

Somatic Sensory System

Objective

- To learn the functional organization of the pathways for touch, limb position sense, and pain and temperature senses
- To be able to localize the site of damage to the CNS by evaluating changes in somatic sensory function.
NTA Ch. 5
Key Figs: 5-1; 5-7; 5-8; 5-9-5-10

Self evaluation

- Be able to identify all structures listed in key terms and describe briefly their principal functions
- Use neuroanatomy on the web to test your understanding

Note on NTA

Chapters 5-15 are each divided into 2 parts. The first present salient features of the functional organization of the neural system. These sections are short enough for you to manage to read before attending lab. The second part describes the anatomical organization, and is in more detail. You will find it helpful to read the second part after you attend lab. This will serve as a review of material covered with your lab instructor.

List of media

A-1 Receptors of the Glabrous Skin.

This slide illustrates a section through the glabrous skin. Meissner's corpuscles and Pacinian corpuscles are rapidly adapting mechanoreceptors. Merkel's discs (receptors) are slowly adapting mechanoreceptors. These mechanoreceptors are the distal portions of large diameter primary afferent fibers. In glabrous skin, the free nerve endings, the distal processes of small diameter primary afferent fibers, are nociceptors and thermoreceptors. What somatic sensation do Pacinian corpuscles mediate? What receptors mediate pain?

A-6 Upper spinal and brain stem course of the dorsal column-medial lemniscal system.

This and the next slide illustrate the three-dimensional configuration of the major ascending somatic sensory systems; do not be concerned with details now. It

will be helpful to refer back to these slides while you view the myelin-stained sections through the brain stem. At this point, get your brain stem model. As you examine sections through the brain stem, be sure to identify the level on the model. Nuclear regions are colored blue and tract, yellow.

On this slide follow the dorsal column-medial lemniscal system. Where is the first synaptic site? Where is the decussation.

A-7 Upper spinal and brain stem course of the anterolateral system.

Follow the anterolateral system. Where is the first synapse? Where is the decussation?

A-2 Sacral-Spinal Segment-Myelin stain

One purpose of examining this and the next image (A-3) is to note the difference in the appearance of myelin-stained (e.g., Weigert) and cell-stained (e.g., Nissl) material. Slide A-2 is a myelin-stained section and A-3 is an adjacent cell-stained section. Notice that the myelin-stained section is similar to a “negative” image of the cell-stained section. On the myelin-stained section cellular regions appear paler and myelinated regions appear darker than a corresponding cell-stained section. Identify the following structures: gray and white matter; dorsal and ventral horns; intermediate zone; dorsal and ventral median sulcus, which divide the spinal cord into two symmetrical halves. In the dorsal horn, also identify the lamina 1, or marginal zone; lamina 2, or substantia gelatinosa. Identify the ventral commissure. Explain why damage to this commissure disrupts pain and temperature senses but not discriminative tactile sensation, vibration sense and position sense. Also, explain why the sensory impairment is bilateral.

In which portion of the gray matter do small diameter afferent fibers terminate? What about large diameter fibers?

The gray matter of the spinal cord contains numerous nuclear groups. With the aid of your atlas, identify the approximate locations of the marginal zone, substantia gelatinosa, and the motor nuclei. To which diencephalic nucleus do neurons of the marginal zone project their axons?

A-3 Sacral-Spinal Segment -Nissl stain

On this Nissl stained section note the general difference in appearance of te myelin and Nissl stained sections. Identify the large fiber entry zone and Lissauer’s tract.

X-5 Spinal cord segments - Weigert stain

This slide shows the configurations of spinal cord segments at different rostro-caudal levels (cervical upper left; thoracic-upper right; lumbar-lower left; sacral-lower right). Note the general differences in the size of the segments, the

shape of the gray matter, and the relative amount of gray matter to white matter. Three key rostro-caudal differences to be noted are: 1) amount of white matter becomes progressively larger from caudal to rostral (Why?); 2) the gray matter is enlarged in the lumbo-sacral enlargement (upper left section) and the cervical enlargement (bottom right section) Why?; 3) the intermediolateral nucleus (sometimes called the "intermediate horn") is located in the thoracic (and upper lumbar) segments.

In addition, identify the dorsal intermediate septum in the cervical section, which separates the dorsal columns into the cuneate and gracile fascicles (see below). In what part of the spinal cord do the fibers of the anterolateral system ascend? In the thoracic spinal cord, the dorsal columns consist of the gracile fascicle only. What sensory modalities and from what body parts ascend in the gracile fascicle? (These sections were reproduced from Atlas of the Human Brain by DeArmond et al.)

A-4 Sections through the spinal cord rostral to a lumbar crush (lesion) - Weigert stain

Two principal methods have been devised for visualizing the ascending tracts of the spinal cord. The first of these identifies the actual boundaries of the major tracts by examining lesioned spinal material using a myelin stain like the Weigert method. Axons of a lesioned tract degenerate, since the cell body becomes isolated from the axon (i.e., Wallerian degeneration). This method shows the tract's location as a light-colored region of poorly stained demyelinated tissue amidst normally stained background. Sections above the lesion illustrate the position of an ascending tract (NTA Fig. 5-9). Conversely, sections below the lesion illustrate the position of a descending tract. The second method uses normal material, usually stained for myelin. Here, by using existing landmarks (i.e., posterior intermediate septum or medial border of ventral horn) and illustrations of tract locations in atlases and textbooks, one can outline the approximate boundaries of the tract (i.e., where it should be).

Note that the structures damaged by the lumbar lesion appear lighter in color than normal regions. Focusing on the level closest to the lesion (top row, left section), you will observe almost complete degeneration of the dorsal columns. Follow the dorsal columns to more rostral segments. The region of degenerated fibers becomes restricted to the more medial portions of the dorsal columns. How do you explain the difference in appearance of the dorsal columns in these two sections? Estimate the extent of sensory loss that was experienced by this patient. The anterolateral quadrant of the spinal cord exhibits some degeneration, although less marked than the dorsal column. The somatotopic organization of the anterolateral system is not obvious from material on these slides. Degeneration of the pathways to the cerebellum also contributes to the general lightened appearance of the anterolateral quadrant, especially the lateral margin of the spinal cord.) It is

not possible to distinguish the locations of spinoreticular, spinotectal, and spinothalamic fibers.

medlemniscus Medial lemniscus (movie)

Animation of the dorsal column medial lemniscal system

Key:

Dorsal column nuclei=aqua/green

Medial lemniscus=yellow

Thalamus=brown

spinothal Spinothalamic tract (movie)

Animation of the anterolateral system

Key:

Anterolateral fibers=yellow

Medial lemniscus (in cross section), dorsal columns=yellow

Corticospinal and corticobulbar fibers=purple/blue

X-15 Lower medulla - Weigert stain

Note the location of the cuneate and gracile nuclei and their respective components of the dorsal columns, the cuneate and gracile fascicles. Fibers leaving the dorsal column nuclei initially swing ventrally then medially. The fibers are called the internal arcuate fibers, which cross the midline and course rostrally in the medial lemniscus. The medial lemniscus is somatotopically organized: afferent input from the leg is ventral to the trunk, which is ventral to the arm. Compare the position of the anterolateral pathway in this section with its position in the spinal cord. The actual location of the anterolateral pathway in this and subsequent sections must be inferred from lesioned material. The anterolateral system also terminates in the reticular formation in addition to the midbrain tectum and the thalamus. Locate the reticular formation. What are some of the functions served by the reticular formation?

X-20 Intermediate medulla - Weigert stain

In the medulla, the medial lemniscus occupies the ventral half of the darkly staining nest of myelinated fibers along the midline. The anterolateral pathway is located dorsal to the inferior olive, along the lateral margin of the brain stem. On this slide, identify the regions supplied by the vertebral and posterior inferior cerebellar (PICA) arteries. Why does occlusion of PICA interrupt pain and temperature senses but not tactile and position senses? (See NTA Fig. 5-13)

X-25 Rostral medulla- Weigert stain

On Slide X-25 identify the Raphe nuclei. What is the neurotransmitter of raphespinal neurons? What are the actions of this system on spinal cord neurons?

X-35 Pons - Weigert stain

Identify the locations of the medial lemniscus, reticular formation, and the anterolateral system. Note how the orientation of the medial lemniscus changes in more rostral sections.

X-40 Midbrain, level of inferior colliculus - Weigert stain

Identify the locations of the medial lemniscus and the anterolateral system. Identify the periaqueductal gray and the tectal region, which is dorsal to the cerebral aqueduct. Beginning at this level, what is the complete circuit for descending inhibitory control of pain?

X-45 Midbrain - level of superior colliculus

Identify the locations of the medial lemniscus and the anterolateral system. At this rostral midbrain level, most spinoreticular and spinotectal fibers have terminated; therefore, only the spinothalamic fibers of the anterolateral system remain.

X-100 Sagittal section, close to midline

Identify which dorsal column and dorsal column nucleus is shown on this section. What is the tract located on the ventral surface? Locate the medial lemniscus. Why does the medial lemniscus disappear from view in the midpons? Use this slide to review the brain stem components of the pain suppression pathway.

AN-01 Thalamo-cortical relations (animation)

Different thalamic nuclei project to different regions of the cortex. You will recall from the lab on internal brain structure that the lateral geniculate nucleus projects to the visual cortex and that the medial geniculate nucleus projects to the auditory cortex. Here we will consider the ventral posterior nucleus, the somatic sensory relay nucleus.

Although not shown on this animation, the ventral posterior nucleus contains a medial and lateral subdivision, termed the ventral posterior medial nucleus and the ventral posterior lateral nucleus. The ventral posterior medial nucleus receives input principally from the face via the trigeminal nerve. The ventral posterior lateral nucleus processes input from the limbs and trunk, transmitted to the thalamus principally by the medial lemniscus and the spinothalamic tract. In what portions of the postcentral gyrus are the representations of the lower and upper limbs? Occlusion of the anterior cerebral artery would produce deficits in tactile sensations over which portion of the body? In which cortical laminae do the axons from the ventral posterior nucleus terminate? How is afferent information distributed: 1) within a local cortical area (i.e., cortical column), 2) between columns, and 3) from one somatic sensory cortical region to another (i.e., SI to SII)?

somatosensrad Somatic sensory radiations (movie)

Note, the striatum is the green structure that flies away.

Key:

Projection fibers from VP to the postcentral gyrus=yellow
Postcentral gyrus=aqua
Thalamus=purple

X-55 Oblique section through posterior diencephalon.

This section is roughly between the coronal and horizontal planes. The lower portion of the section is rostral to the upper portion of the section. Use your brain stem model to reconstruct the plane of section. The medial lemniscus and the spinothalamic component of the anterolateral pathway terminate in the ventral posterior lateral nucleus of the thalamus. The ventral posterior medial nucleus is the thalamic relay for trigeminal afferent input. Identify the medial (i.e., trigeminal) and lateral (i.e., spinal) components of the ventral posterior (VP) nucleus. While examining this slide note the circular-shaped centromedian (CM) nucleus, and the lightly stained pulvinar, which is dorsal to VP and CM.

X-120 Horizontal section through the thalamus.

The internal capsule is located lateral to the thalamus and the caudate nucleus and medial to the putamen. It consists of three portions: anterior limb, posterior limb, and the genu, which joins the two limbs. Identify the three components of the internal capsule. Through which limb of the internal capsule do axons from the ventral posterior nucleus course en route to the primary somatic sensory cortex?

Key Structures and Terms

Dorsal root ganglion cell
Lissauer's tract
Dorsal column
Lateral column
Ventral column
Spinoreticular tract
Spinothalamic tract
Spinotectal tract
Marginal zone (lamina I) and
terminations of lamina I neurons
projection neurons
Substantia gelatinosa (laminae II)
Gracile fascicle
Cuneate fascicle
Gracile nucleus
Cuneate nucleus
Internal arcuate fibers
Periaqueductal gray
Raphe nuclei
Midbrain tectum
Reticular formation
Internal medullary laminae
Ventral posterior lateral nucleus
Ventral posterior medial nucleus
Intralaminar nuclei
Primary somatosensory cortex
(Brodmann's areas 1, 2, and 3)
Some important somatic sensory
system neurotransmitters:
serotonin
enkephalin
glutamate