Sensory and Motor Brain Systems

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The motor system of the brain consists of the pyramidal as well as the extrapyramidal tracts. Information from the motor cortex and other areas is led through these tracts to the respective muscle groups in order to initiate movement. The somatosensory information from the periphery is transmitted to the brain via the afferent sensory tracts. The constituting tracts are the anterolateral system (tractus spinothalamicus or spinothalamic tract), the dorsal column system, and the posterior and anterior spinocerebellar tract (tractus spinocerebellaris).

The Motor System of the Brain

The motor tracts of the brain extend as efferent fibers via the spinal cord to the respective motor neurons of the skeletal muscles. The motor system comprises of the pyramidal tract (**tractus pyramidalis**) and the extrapyramidal system.

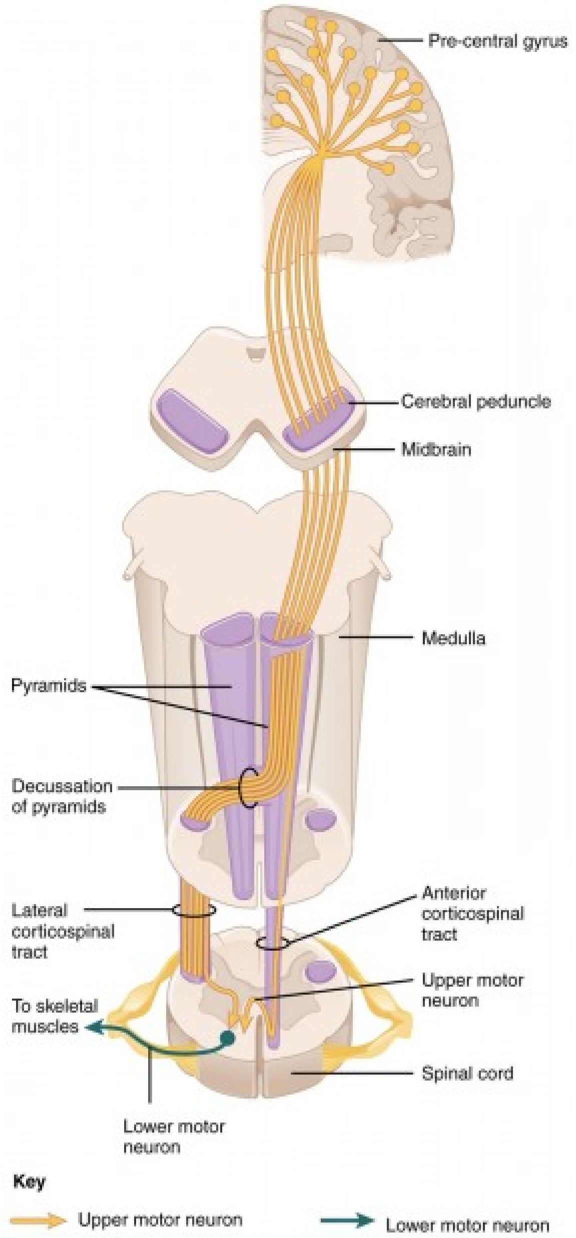

Image: 'Corticospinal Tract' by Phil Schatz. License: CC BY 4.0

Structure of the pyramidal tract

The pyramidal tract can be further subdivided into 3 sections: the **corticospinal fibers**, the **bulbar corticonuclear fibers,** and the **corticoreticular fibers**. It controls motor functions of the body. The joint origin of these fiber tracts is located in the primary motor cortex of the telencephalon.

The primary motor cortex, or simply the motor cortex, is situated in the area of the precentral gyrus of the frontal lobe. The 3 sections of the pyramidal tract have the same origin but extend to different target areas according to their designation.

1. The **corticospinal fibers** extend via the internal capsule to the spinal cord. At the level of the **medulla oblongata**, 80% of the fibers cross over to the contralateral side. This fraction of fibers is called the **lateral corticospinal tract,** subsequent to the crossing (pyramidal decussation). The remaining 20% of fibers continue as **an anterior corticospinal tract** and pass over to the opposite side in their course.

Both fiber systems end in the area of the spinal cord at the **interneurons,** which are connected to the **motor neurons** of the spinal cord. This tract is responsible for the transmission of impulses to the cranial nerves that control the muscles of the face and the neck.

2. The **bulbar corticonuclear fibers** have their origin in the area of the premotor cortex, which represents the facial regions according to the **motor homunculus**. From this site, the fibers continue on to the motor nuclei on the contralateral side, i.e. the fibers cross over to the opposite side already on the level of the brain stem.

However, there is – in addition to the contralateral – also an ipsilateral feed to some of the nuclei, resulting in a bilateral innervation. This bilateral innervation is observable for instance, in a **central facial palsy**. In contrast to the **peripheral facial nerve paralysis**, in central **facial palsy,** the ability of **eyelid closure** and the ability to raise the eyebrows are preserved because the responsible nuclei are also supplied via the contralateral side.

However, the face muscles below the area around the eyes are not bilaterally supplied, which causes, e.g., hypokinesia of the mouth. This hypokinesia becomes especially apparent when the patient is asked to smile. In other words, the corticobulbar tract is responsible for transmitting impulses related to facial expression.

3. Inside the reticular formation, the **corticoreticular fibers** lead to the **gigantocellar reticular nucleus.** They are major pathways that send impulses from the muscles to the brain stem of the brain for transmission of information from muscles to the brain.

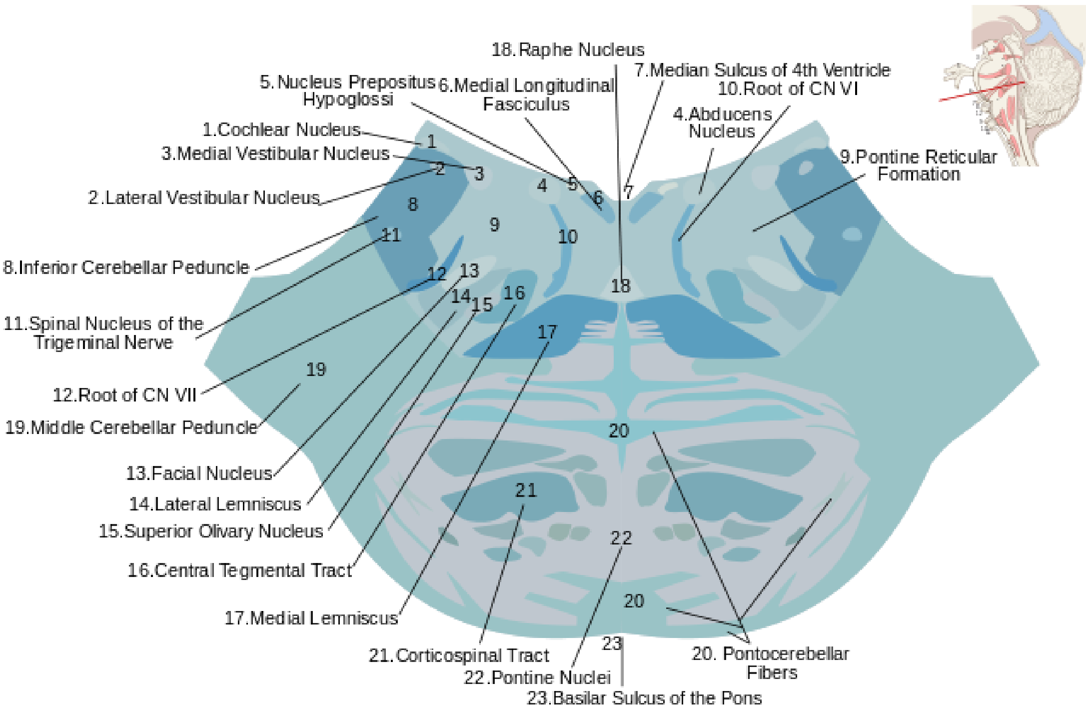

Image: ‘Lower pons horizontal KB’ by Marshall Strother. License: CC BY 3.0

Structure of the extrapyramidal motor system

The extrapyramidal system consists of several tracts that have their origin in medulla and pons extending to the target neurons in the spinal cord. It is responsible for movement, walking, and reflexes.

Part of the tracts, which are assigned to the extrapyramidal system, are the **rubrospinal tract**, the **olivospinal tract**, the **vestibulospinal tract**, the **reticulospinal tract**, and the **tectospinal tract**.

These tracts end collectively at the interneurons of the spinal cord, which in turn, are connected to the α- and γ-motor neurons of the spinal cord. Thereby, the extrapyramidal system has a modulating effect on the **aforementioned motor neurons** via the interneurons.

Symptoms of a lesion to the central motor tracts

On the one hand, the symptoms of a lesion to the central motor tracts depend on which tracts are affected by the lesion. On the other hand, the level at which the lesion occurred also plays an important role.

Depending on which tract system is affected, a distinction can be made between a **spastic** and **flaccid paralysis**. A complete, spastic paralysis (**plegia**) is caused when the extrapyramidal tracts are implicated, whereas an incomplete, flaccid paralysis (**paresis**) is generated by the involvement of only a pyramidal tract.

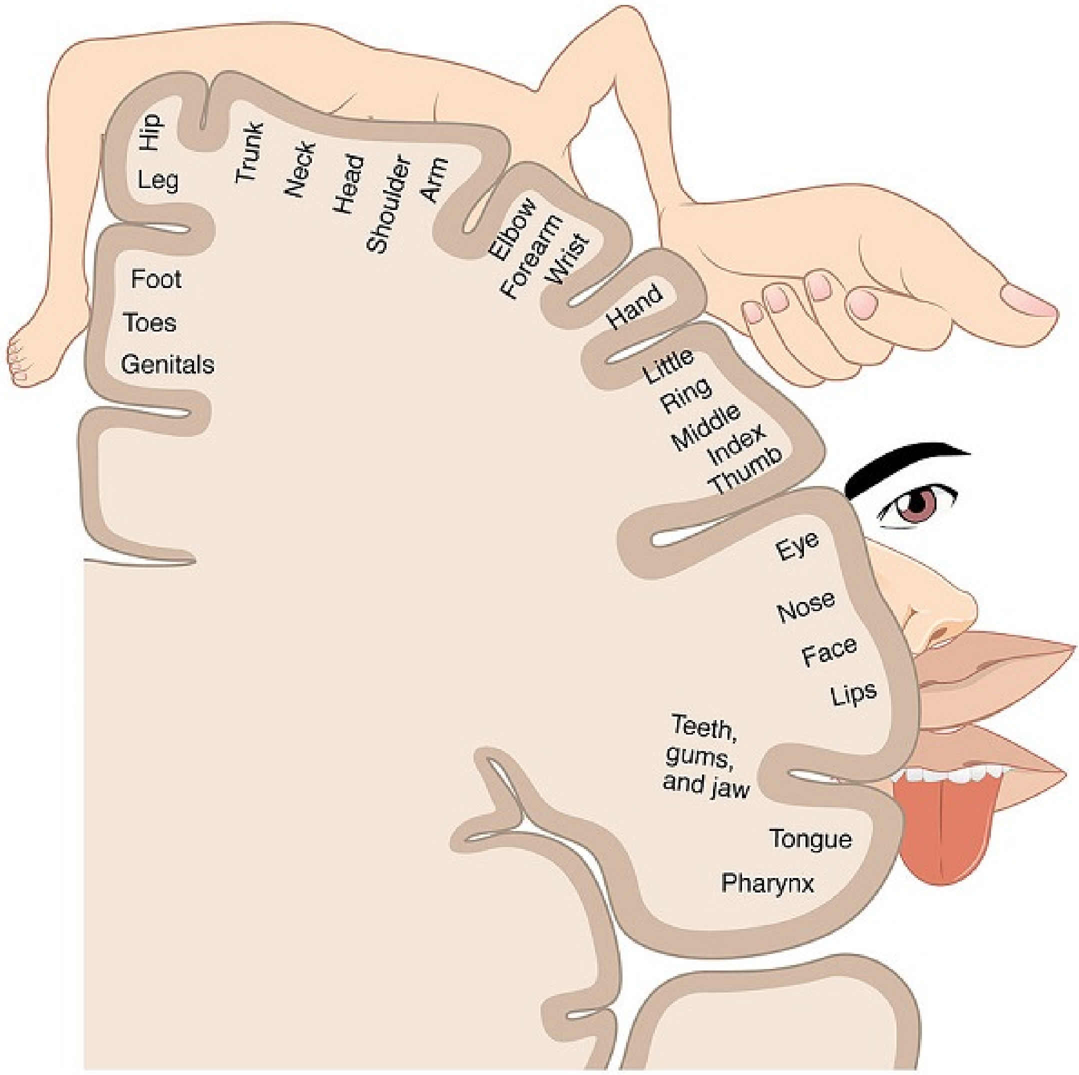

Image: 'Sensory Homunculus' by OpenStax College. License: CC BY 3.0

Because of the close anatomical and functional connection between the pyramidal tract and the extrapyramidal system, there is a spastic paresis in the majority of the centrally generated paralyzes. In contrast, a **flaccid paralysis** usually occurs when the **2nd motor neuron** at the level of the spinal cord is damaged.

On account of the fact that the fiber tracts cross over to the opposite side (e.g., the pyramidal tract at the level of the **medulla oblongata**), the respective contralateral half of the body is affected by a central impairment.

In relation to the level at which the lesion occurs, a distinction can be made between **cortical lesions**, lesions in the area of the **internal capsule**, at the level of the **cerebral crus**, the **pons**, the **pyramid**, the **spinal cord**, and at the level of the **peripheral nerves**.

In case of an injury to the motor system in the area of the cortex, paralysis of the contralateral half of the body occurs, especially pertaining to the regions of the face and arms. This can be attributed to the fact that the arms as well as the face, constitute a relatively large proportion of the motor cortex. This amplified representation is illustrated graphically in the **homunculus**.

Because the pyramidal tract and the extrapyramidal system in the area of the internal capsule exhibit a common path, a lesion in this area induces **contralateral spastic hemiplegia**. The same clinical symptoms occur when the area of the cerebral crus is impaired.

When the area of the pons is damaged, there may be contralateral as well as bilateral pareses – depending on the extent of the lesion.

In the area of the pyramid, the fibers of the extrapyramidal system proceed further dorsally, so that an isolated lesion of the pyramidal tract may occur. In this case, the result is a flaccid paralysis (see above).

At the level of the spinal cord, the 2 systems, i.e. the pyramidal tract and the extrapyramidal system, are closely connected, resulting in a spastic paralysis when damaged. Because the fibers of both systems have already crossed at this point, the paresis occurs on the ipsilateral side of the lesion.

When the 2nd motor neuron at the level of the **peripheral nerves** is injured, an **ipsilateral flaccid paralysis** ensues.

The Sensory System of the Brain

By means of the sensory system, different sensations from the periphery are perceived by receptors and subsequently conveyed to the brain. The different qualities of sensory perceptions are in part assembled in distinct systems or tracts, respectively.

The conveyed qualities include, for instance, pain, temperature, and the crude sense of touch. These 3 qualities are summarized by the term protopathic sensibility. Another system is represented by **epicritic sensibility**, which comprises the fine sense of touch in the area of the face.

Another quality, which is conveyed via the sensory system, is **proprioception**. By means of proprioception, spatial perception of the body’s own extremities is maintained.

Additionally, this system receives further information from the **muscle** and **tendon spindles,** in order to obtain information about the position of the joints as well as the velocity and direction of movement. Furthermore, the muscular power, which is generated upon movement of the joint, is being perceived and transferred to the proprioceptive system. Taken together, these 3 kinds of information are designated as follows:

- Joint position sense
- Kinaesthetic sense
- Strength sense

Within the proprioceptive system, a distinction can be made between unconscious and conscious proprioception. Both systems are relayed to different target areas.

The information gathered by unconscious proprioception arrives at the **cerebellum** via the **spinocerebellar tract**. In comparison, information obtained by conscious proprioception reaches the **thalamus** via the **dorsal column system** and a switch in its nuclei, where it is transferred to the **somatosensory cortex** and thus enters consciousness (see below).

Among the receptors of the somatosensory system are, e.g., the skin and joint receptors. The receptors always constitute the **1st neuron** of the respective sensory tract.

The above-mentioned qualities are conducted in the sensory system through 3 tracts, some of which can be further subdivided. Among these tracts are the anterolateral system, the dorsal column system as well as the spinocerebellar tracts.

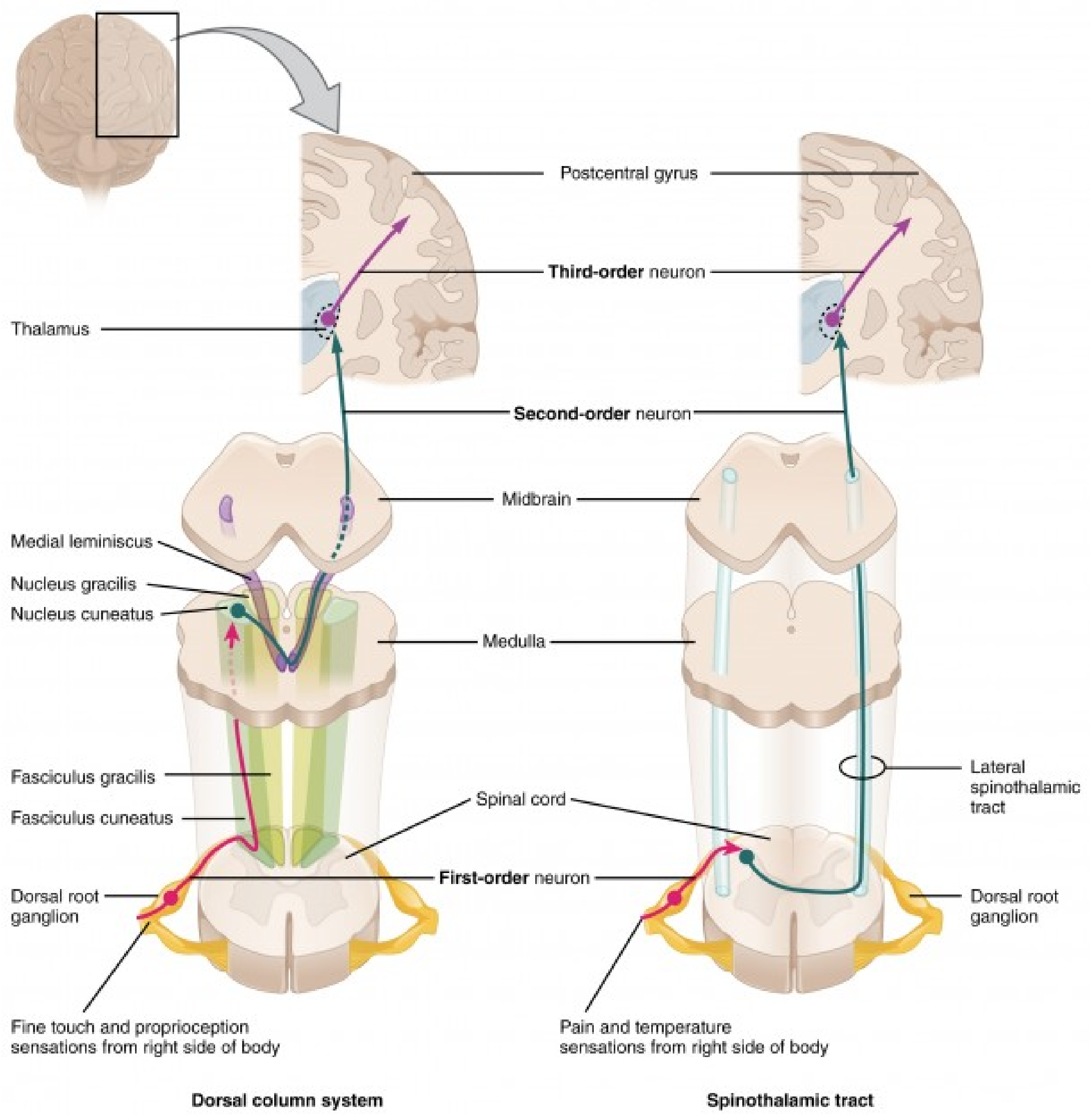

Image: "Ascending Sensory Pathways of the Spinal Cord" by Phil Schatz. License: CC BY 4.0

Tracts and connections of the anterolateral system

The **anterolateral system** can be further divided into the **anterior spinothalamic tract** and the **lateral spinothalamic tract**. The anterior spinothalamic tract conveys the crude sense of touch, while the lateral spinothalamic tract serves to conduct the information related to the sense of pain and temperature.

The **perikarya** of the 2nd neurons of the anterior spinothalamic tract are located in the **posterior horn**, and the perikarya of the 2nd neurons of the lateral spinothalamic tract are found in the **gelatinous substance of the spinal cord**.

In contrast to the lateral spinothalamic tract, the 2nd neuron of the anterior spinothalamic tract may be 15 segments above or up to 2 segments below the 1st neuron. The axons of both tracts pass over to the opposite side on the level of the spinal cord in the area of the **anterior commissure**.

The ensuing path of both tracts is identical, too. In the area of the ventral posterolateral nucleus of the thalamus, the connection to the 3rd neuron (whose axon extends to the postcentral gyrus) is established.

Tracts and connections of the dorsal column system

The dorsal column system is composed of the **gracile fasciculus** and the **cuneate fasciculus**. Both of them convey information of the fine sense of touch, including sensitivity to vibrations (transferred via the **lamellar corpuscles** of the skin) as well as conscious **proprioception**.

In conjunction with the conscious proprioception, the information from the lower extremity is conveyed through the **gracile fasciculus**, while the information from the upper extremity is conveyed through the **cuneate fasciculus**.

The axons of the 1st neurons extend inside of the **medulla oblongata** to the **homonymous nuclei**, i.e. the axons of the gracile fasciculus span to the gracile nucleus, and the axons of the **cuneate fasciculus** stretch to the **cuneate nucleus**. The respective nucleus constitutes the 2nd neuron of the dorsal column system.

The axons of the 2nd neurons cross over to the opposite side in the brain stem area and subsequently extend inside the **medial lemniscus** to the **ventral posterolateral nucleus** of the **thalamus**. At this point, the connection to the 3rd neuron is established, and the information is transferred to the **postcentral gyrus**.

Note: The dorsal tracts only cross over to the opposite side at the level of the brain stem.

Paths and connections of the spinocerebellar tracts

The quality of unconscious proprioception is relayed within the **spinocerebellar tracts.** This is realized via the **anterior and posterior spinocerebellar tracts**.

The **anterior spinocerebellar tract** passes proportionately to the **contralateral side** at the level of the spinal cord, while in the **posterior spinocerebellar tract,** the information passes to the cerebellum exclusively in an **ipsilateral manner**.

The 2nd neuron of the **anterior spinocerebellar tract** is situated in the central part of the **grey matter of the spinal cord**, while the 2nd neuron of the **posterior spinocerebellar tract** is located in the **thoracic nucleus**. The thoracic nucleus can be found in the area of the **posterior horn** of the grey matter.

Subsequently, the axons extend to the cerebellum, while the fraction of the **anterior spinocerebellar tract,** which had previously crossed over, passes to the ipsilateral side again, before entering the cerebellum. Thereby, the cerebellum exclusively receives ipsilateral information from the spinal cord via the spinocerebellar tracts.

The information is conveyed through a different respective peduncle to the cerebellum. The axons of the anterior spinocerebellar tract continue via the **superior cerebellar peduncle**, and the axons of the **posterior spinocerebellar tract** extend via the **inferior cerebellar peduncle** to the **cerebellar vermis**.

Note: There is no 3rd neuron in the spinocerebellar tracts.

Pathology of a lesion to the sensory system

The pathology of a lesion to the sensory system is comparable to a motor system impairment insofar as it depends on the affected fiber tract and its path.

The result of **cortical** or **subcortical lesions** are **paresthesiae**, which often manifest themselves as sensations of tingling and numbness in the contralateral half of the body, which are frequently distally emphasized.

In case of an injury to the **thalamus** or **subthalamic lesion,** respectively, the information from the sensory system does not enter consciousness anymore, causing the cessation of the sensory perception on the contralateral half of the body.

In the event of damage to 1 of the 3 sensory tracts, different symptoms develop according to the path of the tract and its transferred qualities. The unconscious information conveyed through the **spinocerebellar** tracts, however, is an exception, which induces **sensorimotor deficits**.

Deficiency of the anterolateral system

In case of a complete lesion to the **anterolateral system**, there is a loss of the crude sense of touch (**anterior spinothalamic tract**) as well as a loss of the sensation of pain and temperature (**lateral spinothalamic tract**). This deficit occurs on the contralateral side because of both fiber tracts of the anterolateral system crossing over to the opposite side at the level of the spine.

In addition to a complete lesion, there may be an isolated deficit of a fiber tract, so that only the correspondingly transferred quality on the contralateral side is canceled.

Deficiency of the dorsal column system

When the dorsal columns are lesioned, the proprioception, as well as the fine sense of touch on the ipsilateral side, is affected. The ipsilateral pathology is explained by the fact that the fibers of the dorsal column do not cross over to the opposite side before the level of the brain stem is reached.

Possible causes for impairment are, for instance, a vitamin B12 deficiency, which can occur in the context of alcoholism. This clinical picture is called **subacute combined degeneration of the spinal cord (SACD)**, in which the lateral columns are affected, in addition to the dorsal columns.

References

Edelman, G. M., Changeux, & J.-P. (2001). *The brain*. New Brunswick [NJ] (U.S.A.: Transaction Publishers.

Frackowiak, R. S. (2004). *Human brain function*. Amsterdam: Elsevier Academic Press.

Frackowiak, R. S., Friston, K. J., Frith, C. D., Dolan, R. J., & Price, C. J. (2003). *Human Brain Function*. Burlington: Elsevier.

Watson, C., Kirkcaldie, M., &Paxinos, G. (2010). *The brain: An introduction to functional neuroanatomy*. Amsterdam: Elsevier/Academic.

Notes