Medical Neuroscience | Tutorial Notes

Corticospinal and Corticobulbar 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.

NCC4. Life experiences change the nervous system.

LEARNING OBJECTIVES

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

1. Characterize the organization of the corticospinal pathway from cortex to lower motor circuits in the spinal cord.
2. Characterize the organization of the corticobulbar pathway from cortex to lower motor circuits in the brainstem.
3. Recognize components of the corticospinal and corticobulbar pathways in the hemispheres, brainstem and spinal cord.
4. Sketch the corticospinal and corticobulbar pathways from cortex to lower motor circuits for volitional movement.

TUTORIAL NARRATIVE

Introduction

The goal of this tutorial is to review the organization of the pathways by which the upper motor neurons of the motor cortex governs the lower motor neuronal circuits of the spinal cord and brainstem. The neuroanatomical organization of these pathways is covered here. The more detailed account of their neurophysiological roles in motor control is provided in prior tutorials in Unit 4, and in Purves et al., *Neuroscience 5th Ed.*[2], Chapters 16-17 (Sinauer Assoc., Inc.). It is important for your understanding of neurological deficits seen in the clinic to know where these pathways travel relative to the somatic sensory pathways and to other structures (including the cranial nerve nuclei) in the brain and spinal cord.

Descending pathways to the spinal cord

The corticospinal and corticobulbar pathways are illustrated in **Figures 1** and **2**. Neurons in layer V of the motor cortex give rise to axons that descend through the **internal capsule**, the **cerebral peduncle** and the **medullary pyramids** to the caudal end of the medulla where most of them cross in the **pyramidal decussation**. These crossed fibers descend through the **lateral corticospinal tract** to terminate on motor neurons and

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

interneurons in the lateral aspect of the ventral horn. A small number of fibers do not cross in the pyramids but remain on the same side. These axons form the **anterior corticospinal tract** and innervate the medial aspects of the ventral horn bilaterally.

Descending cortical axons that innervate the cranial nerve motor nuclei for the muscles of the face and head are known as the **corticobulbar tract**[3]. Most of these axons innervate *bilaterally* premotor interneurons associated with brainstem reticular formation. The interneurons of the reticular formation, in turn, supply the motor nuclei. Some of the cranial nerve motor nuclei also receive direct bilateral input from the motor cortex. The consequence of the bilateral corticobulbar innervation is that damage to the fibers on only one side does not result in dramatic deficits in function. There are three notable exceptions to the pattern of symmetrical, bilateral cortical innervation of the local circuits controlling cranial nerve motor nuclei. For each of these motor nuclei, corticobulbar inputs arise from both cerebral hemispheres, but there is some bias in favor of inputs from the *contralateral* motor cortex:

1) the hypoglossal nucleus;
2) the trigeminal motor nucleus;
3) the part of the facial motor nucleus that innervates the lower face. (The part of the facial motor nucleus that innervates the upper face is innervated bilaterally)[4].

Essentially, functions involving muscles of the face that may be performed unilaterally (i.e., on one side of the face, such as pushing the tongue against one cheek, biting on one side with the lateral dentition, or raising one corner of the mouth) are governed by upper motor neuronal control signals from the contralateral motor cortex.

There are other important descending pathways to the spinal cord. The **vestibulospinal** and **reticulospinal** pathways are the most important, providing descending fibers from the **vestibular nuclei** and the **reticular formation**, respectively, that innervate lower motor neurons located medially in the spinal cord. You may also learn about a "tectospinal" pathway from the superior colliculus to the cervical spinal cord, but most of the descending output from the superior colliculus appears to be mediated via indirect connections through reticulospinal projections. Here's what's important to know about these brainstem-to-spinal cord pathways:

- **vestibulospinal tracts**—*feedback* adjustments of posture in response to head movements and disturbances of postural stability
- **reticulospinal tract**—*feedforward* adjustments of posture that <u>anticipate</u> instability associated with voluntary movements
- **tectospinal tract** (mediated by projections to reticular formation and reticulospinal projections)—*feedback* adjustments of head and neck posture that support a change in direction of gaze

[3] A note about this term, "corticobulbar". The brainstem has a shape somewhat resembling a bulb, especially when one considers the shape of the pons. Some authors use this term "corticobulbar" to refer to <u>all</u> projections from cortex that terminate in the brainstem, including the massive input to the pontine gray matter that we considered when we discussed input to the cerebellum via the middle cerebellar peduncles. However, for our purposes, the term "corticobulbar" will be used to refer to just those cortical projections that innervate circuits associated with cranial nerve nuclei in each division of the brainstem. We will use the term "corticopontine" to refer to those cortical axons that terminate among the pontine nuclei in the base of the pons.

[4] See Box 17A in *Neuroscience, 5th Ed.* for a detailed explanation of this pattern of corticobulbar innervation. The differential supply of corticobulbar inputs to these two parts of the facial motor nucleus is why it is important to test the lower face and the upper face separately in a neurological examination.

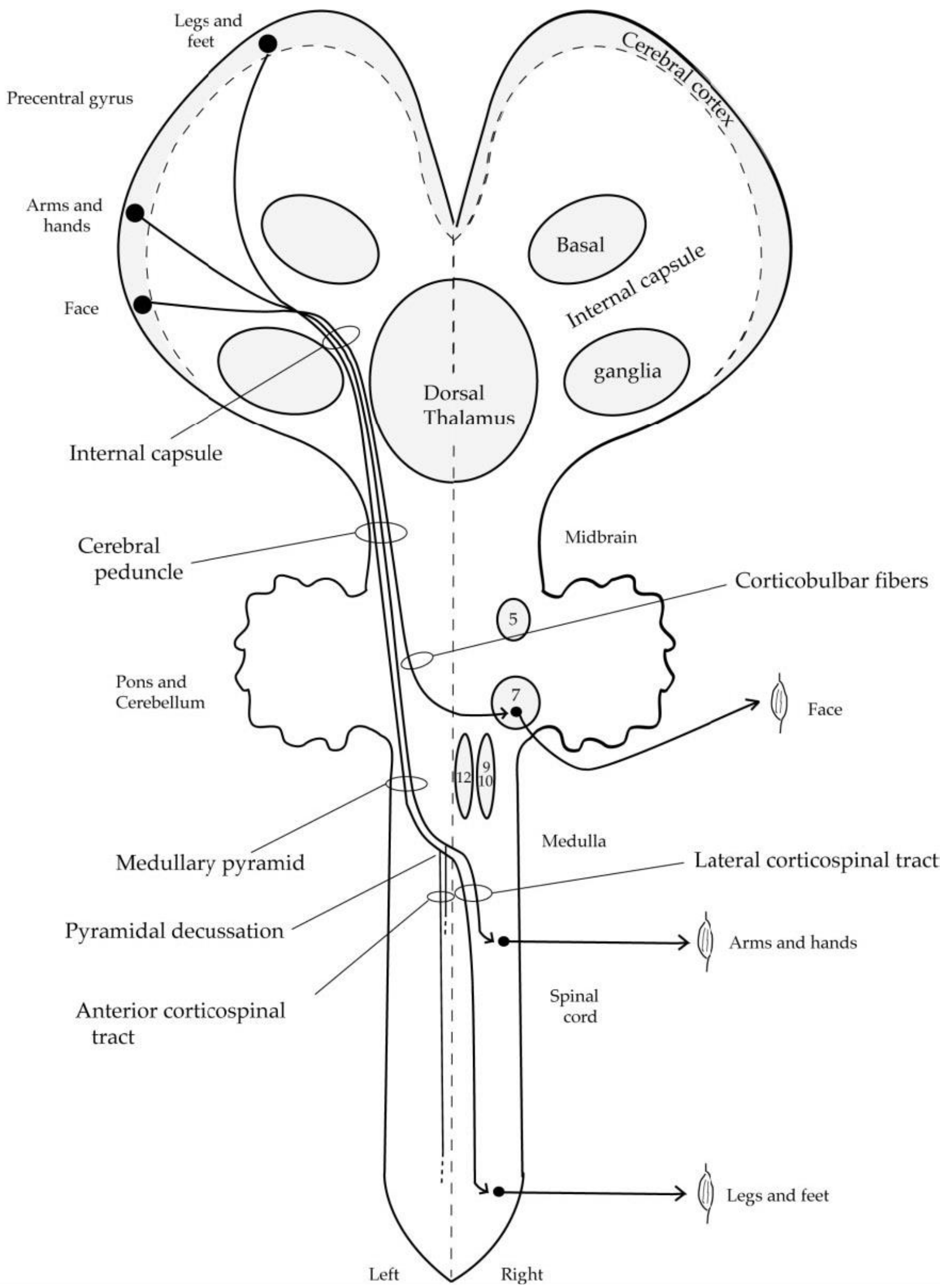

Figure 1. Diagram of the corticospinal and corticobulbar tracts. Most of the corticospinal fibers cross in the pyramidal decussation to form the lateral corticospinal tract. A small percentage of the fibers in the medullary pyramids do not cross in the decussation. These form the anterior corticospinal tract. Some of these fibers ultimately cross the midline lower in the spinal cord (not shown). Descending fibers that innervate the cranial nerve motor nuclei are known as corticobulbar fibers. Unlike the corticospinal tract, which is mostly crossed, most of the corticobulbar fibers give rise to bilateral innervation, as noted in the text. On this diagram, only the corticobulbar fibers that innervate the contralateral motor nucleus of the seventh nerve are illustrated. (Illustration by N.B. Cant; cf. Figure 17.4 in *Neuroscience, 5th Ed.*, Sinauer Assoc., Inc.)

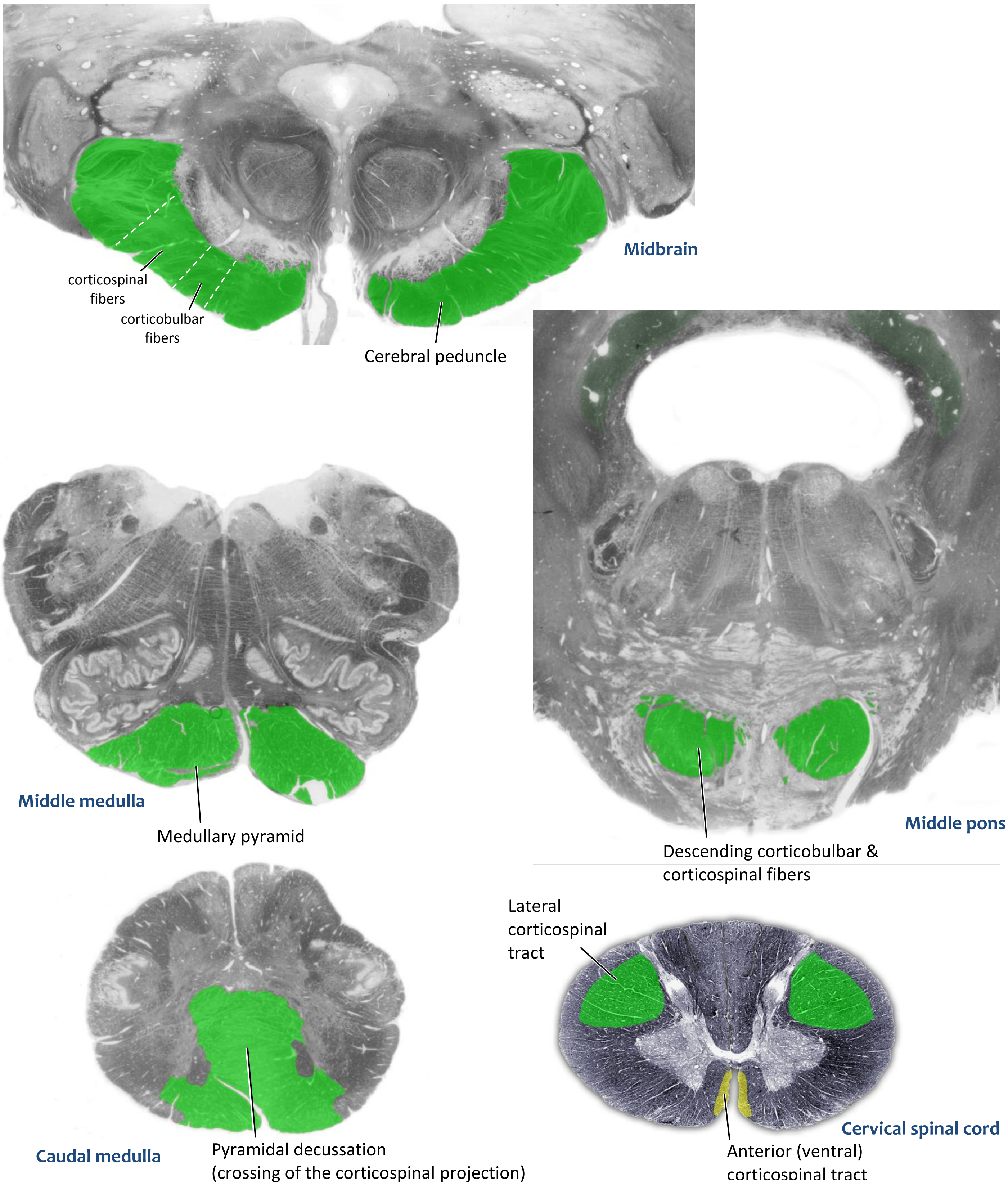
corticospinal fibers
corticobulbar fibers
Cerebral peduncle
Midbrain
Middle medulla
Medullary pyramid
Descending corticobulbar & corticospinal fibers
Middle pons
Lateral corticospinal tract
Caudal medulla
Pyramidal decussation (crossing of the corticospinal projection)
Cervical spinal cord
Anterior (ventral) corticospinal tract

Figure 2. (previous page) Sections through the spinal cord and brainstem with components of the descending corticospinal and corticobulbar pathways labeled. Note the approximate locations of these pathways in the cerebral peduncle (see midbrain section). It is important to understand the location of the motor tracts with respect to the somatic sensory tracts considered in Unit 3. (sections from ***Sylvius4***)

> There are about 20 million axons in the each cerebral peduncle, but only 1 million axons (more or less) in each medullary pyramid. (So please don't refer to the cerebral peduncle as the "corticospinal tract.") This means, obviously, that about 95% of the axons in the cerebral peduncle do not terminate in the spinal cord. The largest component of the cerebral peduncle is the "corticopontine" projection, which is the input from the cerebral cortex to the scattered nuclei in the base of the pons that relay cortical signals into the cerebellum. Accordingly, there are also about 20 million axons in each middle cerebellar peduncle.

STUDY QUESTIONS

Q1. Where would you find most of the synapses made by axons in one medullary pyramid?

- A. ipsilateral motor cortex
- B. contralateral motor cortex
- C. contralateral ventral horn
- D. ipsilateral ventral horn
- E. contralateral dorsal horn
- F. ipsilateral dorsal horn

Q2. Damage to one medullary pyramid would impact which "activity of daily living" most significantly?

- A. writing using the contralateral hand
- B. writing using the ipsilateral hand
- C. pushing open a door with the contralateral hand
- D. pushing open a door with the ipsilateral hand
- E. kicking a ball with the contralateral foot
- F. kicking a ball with the ipsilateral foot
- G. walking
- H. jumping

Q3. What cranial nerve innervates the muscles of facial expression?

- A. CN III
- B. CN V
- C. CN VII
- D. CN IX

Q4. Where would you find the facial motor nucleus?

A. thalamus
B. midbrain
C. pons
D. medulla oblongata