Medical Neuroscience | Tutorial Notes

Lower Motor Neuronal Control—Overview and Motor Units

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.

LEARNING OBJECTIVES

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

1. Discuss the general somatotopic organization of motor neurons in the ventral horn of the spinal cord.
2. Characterize the motor unit and discuss different types of motor units.

TUTORIAL OUTLINE

I. Introduction

- A. Overall organization of the neural centers that control movement (see **Figure 16.1**[2])
  - 1. spinal cord circuits: "final common pathway" or "basic motor system"
    - a. **segmental reflexes** involving alpha (and gamma) motor neurons (i.e., **"lower motor neurons"**), local circuit interneurons, and afferent somatic sensory input (e.g., myotatic or "knee-jerk" reflex)
    - b. **intersegmental reflexes** mediated by interneurons that coordinate the activities of segmental circuits at multiple levels of the spinal cord (and brainstem) (e.g., central pattern generators for locomotion)
  - 2. descending control systems
    - a. volitional somatic movement: pyramidal motor system
      - (i) **motor cortex** (primary motor cortex and premotor cortex) plans and directs the execution of volition movements ("pyramidal" -- outflow from the motor cortex is directed down the pyramidal tract; i.e., via the medullary pyramids)
    - b. involuntary somatic movement ("extrapyramidal" -- outflow does not involve the pyramidal tract)

---

[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]

(i) brainstem centers (**reticular formation**, **vestibular nuclei**, **superior colliculus**) coordinate somatic motor activities that are largely involuntary (e.g., postural adjustments and orienting reflexes toward sensory stimuli)

(ii) limbic centers in the forebrain (**amygdala, orbital-medial prefrontal cortex, hypothalamus**) also motivate movement (important in emotional or appetitive behavior, as well as addictive behavior)

c. visceral motor activity -- related to homeostasis and emergency responses ("fight or flight"), and the expression of emotional behavior

(i) activities are usually integrated with somatic motor behavior

3. major brain systems that modulate descending control systems

a. **basal ganglia** (dorsal stream) selects and initiates appropriate motor programs and suppresses inappropriate motor programs

b. **cerebellum** adjusts motor programs "on-line" with the aid of proprioceptive feedback

II. Spinal Cord Circuitry and the Control of Movement

A. distribution of lower motor neurons

1. spinal cord (see Appendix **Figure A4-A6**, **Table A1**, and **Figure 16.2**)

a. motor neurons (both alpha and gamma) are located in the ventral horn of the spinal cord

b. the **motor neuronal pool** for a given muscle (i.e., all the motor neurons that innervate a muscle) forms a rod-shaped column that spans several cord segments

c. somatotopy within the ventral horn

(i) segmental organization: **cervical** and **lumbar enlargements** contain motor neurons that govern the arms and legs

(ii) organization across the ventral horn (see **Figure 16.3**)

- *neurons that innervate axial and proximal musculature are located medially in the ventral horn*

- *neurons that innervate the distal extremity are located laterally in the ventral horn*

2. brainstem (see Appendix **Figure A8**)

a. motor neurons are located in cranial nerve nuclei in the dorsal-medial (somatic motor) and paramedian (branchial motor) zones

b. the motor neuronal pool for a given muscle forms a column or cluster in a brainstem motor nucleus

B. The motor unit and its recruitment

1. **motor unit** = an alpha motor neuron and the muscle fibers it innervates (see **Figures 16.5** & **16.6**)
    a. slow motor units
    b. fast fatigue-resistant motor units
    c. fast fatigable motor units
2. regulation of muscle force
    a. **size principle**: slow motor units are recruited first, then fast fatigue-resistant motor units, and finally fast fatigable motor units (**Figure 16.7**)
    b. provides for the matching of the physiological properties of different motor unit types with the demands of specific motor task
    c. motor units are subject to use-dependent plasticity (see **Box 16A**)

STUDY QUESTION

Q1. What kinds of neurons innervate skeletal muscle?

A. neurons in the motor cortex
B. neurons in the cerebellum
C. neurons in the basal ganglia
D. neurons in the ventral horn of the spinal cord
E. neurons in the dorsal horn of the spinal cord

Q2. Make fist. Now squeeze harder. What just happened?

A. When you squeezed harder, you recruited additional smaller motor units than the ones that were first activated.
B. When you squeezed harder, you recruited additional larger motor units than the ones that were first activated.
C. When you squeezed harder, you decreased the activity of lower motor neurons in the ventral horn of the cervical spinal cord.