■ 7. SPINORETICULAR TRACT

Spinoreticular tract is formed by the fibers of second order neurons.

Situation

Spinoreticular tract is situated in **anterolateral white** column.

Origin

Fibers of this tract arise from **intermediolateral nucleus.**

Course

Spinoreticular tract consists of **crossed** and **uncrossed** fibers. After taking origin, some of the fibers cross the midline and then ascend upwards. Remaining fibers ascend up in the same side without crossing.

Termination

All the fibers terminate in the reticular formation of brainstem by three ways:

i. Some fibers terminate in **nucleus reticularis gigantocellularis** and **lateral reticular nucleus** of medulla in the same side. Some fibers terminate in the nuclei present in the opposite side.
ii. Some fibers terminate in **nucleus reticularis pontis caudalis** of the pons in the same side or opposite side
iii. Very few fibers terminate in midbrain.

Function

Fibers of the spinoreticular tract are the components of ascending reticular activating system and are concerned with consciousness and awareness.

■ 8. SPINO-OLIVARY TRACT

Spino-olivary tract is situated in anterolateral part of white column. Origin of the fibers of this tract is not specific. However, the fibers terminate in olivary nucleus of medulla oblongata. From here, the neurons project into cerebellum. This tract is concerned with **proprioception.**

■ 9. SPINOVESTIBULAR TRACT

Spinovestibular tract is situated in the **lateral white** column of the spinal cord. Fibers of this tract arise from

all the segments of spinal cord and terminate on the **lateral vestibular nucleus.** This tract is also concerned with **proprioception.**

■ 10. FASCICULUS GRACILIS (TRACT OF GOLL) AND

■ 11. FASCICULUS CUNEATUS (TRACT OF BURDACH)

Fasciculus gracilis and fasciculus cuneatus are together called **ascending posterior column tracts.** These tracts are formed by the fibers from posterior root ganglia. Thus, both the tracts are constituted by the fibers of **first order neurons** of sensory pathway (Fig. 143.6).

Situation

Tracts of Goll and Burdach are situated in **posterior white column** of spinal cord hence the name posterior column tracts. In the cervical and upper thoracic segments of spinal cord, the posterior white column is divided by posterior intermediate septum into medial fasciculus gracilis and lateral fasciculus cuneatus.

Thus, the fasciculus gracilis is situated medially in between posterior median sulcus and posterior median septum on one side and posterior intermediate sulcus and posterior intermediate septum on the other side. Fasciculus cuneatus is situated laterally. It is bound medially by posterior intermediate septum and sulcus and laterally by posterior gray horn, tract of Lissauer and posterior nerve root.

Origin

Fibers of these two tracts are the axons of **first order neurons.** Cell body of these neurons is in the **posterior root ganglia** and their fibers form the medial division (bundle) of posterior nerve root.

Course

After entering spinal cord, the fibers ascend through the **posterior white column.** These fibers do not synapse in the spinal cord. Some fibers of medial division of posterior nerve root descend through posterior white column in the form of **fasciculus interfascicularis** or **comma tract of Schultze.**

Fasciculus gracilis contains the fibers from **lower extremities** and **lower parts of the body,** i.e. from sacral, lumbar and lower thoracic ganglia of posterior nerve root. Fasciculus cuneatus contains fibers from **upper part of the body,** i.e. from upper thoracic and cervical ganglia of posterior nerve root.

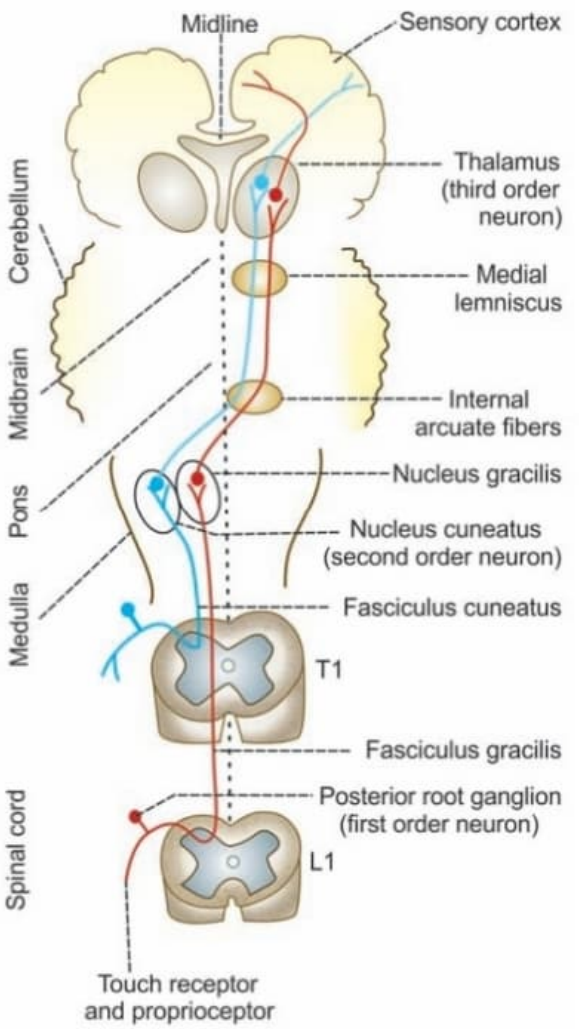

FIGURE 143.6: Ascending tracts in posterior white column of spinal cord and pathway for – 1. Fine touch sensation, 2. Tactile localization, 3. Tactile discrimination, 4. Vibratory sensation, 5. Conscious kinesthetic sensation, 6. Stereognosis.

Termination

Tracts of Goll and Burdach terminate in the medulla oblongata. Fibers of fasciculus gracilis terminate in the **nucleus gracilis** and the fibers of fasciculus cuneatus terminate in the **nucleus cuneatus.** Neurons of these medullary nuclei form the second order neurons.

Axons of second order neurons form the **internal arcuate fibers.** Internal arcuate fibers from both sides cross the midline forming **sensory decussation** and then ascend through pons and midbrain as **medial lemniscus.** Fibers of medial lemniscus terminate in **ventral posterolateral nucleus of thalamus.** From here, fibers of the third order neurons relay to **sensory area of cerebral cortex.**

Functions

Tracts of the posterior white column convey impulses of following sensations:

i. **Fine** (epicritic) **tactile sensation**
ii. **Tactile localization** (ability to locate the area of skin where the tactile stimulus is applied with closed eyes)
iii. **Tactile discrimination** or two point discrimination (ability to recognize the two stimuli applied over the skin simultaneously with closed eyes)
iv. **Sensation of vibration** (ability to perceive the vibrations from a vibrating tuning fork placed over bony prominence conducted to deep tissues through skin). It is the synthetic sense (Chapter 144) produced by combination of touch and pressure sensations.
v. **Conscious kinesthetic sensation** (sensation or awareness of various muscular activities in different parts of the body)
vi. **Stereognosis** (ability to recognize the known objects by touch with closed eyes). It is also a synthetic sense produced by combination of touch and pressure sensations.

Effect of Lesion

Lesion of nerve fibers in tracts of Goll and Burdach or lesion in the posterior white column leads to the following symptoms on the same side below the lesion:

i. Loss of fine tactile sensation; however, crude touch sensation is normal
ii. Loss of tactile localization
iii. Loss of two point discrimination
iv. Loss of sensation of vibration
v. **Astereognosis** (inability to recognize known objects by touch while closing the eyes)
vi. Lack of ability to differentiate the weight of different objects
vii. Loss of proprioception (inability to appreciate the position and movement of different parts of the body)
viii. **Sensory ataxia** or posterior column ataxia (condition characterized by uncoordinated, slow and clumsy voluntary movements because of the loss of proprioception).

■ 12. COMMA TRACT OF SCHULTZE

Comma tract of schultze is also called fasciculus interfascicularis. It is situated in between tracts of Goll and Burdach. This tract is formed by the short descending fibers, arising from the medial division of posterior nerve root. These fibers are also considered as the descending branches of the tracts of Goll and Burdach. Function of this tract is to establish intersegmental communications and to form short reflex arc.