Medical Neuroscience | Tutorial Notes

Internal Anatomy of the Spinal Cord

MAP TO NEUROSCIENCE CORE CONCEPTS[1]

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

LEARNING OBJECTIVES

After study of the assigned learning materials, the student will:

1. Discuss the organization of gray matter in the spinal cord and the general functions associated with the dorsal horn, ventral horn and intermediate gray matter.
2. Discuss the organization of white matter in the spinal cord and the general functions associated with each column.

NARRATIVE

by **Leonard E. White** and **Nell B. Cant**
Duke Institute for Brain Sciences
Department of Neurobiology
Duke University School of Medicine

Introduction

After working through this tutorial, you should be able to discuss the organization of the various components of gray matter and white matter in the spinal cord. Let's begin by making sure that you understand the basic layout of sensory and motor neurons in the spinal cord.

The central nervous system interacts with the outside world through primary sensory neurons, which convey information from the body or its environment into the brain and spinal cord, and motor neurons, which activate striated muscles and modulate the activity of cardiac and smooth muscles and glands (see **Fig. 1** below and/or **Figure A1A**[2]). The cell bodies of primary sensory neurons lie in the **dorsal root ganglia** or the **cranial nerve ganglia**. Each neuron gives rise to a peripheral process, which receives information either directly or through association with receptors, and a central process, which enters the central nervous system and forms synapses with second order neurons. The cell bodies of somatic motor neurons lie in clusters or **nuclei** within the central nervous system and give rise to axons that innervate striated muscles in the body or head. You will also be introduced to other motor neurons that are part of the visceral motor system (a.k.a., autonomic nervous system) and are indirectly responsible for governing cardiac muscle, smooth muscle or glands.

---

[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] Figure references to Purves et al., *Neuroscience, 5th Ed.*, Sinauer Assoc., Inc., 2012. [click here]

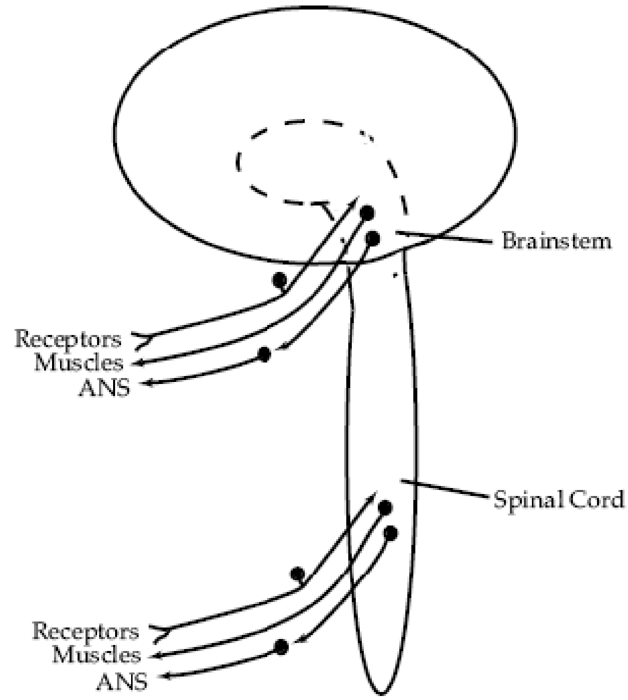

Fig. 1. Both the spinal cord and brainstem receive input from primary sensory neurons; the cell bodies of these neurons lie in sensory ganglia. In addition, both the spinal cord and brainstem give rise to motor output to striated muscles and to the autonomic ganglia (*ANS*, autonomic nervous system; synonymous with visceral motor system). (Illustration by N.B. Cant)

The internal anatomy of the spinal cord

The following brief discussion of the internal anatomy of the spinal cord will introduce some of the general principles of organization that also hold true for the brainstem. A cross-section through the spinal cord is illustrated schematically in **Fig. 2**. The gray matter forms the interior of the spinal cord; it is surrounded on all sides by the white matter. The white matter is subdivided into **dorsal** (or posterior), **lateral**, and **ventral** (or anterior) **columns**. Each of these columns contains bundles of axons related to specific functions. For example, the lateral columns are made up partly of axons that travel from the cerebral cortex to form synapses with motor neurons in the ventral horn. The dorsal columns carry much of the ascending sensory information from mechanoreceptors (more on these long pathways in later sessions).

The gray matter of the spinal cord is divided into **dorsal** and **ventral** (or posterior and anterior) '**horns**.' The dorsal horn is the part of the gray matter that receives sensory information entering the spinal cord via the dorsal roots of the spinal nerves. (Not all sensory fibers terminate in the dorsal horn of the spinal cord; axons carrying sensory information from mechanoreceptors travel to the medulla before making their first synapse in the pathway to conscious perception; they will be covered later.) The ventral horn contains the cell bodies of motor neurons that send their axons out via the ventral roots to terminate on striated muscles. Thus, one important general rule of organization is that neurons in the spinal cord that process sensory information are spatially separate from motor neurons. (See **Fig. 3** below and **Table A1** of *Neuroscience, 5th Ed.*, for more detail on the internal organization of spinal gray matter.)

As seen in a previous tutorial, the inputs and outputs of the spinal cord are arranged segmentally into the 31 spinal nerves. However, the gray matter of the spinal cord is not obviously segmented. It can be thought of as continuous columns (ventral horn) and layers (dorsal horn) of cells that run the length of the cord, with important differences in the size of the dorsal and ventral horns at different levels. The dorsal and ventral horns are largest where they supply the upper and lower limbs, because there are significantly greater numbers of outgoing and incoming nerve fibers at those levels. There is also variation along the length of the cord in the number of fibers in the columns of white matter (and, therefore, in their relative size). The amount of white matter is greatest at cervical levels and least at sacral levels. This is because ascending and descending fibers from and to all levels must pass through the cervical cord. Such variations in the organization of specific gray matter and white matter components along the length of the spinal cord are outlined in the chart on the next below.

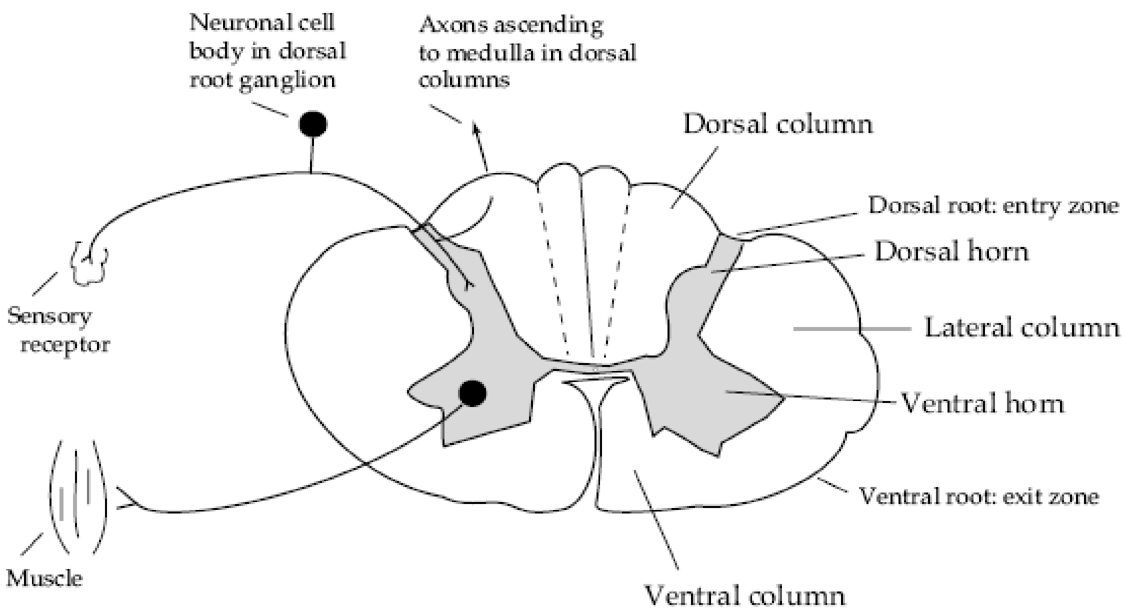

Fig. 2. Cross-section of the spinal cord at the cervical level. The general layout is the same at all levels of the cord, although specific details differ from one level to the next (see chart below). (Illustration by N.B. Cant)

	Internal features								
Spinal cord segment	**Dorsal horn**	**Lateral horn**	**Ventral horn**	**White matter**	**Gracile tract**	**Cuneate tract**	**Lateral corticospinal tract**	**Ventral corticospinal tract**	**Anterolateral system**
Cervical segments (8)	✓	--	✓	+++++	+++	+++	+++	+	+++
Thoracic segments (12)	✓	✓	✓	++++	+++	+ / --	++	+	++
Lumbar segments (5)	✓	--	✓	+++	+++	--	++	+	++
Sacral segments (5)	✓	--	✓	++	++	--	+	+	+
Coccygeal segment (1)	✓	--	✓	+	+	--	--	+	+

Legend: ✓ indicates the structure's presence; -- indicates the structure's absence; +'s indicate the tract's relative abundance across segments.

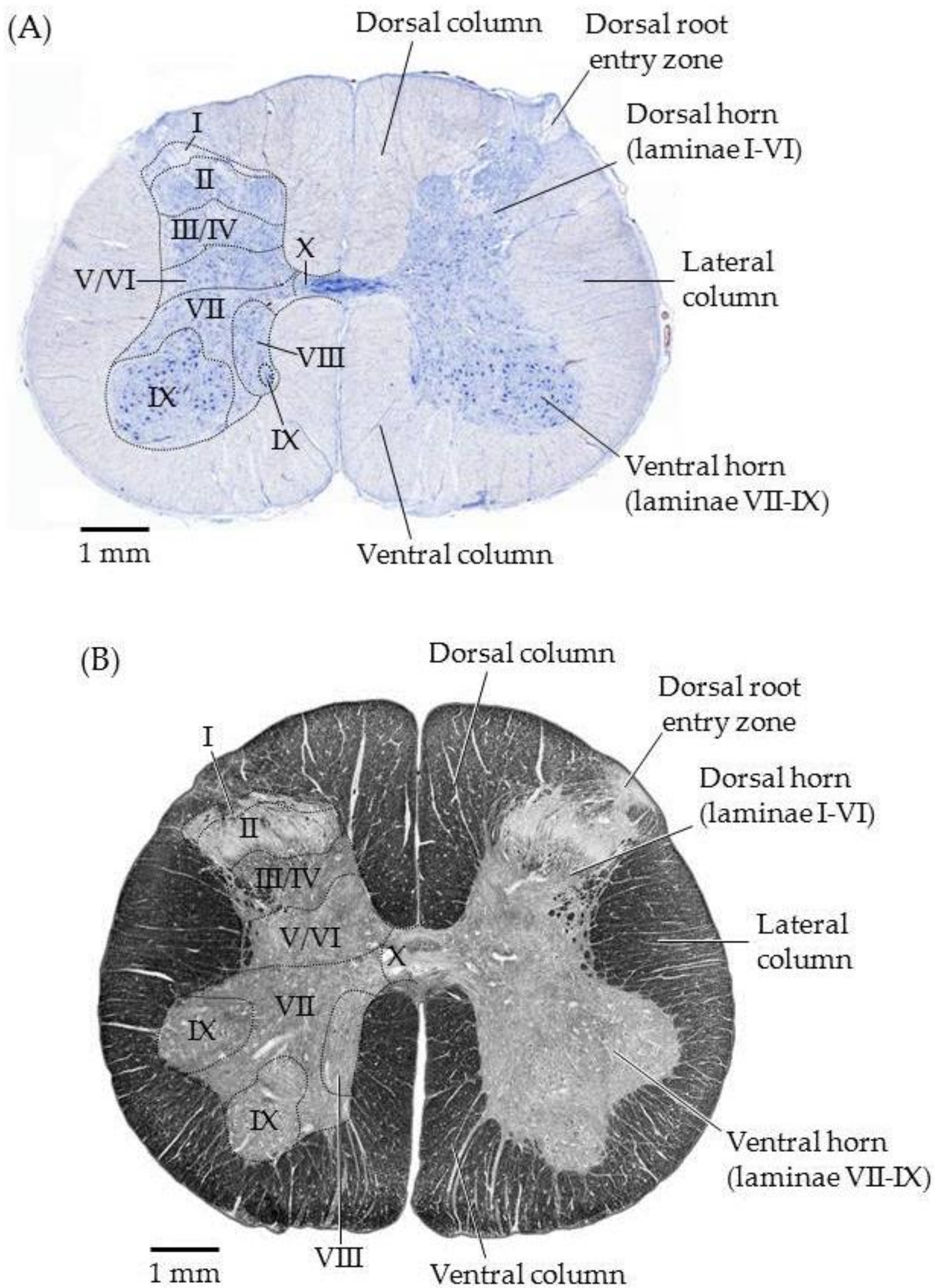

Fig. 3. Cross-sections through a lumbar segment of the human spinal cord. (A) Nissl stain highlighting cell bodies. (B) Facsimile of a myelin stain highlighting (in dark tones) white matter. (images by L.E. White)

STUDY QUESTION

Identify the MOST ACCURATE statement regarding the longitudinal organization of the spinal cord.

A. In the thoracic segments of the spinal cord, the volume of gray matter is greater than the volume of white matter.
B. The sympathetic preganglionic neurons are localized to the thoracic segments of the spinal cord.
C. There is progressively more white matter in the spinal cord from one segment to the next in a caudal progression.
D. The ventral horns achieve their greatest size in the thoracic segments of the spinal cord.
E. There is more neural circuitry in the gray matter of the thoracic segments than in the cervical or lumbosacral enlargements of the spinal cord.