Medical Neuroscience | Tutorial

Pain Pathways

Map to Neuroscience Core Concepts[1]

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

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

NCC7. The human brain endows us with a natural curiosity to understand how the world works.

NCC8. Fundamental discoveries promote healthy living and treatment of disease.

Learning Objectives

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

1. Characterize the organization of the anterolateral system from peripheral nerve ending to cerebral cortex.
2. Recognize components of the anterolateral system in the spinal cord, brainstem, thalamus and cerebral cortex.[2]
3. Characterize the organization of the trigeminal pain & temperature (spinal trigeminal) system from peripheral nerve ending to cerebral cortex.
4. Recognize components of the trigeminal pain & temperature (spinal trigeminal) system in the brainstem, thalamus and cerebral cortex.[1]

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 pain and temperature sensation. 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.

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[1] Visit **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.

[2] As you study somatic sensory pathways, you should begin referring to cross sections through the nervous system (e.g., in Sylvius4) so that you can recognize where relevant nuclei and axonal tracts are located within the brain and spinal cord.

Pathways mediating pain and temperature sensation.

The **anterolateral system** is responsible for conveying information about pain, temperature and crude touch (i.e., touch lacking the spatial resolution of the dorsal column system) from the post-cranial body. Comparable information about the face is processed in trigeminal pathways. These pathways are illustrated in **Figures 1** and **2**. Most peripheral processes associated with the **dorsal root ganglion cells** that contribute to this system are "free." That is, they are not associated with encapsulated endings like those in the dorsal column-medial lemniscal system. In addition, the first-order fibers associated with the anterolateral system are generally much smaller in diameter than those associated with the dorsal column system. (So what does this tell you about the relative conduction velocities of these two important somatic sensory pathways?)

The first-order neurons in the anterolateral system, like those in the dorsal column-medial lemniscal system, have their cell bodies in the dorsal root ganglia. The central processes of these neurons *terminate* on second-order neurons in the **dorsal horn of the spinal cord**. Pain and temperature information from receptors in the face is carried into the brain on the fifth nerve. The cell bodies of the first order neurons are in the **trigeminal ganglion** and the central processes of the cells make synapses in a nucleus in the medulla known as the **spinal trigeminal nucleus** (of the fifth nerve). This nucleus is actually continuous with the dorsal horn of the spinal cord.

The second-order neurons in the dorsal horn of the spinal cord send their axons across the midline, where they accumulate in the anterolateral (ventrolateral) part of the white matter. They ascend in this location through the length of the cord. Many of these fibers continue through the medulla, the pons and the midbrain to contact third-order neurons in the **ventral posterior lateral** (VPL) nucleus of the thalamus (as well as other thalamic nuclei). This direct pathway from the spinal cord to the thalamus is often called the **spinothalamic tract**. Actually, the thalamus is only one of the targets of the second-order neurons in the anterolateral system. These neurons also project to central parts of the medulla, pons and midbrain known collectively as the **reticular formation** (this component of the anterolateral system is known as the "spinoreticular tract") and to the **periaqueductal gray matter** and the **superior colliculus** (this component is known as the "spinomesencephalic tract"). Second-order neurons located in the spinal trigeminal nucleus send their axons across the midline to form the **ventral trigeminothalamic tract**, which travels to the **ventral posterior medial** (VPM) **nucleus** of the thalamus.

Third-order neurons in the ventral posterior nucleus and in other thalamic nuclei then project to the cortex via the internal capsule. The postcentral gyrus appears to be important for the ability to discriminate the exact location of painful stimuli, but many other, less well-understood cortical areas (including areas in the anterior part of the cingulate gyrus) appear to be important in the complete sensation of pain, including the complex affective dimensions of pain.

Figure 3 presents a diagram of the major parallel pathways carrying somatic sensory information to the cerebral cortex (see tutorial notes on "**Mechanosensory Pathways**"). The pathways for mechanoreception and the pathways for pain and temperature sensation shown in **Figure A1** are shown together bilaterally.

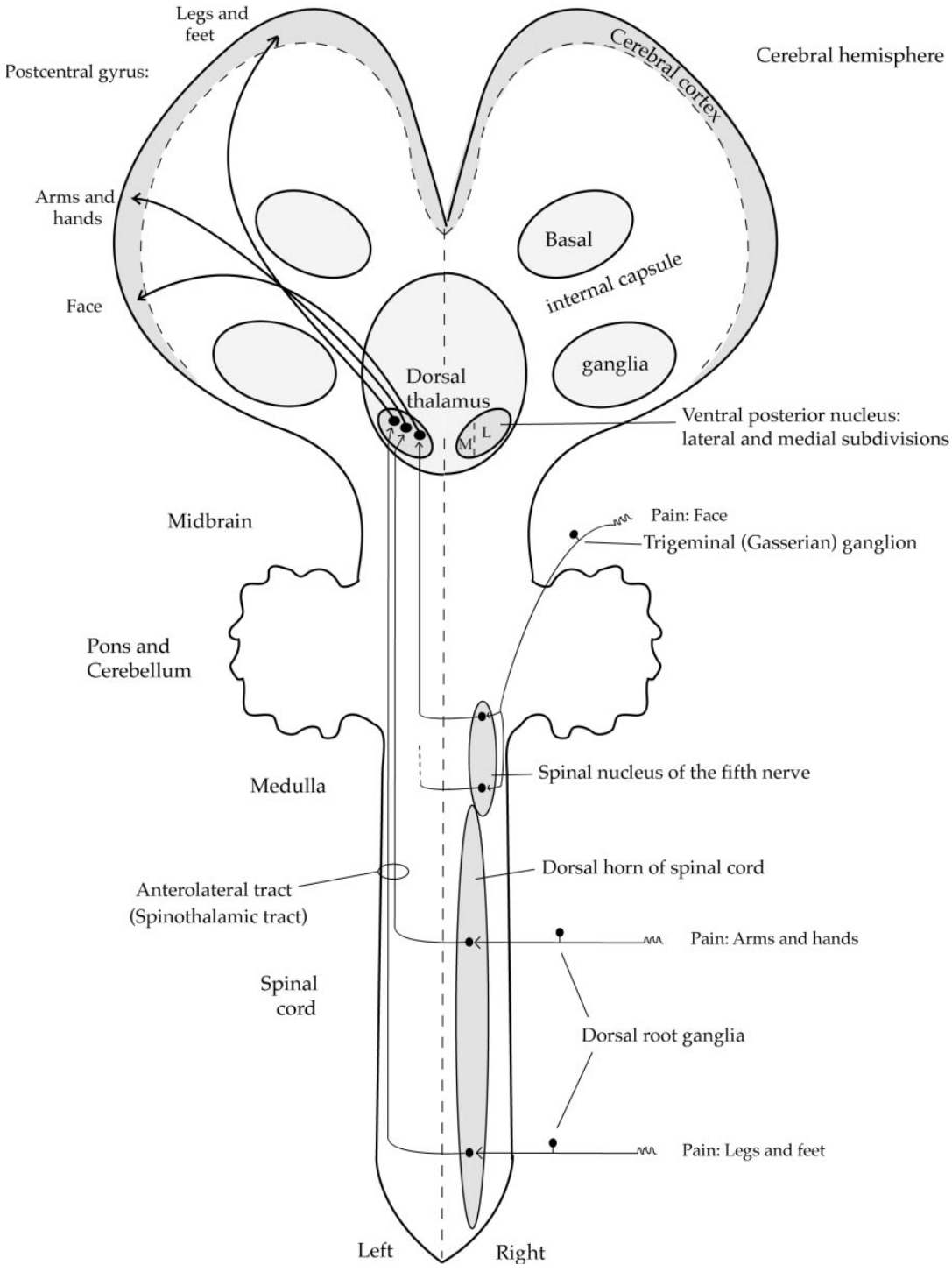


Figure 1. Organization of the central pathways for pain and temperature sensation. These pathways also carry crude information about touch. (As discussed an earlier tutorial, there is a small input into the trigeminal nuclei from the seventh, ninth and tenth nerves, but this input is of little significance clinically.) (Illustration by N.B. Cant)

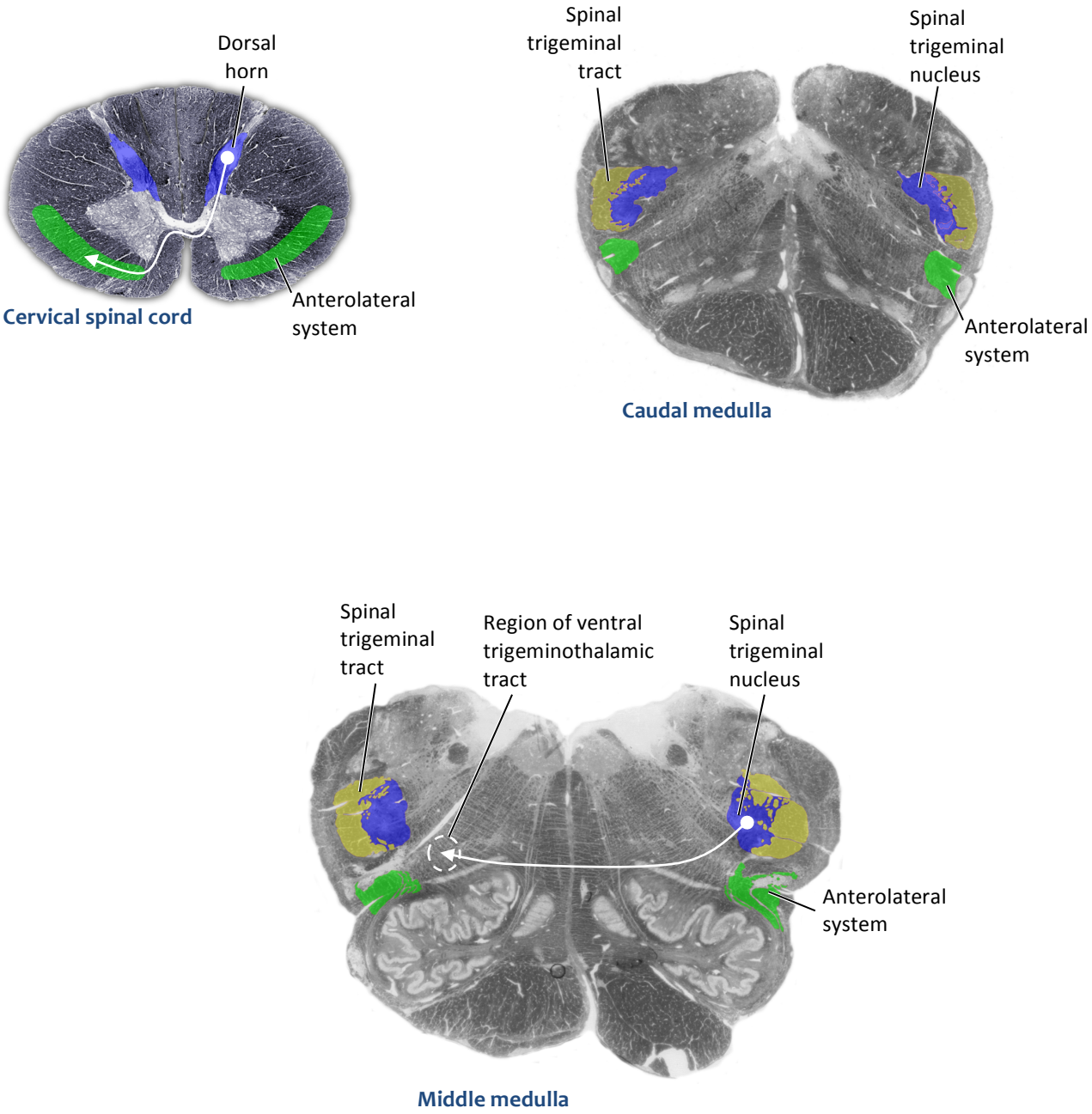
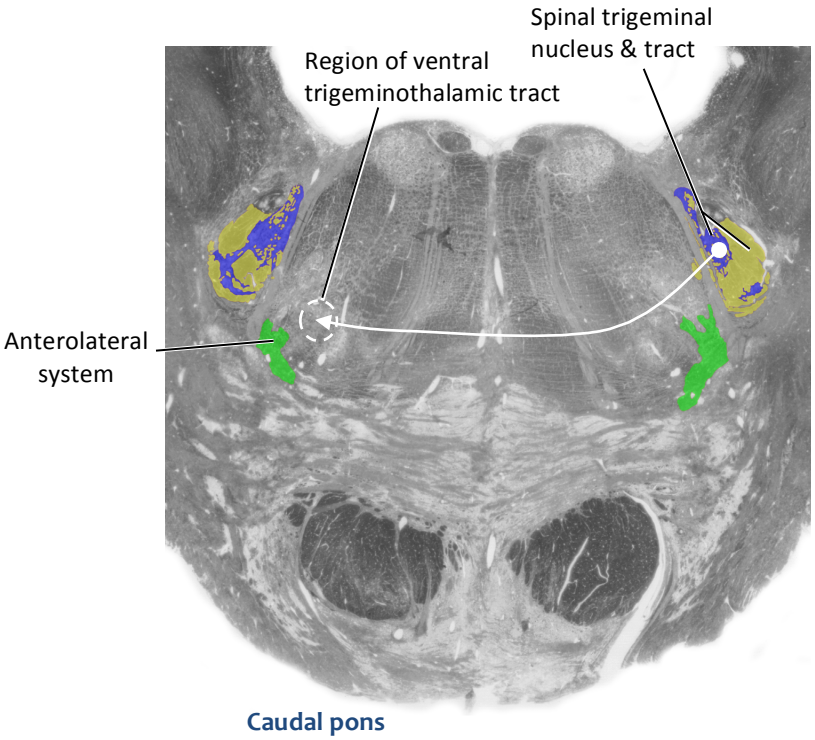
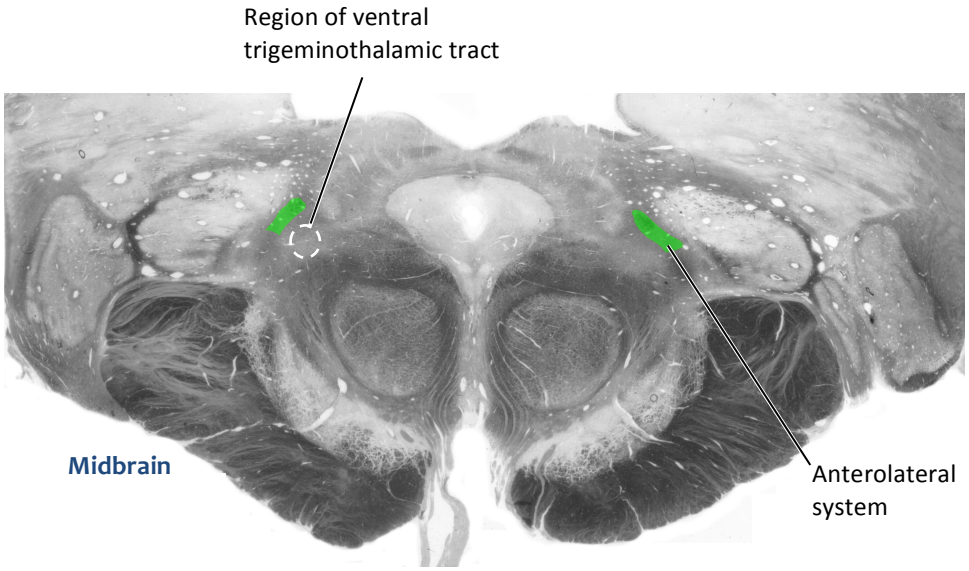


Figure 2. Location of the anterolateral system in the cervical cord and brainstem, with the ventral trigeminothalamic tract, as seen in cross-sections. Note that at all levels, the fibers of both tracts are located in the anterolateral part of the brainstem tegmentum (second-order neurons are illustrated in white). (Sections from ***Sylvius4***) (Figure continued on next page)


Spinal trigeminal
nucleus & tract
Region of ventral
trigeminothalamic tract
Anterolateral
system
Caudal pons


Region of ventral
trigeminothalamic tract
Midbrain
Anterolateral
system

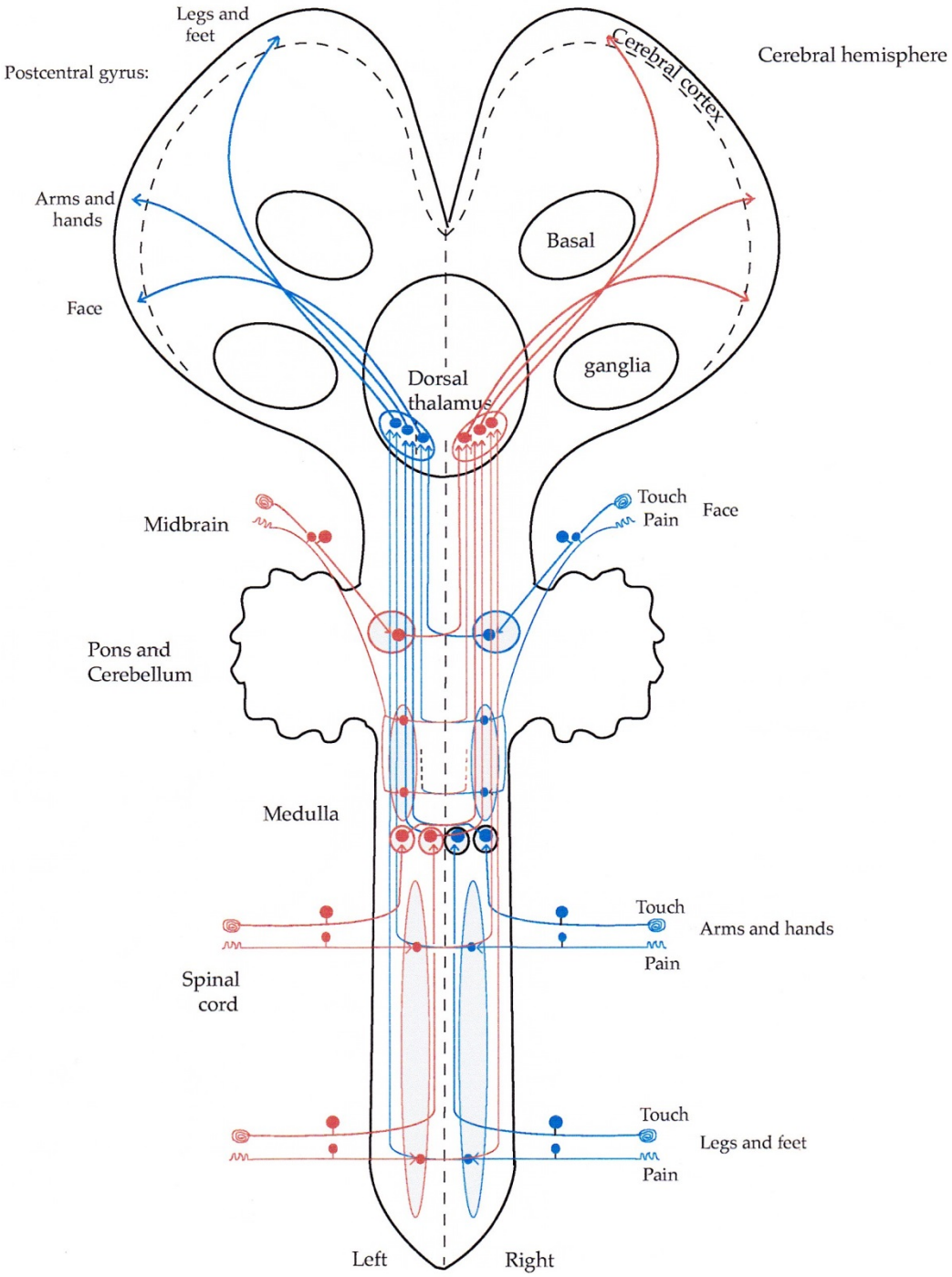


Figure 3. A diagram of the major parallel pathways carrying somatic sensory information to the cerebral cortex. The pathways for mechanoreception and the pathways for pain and temperature sensation are shown together bilaterally in this figure. See related figures labels of nuclei and tracts. (Illustration by N.B. Cant)