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SOMATOSENSORY PATHWAYS

Main Somatosensory Pathways: The term somatosensory refers to bodily sensations of touch, pain, temperature, vibration, and proprioception (limb or joint position sense). The posterior column-medial lemniscal pathway conveys proprioception, vibration sense, and fine, discriminative touch. The anterolateral (or ventrolateral) pathways, include the spinothalamic tract and other associated tracts, convey pain, temperature sense, and crude touch. Since some aspects of touch sensation are carried by both pathways, touch sensation is not eliminated completely in isolated lesions to either pathway.

 There are 4 types of sensory neuron fibers which are classified according to axon diameter. These different fiber types have specialized peripheral receptors that subserve different sensory modalities. Larger-diameter, myelinated axons conduct faster than smaller-diameter or unmyelinated axons. From largest to smallest diameter and conduction velocity, there are called A- alpha, A-beta, A-gamma, and unmyelinated C's.

  Sensory neuron cell bodies are located in the dorsal root ganglia, Each dorsal root ganglion cell has a stem axon that bifurcates, resulting in one long axon that conveys sensory information from the periphery, and a second axon that carries information to the spinal cord through the peripheral region innervated by sensory fibers from a single nerve root level is called a dermatome. Dermatomes for the different spinal levels form a map over the surface of the body. Sensation for the face is provided by the trigeminal nerve (CN V), while most of the remainder of the head is supplied by C2. The nipples are usually at the T4 level, while the umbilicus ("belly button") is at approximately T10.

 The shoulder, arms, and hands are represented in C5 through T1. The L4 and L5 representation extends over the anteriomedial shin and foot to the big toe. S1 and S2 innervate the back (dorsum) of the legs, and S3, S4, and S5 innervate the perineal area in a saddle-like distribution. e dorsal nerve roots.

Just as our knowledge that the corticospinal tract crosses over at the pyramidal decussation helps us localize lesions, it is equally important to know the points of decussation of the two major somatosensory pathways.

 The course of the two main somatosensory pathways are, therefore:

1. **Posterior Column-Medial Lemniscal Pathway**. Large-diameter, myelinated axons carrying information about proprioception, vibration, and fine touch enter the spinal cord via the dorsal root entry zone. Most of these axons then enter the ipsilateral posterior columns to ascend all the way to the posterior column nuclei in the medulla (see figure below). The most medial posterior column is called the fasciculus gracilis which carries sensory information from the legs and lower trunk. The more lateral fasciculus cuneatus carries information from the trunk above about T6, and from the arms and neck.

The first order neurons travel from the sensory receptor in the periphery, into the spinal cord, and then travel all the way up the cord in the posterior columns (fasciculus gracilis and cuneatus) to synapse onto second-order neurons in the nucleus gracilis and nucleus cuneatus located in the medulla (see figure above).

Axons of these second-order neurons decussate as the internal arcuate fibers and then form the medial lemniscus on the other side of the medulla. The next major synapse occurs when the medial lemniscus axons terminate in the ventral posterior lateral nucleus (VPL) of the thalamus. The neurons of VPL then project through the posterior limb of the internal capsule in the thalamic somatosensory radiations to reach the primary somatosensory cortex in the postcentral gyrus (see figure above).

 An analogous pathway called the trigeminal lemniscus conveys touch and vibration sense for the face via the ventral posterior medial (VPM) nucleus of the thalamus to the primary somatosensory cortex. Synaptic inputs to the primary somatosensory cortex from both the face and body occur mainly in cortical layer IV.

2.   **Spinothalamic Tract & Other Anterolateral Pathways**. Smalle rdiameter and unmyelinated axons carrying information about pain and temperature sense also enter the spinal cord via the dorsal root entry zone. However, in contrast to the posterior columns, these axons make their first synapses immediately in the gray matter of the spinal cord.

Second-order anterolateral sensory neurons in the central gray cross over in the spinal cord anterior (ventral) commissure to ascend in the anterolateral (ventrolateral) white matter.

The next major synaptic relay is, again, in the thalamus which projects to the primary somatosensory cortex (Brodmann's areas 3,1, 2) via the posterior limb of the internal capsule (see figure above). Pain and temperature sensation for the face is carried by an analogous pathway called the trigeminothalamic tract.

  The anterolateral pathways consist of three tracts: the spinothalamic, spinoreticular, and spinomesencephalic tracts. The spinothalamic tract is the best known and mediates

discriminative aspects of pain and temperature sensation, such as location and intensity of the stimulus. Like the posterior column-medial lemniscal pathway, the main relay for the spinothalamic tract is the ventral posterior lateral nucleus (VPL) of the thalamus. There are also some spinothalamic projections to other thalamic nuclei, including intralaminar thalamic nuclei and dorsal-medial nucleus.

  The spinoreticular tract within the anterolateral pathways is a phylogenetically older pain pathway responsible for conveying the emotional and arousal aspects of pain. The spinoreticular tract terminates on the medullarypontine reticular formation, which in turn projects to the intralaminar thalamic nuclei (centromedian nucleus). Unlike the VPL which projects specifically in a somatotopic fashion to primary somatosensory cortex, the intralaminar nuclei project diffusely to the entire cerebral cortex and are thought to be involved in behavioral arousal.

  The spinomesencephalic tract projects to the midbrain periaqueductal gray matter and the superior colliculi. The periaqueductal gray participates in central modulation of pain (see below for a more detailed discussion).

  The anterolateral pathways also convey crude touch in addition to pain and temperature sensation, and thus, can help maintain sense of touch when damage to the posterior columns occurs.

  To summarize the functions of the three tracts that make up the anterolateral pathway, if you step on a tack with you foot, your spinothalamic tract enables you to realize "something sharp is puncturing the sole of my foot"; your spinothalamic intralaminar projections and spinoreticular tract cause you to feel "ouch! That hurts!"; and your spinomesencephalic tract leads to pain modulation, allowing you eventually to think "aah, that feels better."

Somatosensory Cortex. From the thalamic VPL (body & neck) and VPM (face) nuclei, somatosensory information is conveyed to primary somatosensory cortex in the postcentral gyrus (Brodmann's areas 3,1,2). Like primary motor cortex, primary somatosensory cortex is somatotopically organized, with the face represented most laterally and the leg most medially. Information from primary somatosensory cortex is conveyed to the secondary somatosensory cortex (SII) located with the Sylvian (lateral) fissure, along its superior margin in a region called the parietal operculum. SII is also somatotopically arranged. Further possessing of somatosensory information occurs in association cortex of the superior parietal lobule, including Brodmann's areas 5 and 7. Lesions of primary and association somatosensory regions produce characteristic deficits referred to as cortical sensory loss.

Central Modulation of Pain. Pain modulation involves interactions between local circuits at the level of the spinal cord dorsal horn and distal modulatory inputs.

In a mechanism called, gate control theory, sensory inputs from fast, largediameter, non-pain A-beta fibers reduce pain transmission through the dorsal horn by blocking (or getting there first) the slower, unmyelinated C pain fibers. Thus, for example, transcutaneous electrical nerve stimulation (TENS) devices work to reduce chronic pain by activating A-beta fibers. This is also why shaking your hand after striking your thumb with a hammer temporarily helps relieve the pain.

The periaqueductal gray receives inputs from the hypothalamus, amygdala, and cortex, and inhibits pain transmission in the dorsal horn of the cord by stimulating release of serotonin (5-HT) from the raphe nuclei in the rostral ventral medulla (RVM).

The Thalamus (meaning "inner chamber" in Greek) is an important processing center located in the middle of the brain. Nearly all pathways that project to cerebral cortex do so via synaptic relays in the thalamus. Although the thalamus is a major sensory relay station, it also conveys nearly all other inputs to the cortex, including motor inputs from the cerebellum and basal ganglia, limbic inputs, and widespread modulatory inputs involved in behavioral arousal and sleep-wake cycles. The thalamus will be discussed fully in this section because of its importance in sensory processing.

The thalamus is part of the diencephalon, together with the hypothalamus and epithalamus. The thalamus is just rostral to the midbrain. In horizontal sections, the thalami are visible as deep gray matter structures, shaped somewhat like eggs, with their posterior ends angled outward, forming an inverted V.

The thalamus is divided into a medial nuclear group, lateral nuclear group, and anterior nuclear group by a Y-shaped white matter structure called the internal medullary lamina. Nuclei located within the internal medullary lamina itself are called the intralaminar nuclei. Finally, the thalamic reticular nucleus (not to be confused with the reticular nuclei in the brainstem) forms an extensive but thin sheet enveloping the lateral aspect of the thalamus. There are three main categories of thalamic nuclei:

1. Relay nuclei

2. Intralaminar nuclei

3. Reticular nucleus

Relay nuclei. Most of the thalamus is made up of relay nuclei, which receive inputs from numerous pathways and then project to the cortex. In addition, relay nuclei receive massive reciprocal connections back from cortex. Projections of relay nuclei to cortex may be localized to specific cortical regions or more diffuse.

 Specific thalamic relay nuclei. Projections from thalamus to the primary sensory and motor areas tend to be the most localized. These specific relay nuclei lie mainly in the lateral thalamus. All sensory modalities, with the exception of olfaction, have specific relays in the lateral thalamus en route to their primary cortical areas. For example, somatosensory pathways relay in the ventral posterior lateral (VPL) and ventral posterior medial (VPM) nuclei before projecting to cortex.

 As may be seen in the table above, visual information is relayed in the lateral geniculate nucleus (LGN), and auditory information is relayed in the medial geniculate nucleus (MGN).   Motor pathways leaving the cerebellum and basal ganglia also have specific thalamic relays in the ventral lateral nucleus (VL) en route to premotor and supplementary motor areas. Some limbic pathways have fairly specific cortical projections, such as those carried by the anterior nuclear group to the anterior cingulated gyrus.

  Widely projecting (nonspecific) thalamic relay nuclei.

There are two important nonspecific thalamic relay nuclei: the dorsomedial nucleus and the pulvinar.   Diffuse relays of limbic imputs occur in the dorsomedial nucleus, as well as in the midline and intralaminar thalamic nuclei. The dorsomedial nucleus forms a large buldge lying medial to the internal medullary lamina and serves as the major thalamic relay for information traveling to the frontal association cortex.

The pulvinar is a large, pillow-shaped nucleus that occupies most of the posterior thalamus (see figure above). It takes visual and other sensory inputs and relays then to large regions of parietal, temporal, and occipital association cortex involved in behavioral orientation (attention) toward relevant stimuli.

Intralaminar Nuclei lie within the internal medullary lamina (see figure above) and receive inputs from numerous pathways and have reciprocal connections with cortex. Their main inputs and outputs come from the basal ganglia via the centromedian nucleus among others. The rostral intralaminar nuclei relay inputs from the ascending reticular activating system (RAS) to the cortex and play an important role in maintaining the alert, conscious state.

Reticular Nucleus forms a thin sheet surrounding the lateral portions of the thalami and are just medial to the internal capsule. The reticular nucleus is the only thalamic nucleus that does not project to cortex. It receives inputs mainly from other thalamic nuclei and the cortex and projects back to the thalamus. The reticular nucleus consists of an almost pure population of inhibitory GABAergic neurons and is thus suited to its role to inhibit or modulate thalamic output to cortex, thereby altering state of alertness and attention.