

Medical Neuroscience | Tutorial Notes

Mechanosensory pathways

MAP TO NEUROSCIENCE CORE CONCEPTS¹

NCC1. The brain is the body's most complex organ.

NCC3. Genetically determined circuits are the foundation of the nervous system.

LEARNING OBJECTIVES

After study of today's learning, the student will:

1. Characterize the organization of the dorsal-column medial lemniscal system from peripheral nerve ending to cerebral cortex.
2. Recognize components of the dorsal-column medial lemniscal system in the spinal cord, brainstem, thalamus and cerebral cortex.
3. Characterize the organization of the trigeminal mechanosensory system from peripheral nerve ending to cerebral cortex.
4. Recognize components of the trigeminal mechanosensory system in the brainstem, thalamus and cerebral cortex.
5. Characterize the organization of the neural pathways that mediate unconscious proprioception ("proper proprioception") from peripheral nerve ending to cerebellum (the spinocerebellar pathway).
6. Recognize components of the spinocerebellar pathway in the spinal cord and brainstem.

TUTORIAL NARRATIVE

Introduction

There are two major, parallel systems that convey somatic sensory information from the periphery of the post-cranial body to the cortex, the **dorsal column-medial lemniscus system** and the **anterolateral system**. There are comparable parallel systems carrying information from the face associated with the central projections of the **trigeminal nerve**. In addition, there is an important system carrying proprioceptive information from the muscle spindles to the cerebellum. This tutorial will focus on the pathways taken by the components of the systems for transmission of neural signals pertaining to the detection and perception of mechanical stimuli. It is important for your understanding of neurological deficits seen in the clinic to know where these pathways travel relative to each other and to other structures (including the cranial nerve nuclei) in the brain.

¹ Visit [BrainFacts.org](https://www.brainfacts.org) for Neuroscience Core Concepts (©2012 Society for Neuroscience) that offer fundamental principles about the brain and nervous system, the most complex living structure known in the universe.

Pathways mediating mechanosensation

The pathways that convey information about touch (especially fine, discriminative touch), pressure, and vibration from the body and face are illustrated in [Figures 1](#) and [2](#). In the dorsal column-medial lemniscal system, which carries information from the body, the first order neuron is the **dorsal root ganglion cell**. The first-order cells have peripheral processes that are often encapsulated (e.g., Meissner corpuscles, Pacinian corpuscles) or are associated with specialized receptor cells (e.g., Merkel's discs). They send central processes into the spinal cord, where major branches travel in the dorsal columns to the caudal end of the medulla. There, they synapse on neurons in the dorsal column nuclei, the **gracile** and **cuneate nuclei**.

The second-order neurons located in the dorsal column nuclei send their axons across the midline, where they form a fiber bundle known as the **medial lemniscus** (hence, the name of this pathway). The axons of the medial lemniscus run through the rest of the medulla, the pons and the midbrain before ending in the **ventral posterior lateral nucleus (VPL)** of the thalamus. Third-order neurons in the VPL send their axons via the internal capsule to terminate in the somatic sensory cortex, which resides in the **postcentral gyrus**.

The first-order neurons associated with receptors in the face lie in the **trigeminal (Gasserian) ganglion**. The central processes enter the brain via the fifth cranial nerve and terminate in the **principal (or chief) sensory nucleus of the trigeminal complex** (or of the fifth nerve). The second-order cells in this nucleus send axons across the midline to form the **dorsal trigeminothalamic tract**, also known as the **trigeminal lemniscus**. These second-order axons travel to the **ventral posterior medial nucleus (VPM)** of the thalamus. Third-order neurons in the VPM send their axons to the postcentral gyrus.

Pathways mediating proprioception

Cutaneous receptors that feed into the dorsal column-medial lemniscal system are one source of information giving us a sense of body position. A second important source of such information is the pathway leading from muscle spindles. Two important targets of this information are the postcentral gyrus and the cerebellar cortex, as illustrated in [Figure 3](#).

The afferent fibers associated with muscle spindles in the legs send their central processes into the spinal cord where they form synapses in a prominent nucleus in the thoracic and upper lumbar spinal cord, known as the **dorsal nucleus of Clarke**. (The axons ascend in the dorsal columns from their point of entry until they reach the thoracic cord, where they form synapses in this nucleus.) The second-order neurons in Clarke's nucleus send very large, heavily myelinated axons into the dorsal-lateral white matter on the same side, where they ascend as the **dorsal spinocerebellar tract**. A major target of the spinocerebellar tract, as its name implies, is the cerebellum. The fibers enter the cerebellum via the **inferior cerebellar peduncle**. Branches of the spinocerebellar tract also form synapses on cells in or near the dorsal column nuclei, which appear to then send axons into the medial lemniscus (joining the pathway already illustrated in [Figure 1](#)).

The afferent fibers associated with muscle spindles in the arms send their central processes into a nucleus at the caudal end of the medulla, known as the **external cuneate nucleus** (because it lies just lateral to the cuneate nucleus, already described). The second-order cells send axons into the cerebellum on the same side via the **cuneocerebellar tract**, which—like the dorsal spinocerebellar tract—enters the cerebellum via the inferior cerebellar peduncle.

The functions of these pathways are:

1. to carry information about the length and tension of muscle fibers in the arms and legs to the cerebellum;
2. to provide information to the cerebral cortex that contributes to a sense of position of the limbs and digits and of the body in space; i.e., a sense of proprioception ("self-awareness").

The locations of major components of these pathways are indicated in [Figure 4](#).

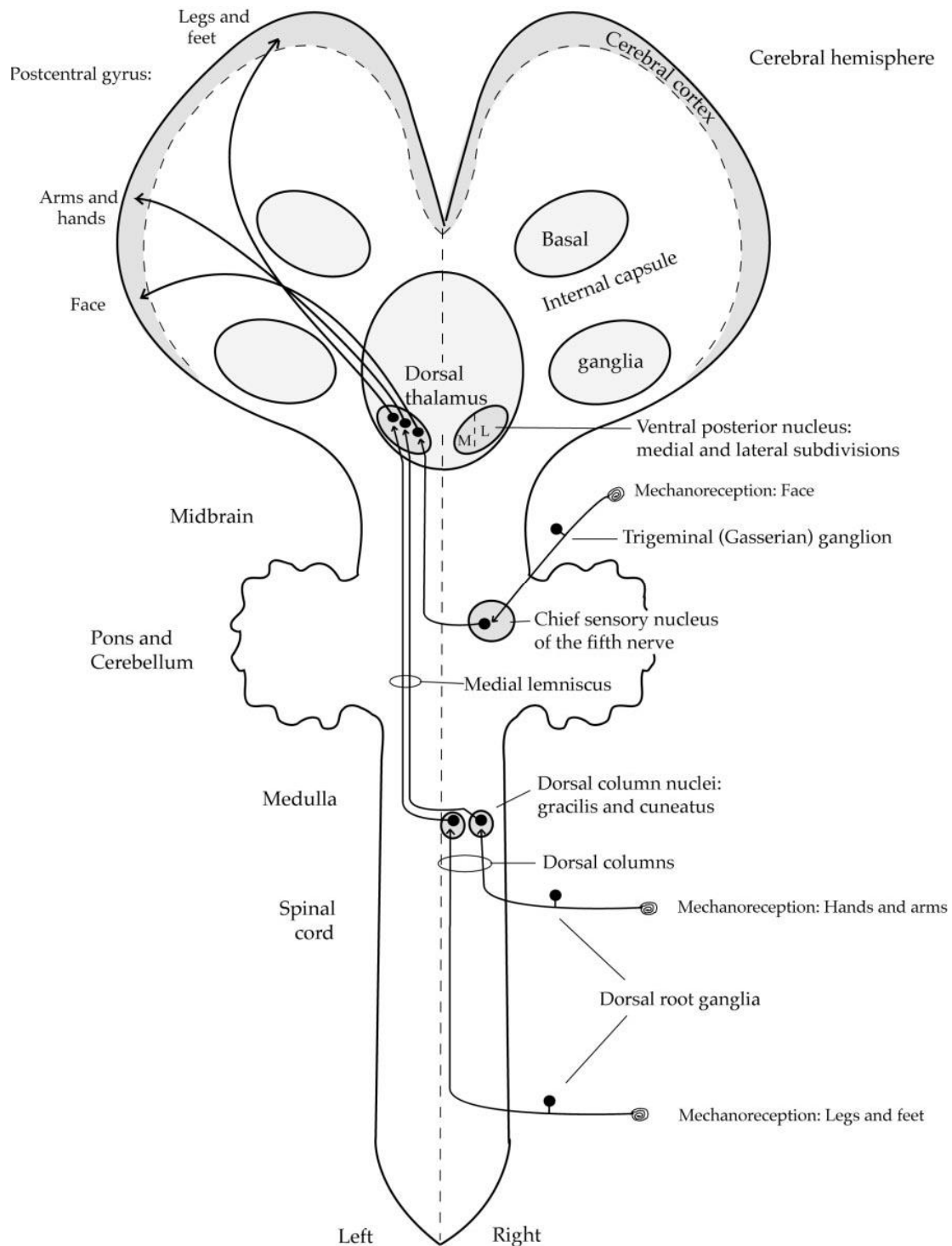


Figure 1. Organization of the central pathways that carry information about discriminative touch, pressure, and vibration. Information about the body and posterior head is conveyed via the spinal nerves. Information about the face is conveyed via the fifth cranial nerve. (Illustration by N.B. Cant)

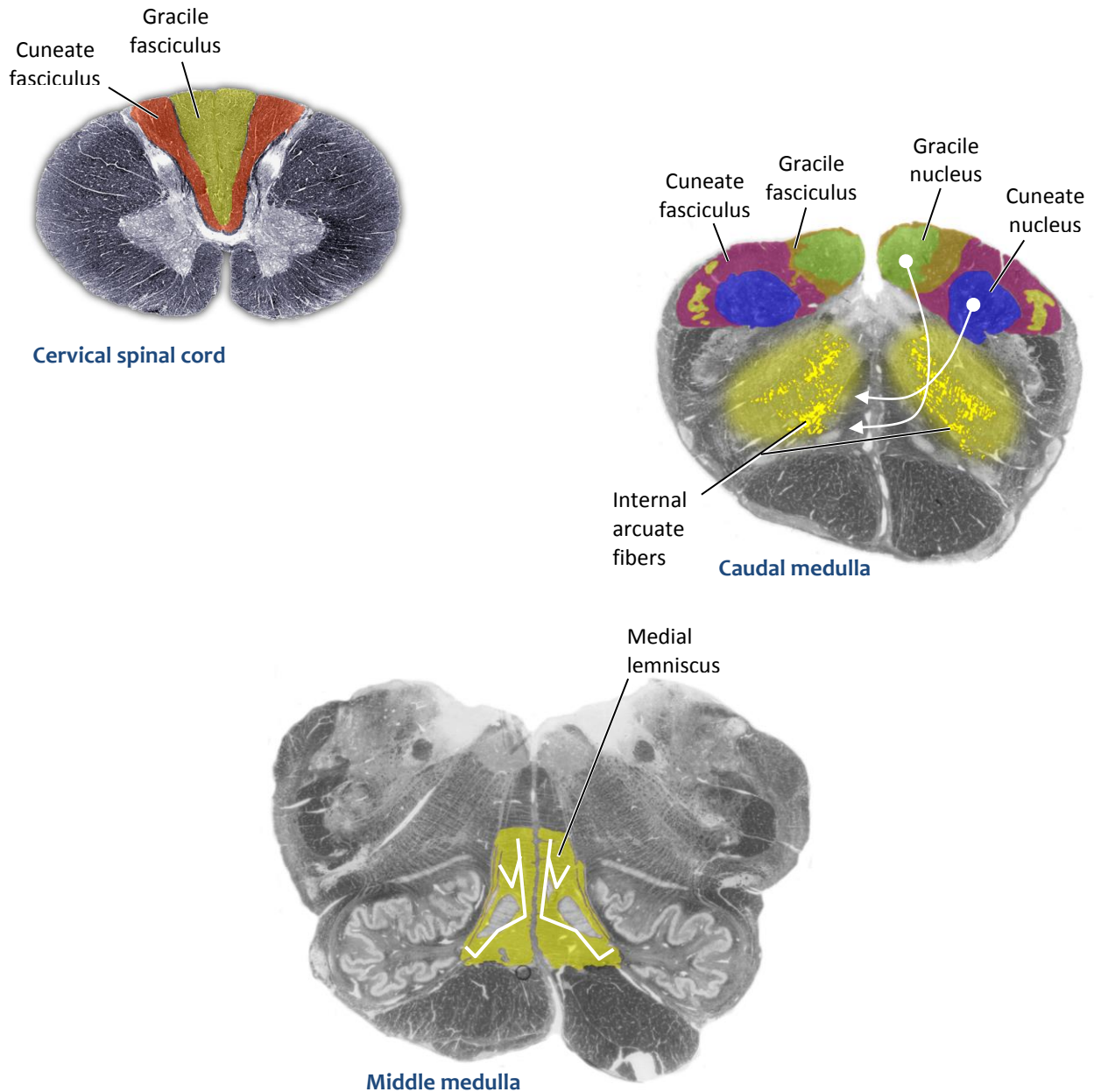
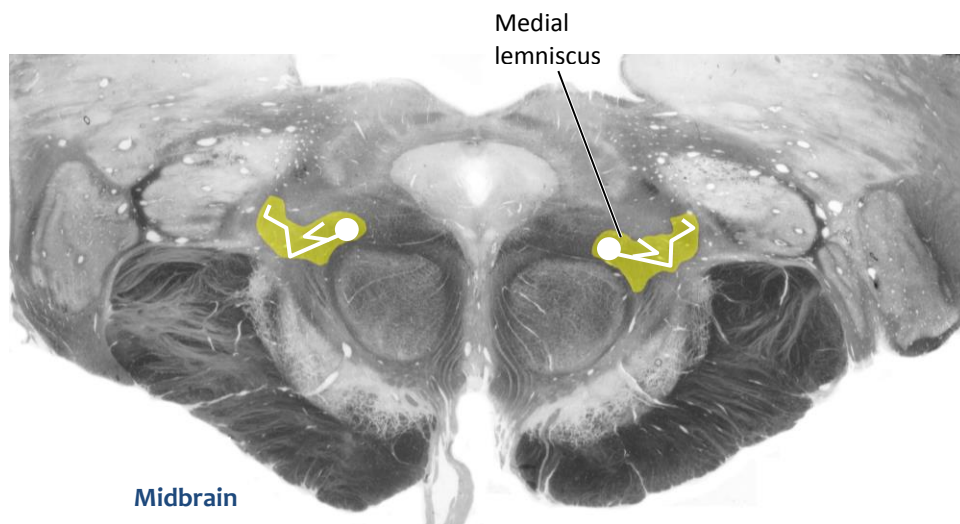
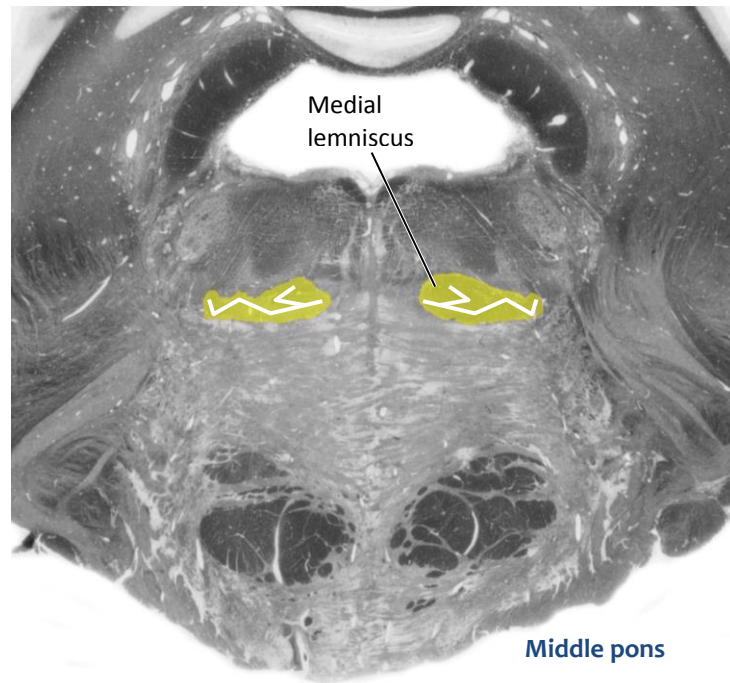


Figure 2. Dorsal column-medial lemniscus system, with trigeminal lemniscus, in cross-sections. At the level of the midbrain, the trigeminal lemniscus joins the medial lemniscus so that all mechanosensory information about the opposite side of the body (including the head) travels together in topographic order as the tracts approach the thalamus (stick figure in white lines indicates somatotopic order of tracts; second-order neurons are shown in caudal medulla section). (Sections from [Sylvius4 Online](#)) (Figure continued on next page)



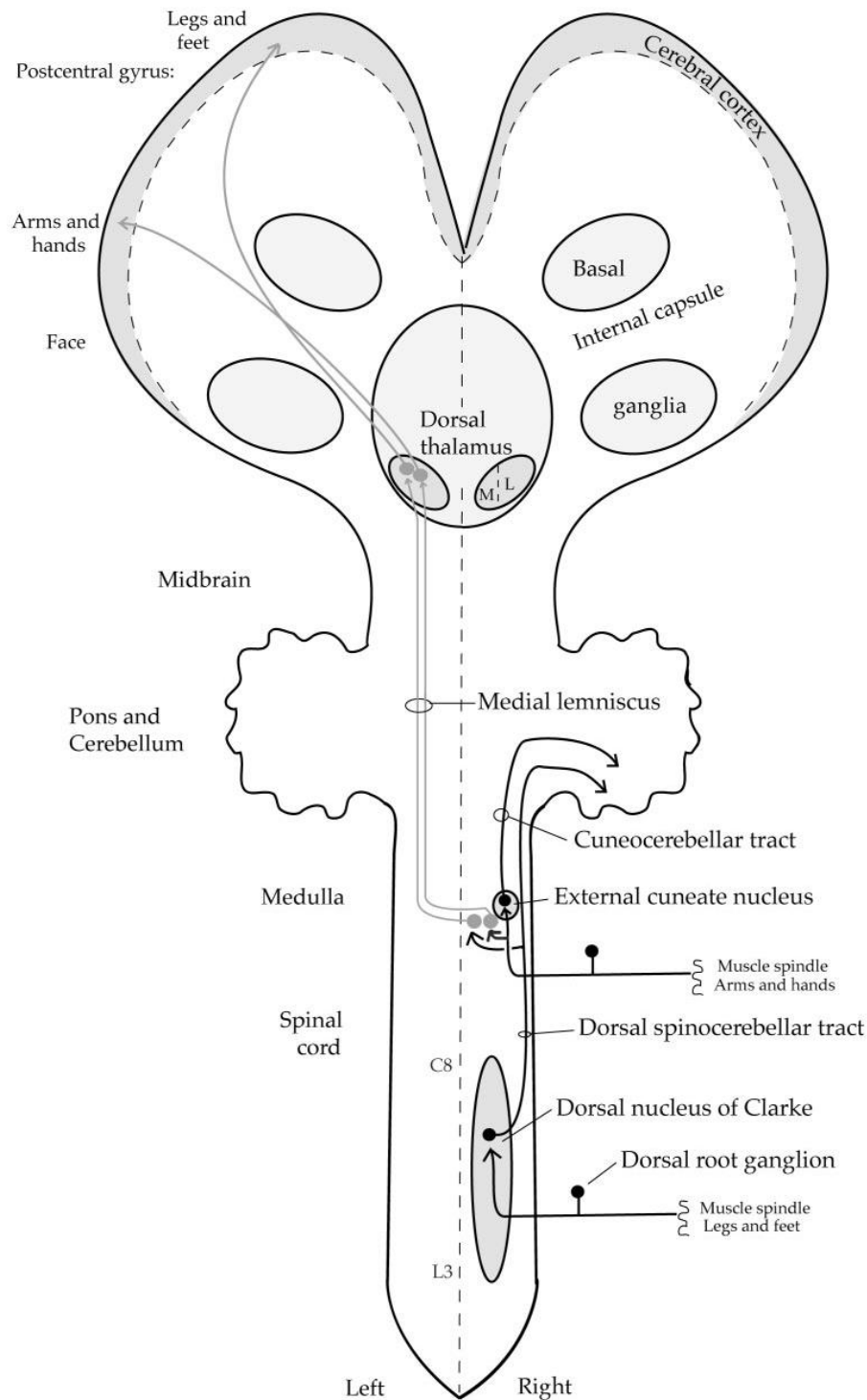


Figure 3. Pathways carrying information from the muscle spindles to the cerebellum and to the cerebral cortex. (Pathways from the dorsal column nuclei to the thalamus and from there to the cortex are shown in a lighter gray. This part of the pathway was presented in Figure 1.) (Illustration by N.B. Cant)

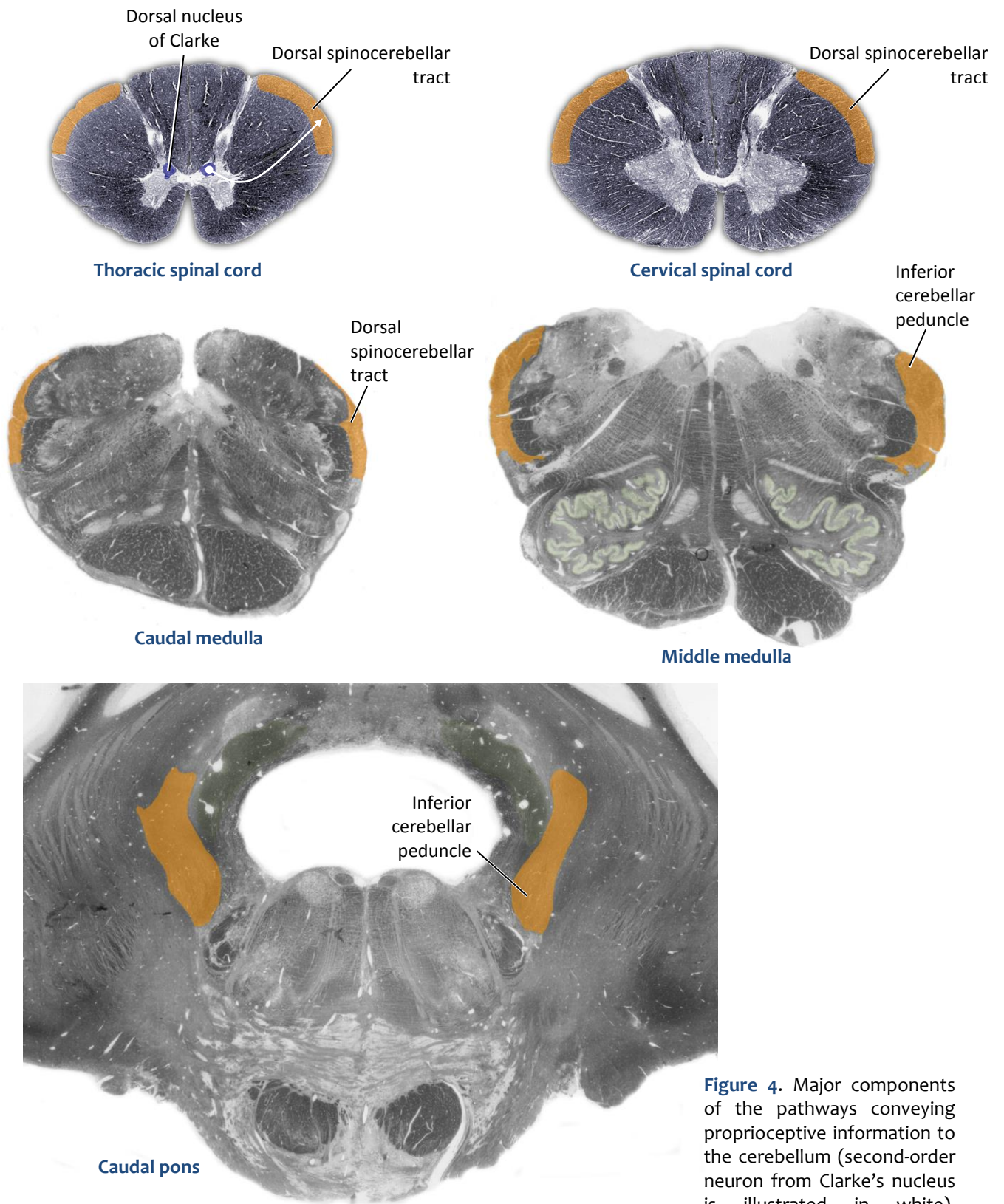


Figure 4. Major components of the pathways conveying proprioceptive information to the cerebellum (second-order neuron from Clarke's nucleus is illustrated in white). (Sections from [Sylvius4 Online](#))

Pathways for light, discriminative touch, pressure, position sense and vibration.

Pathway	Receptors	First-order neurons	Second-order neurons	Third-order neurons	Primary cortical area	Decussation pattern
dorsal-column medial lemniscal system (for postcranial body, including the posterior portion of the head) [see Figure 9.8A]	<ul style="list-style-type: none"> encapsulated endings (Meissner's & Pacinian corpuscles) specialized receptor systems (Merkel disks) 	ipsilateral DRGs ⁱ (dorsal root ganglion neurons) (Aβ, Ia & II afferent fibers)	ipsilateral dorsal column nuclei in the dorsal, caudal medulla: <ul style="list-style-type: none"> gracile nucleus cuneate nucleus 	contralateral ventral posterior complex of the thalamus: <ul style="list-style-type: none"> ventral posterior lateral (VPL) nucleus (axons of VPL neurons project to the cerebral cortex via the posterior limb of internal capsule) 	contralateral primary somatic sensory cortex (S1) in postcentral gyrus Brodmann's Areas (BA) 3, 1 & 2 <ul style="list-style-type: none"> lower extremity is represented in the paracentral lobule upper extremity is represented in the Ω-shaped segment of the postcentral gyrus near the middle of the central sulcus light discriminative touch is first processed in BA 3b deep sensation is first processed in BA 3a 	caudal medulla: second-order axons of the dorsal column nuclei cross the midline as the internal arcuate fibers and ascend the brainstem as the medial lemniscus
trigeminal (principal) mechano-sensory system (for face—anterior third of head) [see Figure 9.8B]	<ul style="list-style-type: none"> encapsulated endings (Meissner's & Pacinian corpuscles) specialized receptor systems (Merkel disks) 	ipsilateral "DRGs" <ul style="list-style-type: none"> trigeminal ganglion neurons in gasserian (trigeminal) ganglion (Aβ, Ia & II afferent fibers)	ipsilateral principal (chief sensory) nucleus of the trigeminal complex in the dorsal-lateral pons	contralateral ventral posterior complex of the thalamus: <ul style="list-style-type: none"> ventral posterior medial (VPM) nucleus (axons of VPM neurons project to the cerebral cortex via the posterior limb of internal capsule) 	contralateral S1 Brodmann's Areas 3, 1 & 2 <ul style="list-style-type: none"> face is represented in the inferior segment of the postcentral gyrus light discriminative touch is first processed in BA 3b deep sensation is first processed in BA 3a 	pons: second-order axons of the principal nucleus cross the midline and ascend the brainstem as the trigeminal lemniscus , which occupies a position near the dorsal and medial edge of the medial lemniscus (supplies a face for lemniscal homunculus)
spino-cerebellar (unconscious) proprioception (for postcranial body, including the posterior portion of the head) [see Figure 9.9]	<ul style="list-style-type: none"> muscle spindles Golgi tendon organs joint receptors 	ipsilateral DRGs (dorsal root ganglion neurons) (same neurons that send branches to the dorsal column-medial lemniscal pathway)	ipsilateral relay nuclei in the thoracic spinal cord and caudal medulla: <ul style="list-style-type: none"> dorsal nucleus of Clarke (for lower extremity) external cuneate nucleus (for upper extremity) 	Ipsilateral cerebellum <ul style="list-style-type: none"> cortex deep nuclei (via the dorsal spinocerebellar and cuneocerebellar tracts, which form the inferior cerebellar peduncle) 	None! <ul style="list-style-type: none"> no feedforward processing of sensory signals in the cerebral cortex via this spinocerebellar pathway; this is why it is considered "unconscious" however, branches of the spinocerebellar axons synapses on proprioceptive dorsal column neurons that do send axons into the medial lemniscus for "conscious" proprioception 	none through the circuitry of the cerebellum (remember: there is ipsilateral representation in the cerebellum!)

ⁱ The terms ipsilateral and contralateral will refer to the side of the peripheral or central nervous system relative to the location of the sensory receptors; e.g., cortical representation of the somatic sensory periphery occurs in the *contralateral* primary somatic sensory cortex.