

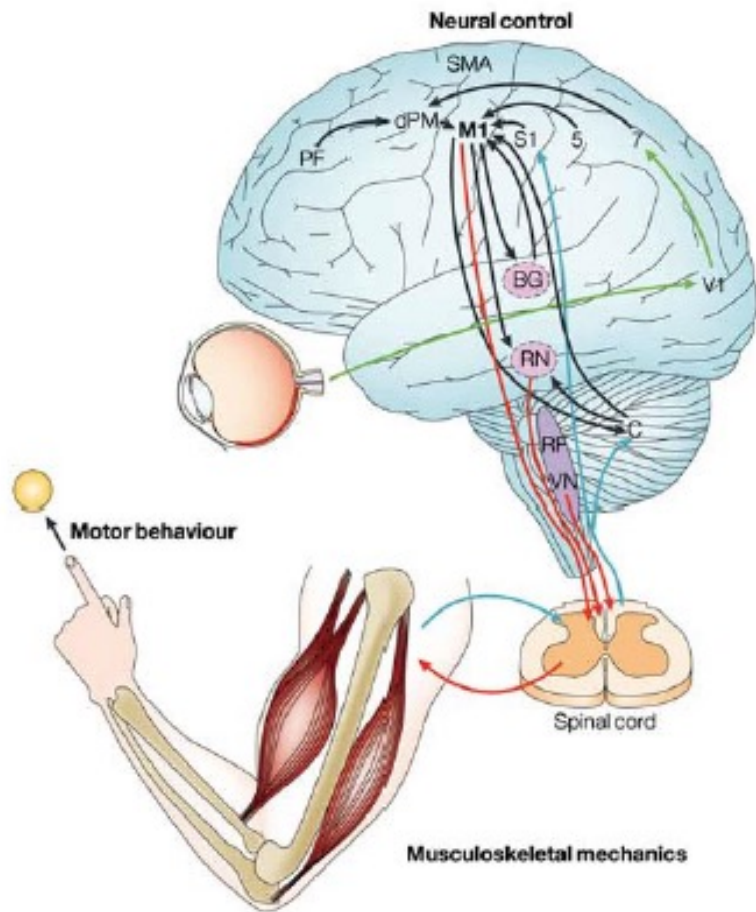
# Overview of the Motor System 2022\_v1

Professor Malcolm A. MacIver

Note correction to lecture 17: Not 200,000 motor units, rather 500,000 motor units in human body. Updated on Canvas (pptx and pdf) for Lecture 17.

- Organization of the motor system
- Alpha motor neuron and the motor unit
- Muscle and the neuromuscular junction
- Spinal reflexes
  - Myotatic reflex
  - Gamma motor neuron
  - Golgi tendon organ
  - Flexor reflex
- Central pattern generators
- Locomotion
- Central motor program
- Basal ganglia
- Cerebellum

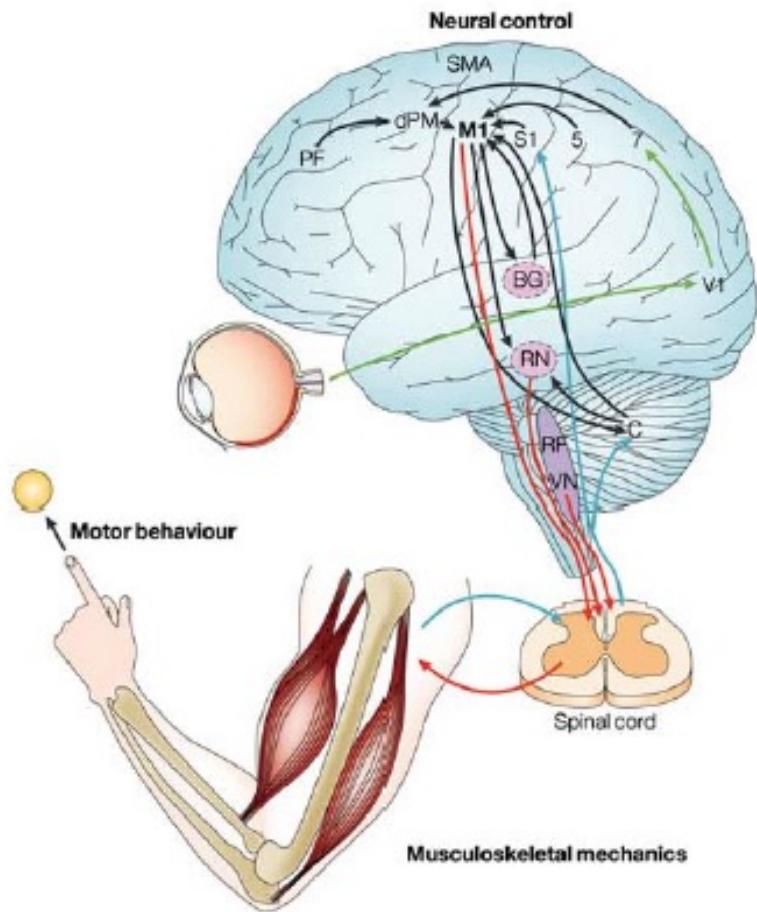
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Nature Reviews | Neuroscience

- dPM: dorsal pre-motor cortex
- M1: primary motor cortex
- PF: prefrontal cortex
- SMA: supplementary motor area
- S1: primary somatosensory cortex
- V1: primary visual cortex
  
- BG: basal ganglia
- C: cerebellum
  
- RF: reticular formation
- RN: red nucleus
- VN: vestibular nucleus

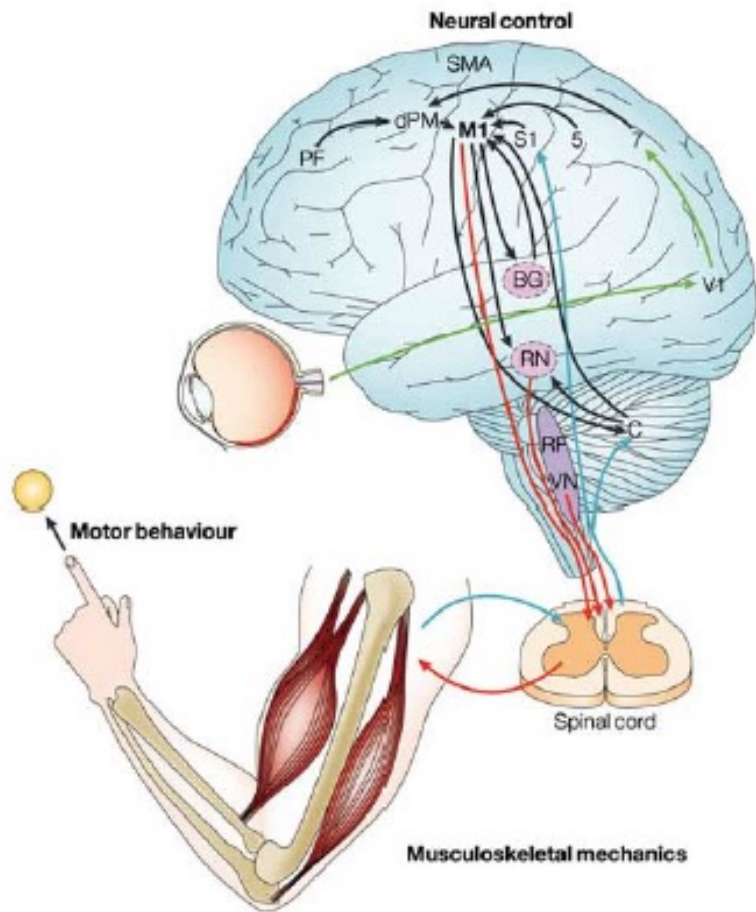
What is missing?



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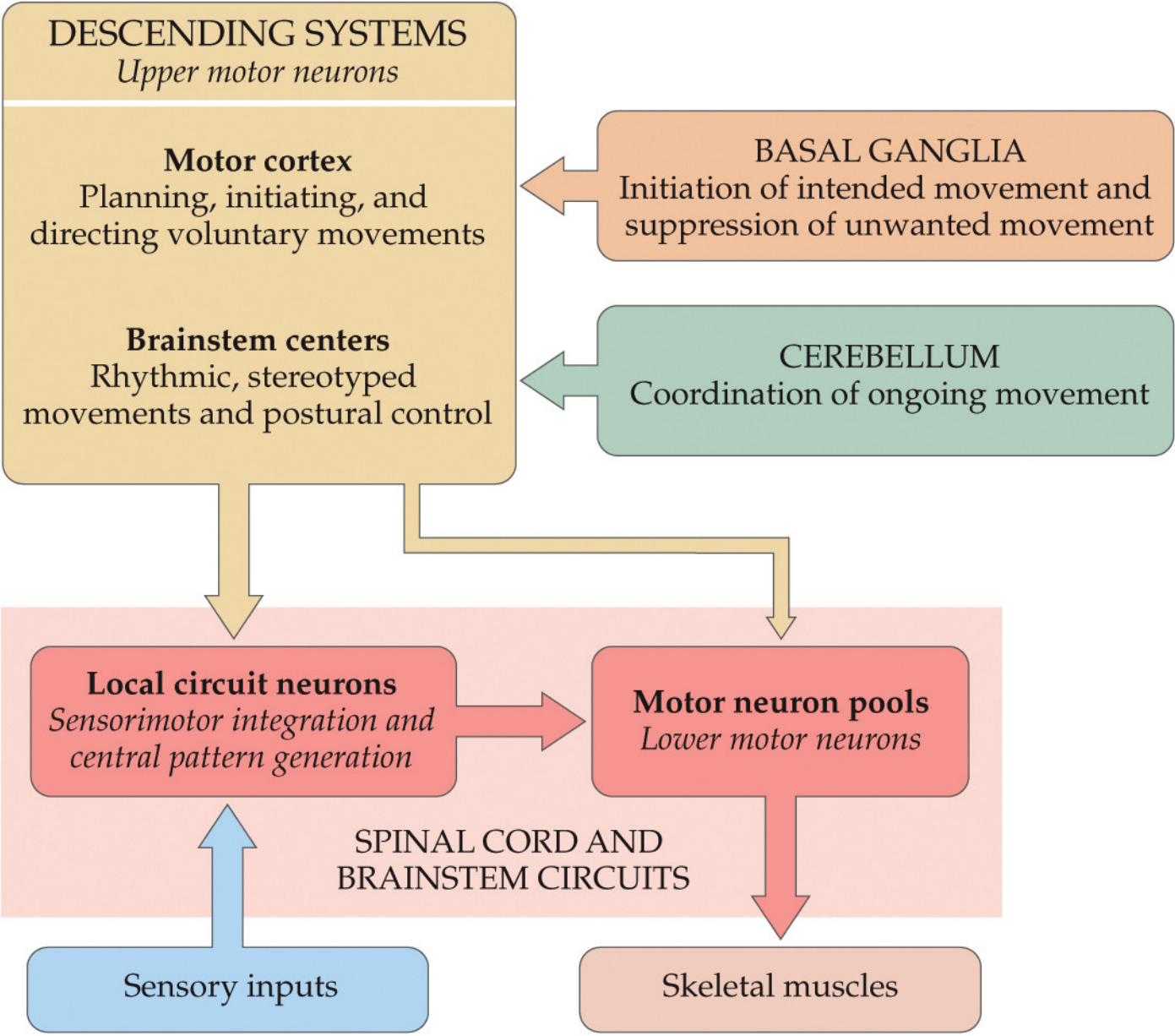
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Thalamus



Red: Motor control  
 Blue: Somatosensation (proprioception)  
 Black: Intrabrain communication  
 Green: Vision

FIGURE 16.1 Organization of neural structures involved in the control of movement





STRUCTURE	BEHAVIORS
Spinal Cord and Muscle	Basic reflexes and “preflexes”; basic coordination patterns
Brainstem	Multi-limb reflexes; postural stabilization
Cortex/telencephalon	Goals and planning; flexible sensorimotor tuning; adaptation

Preflexes are zero delay viscoelastic responses of muscle that correct for unintended stretch

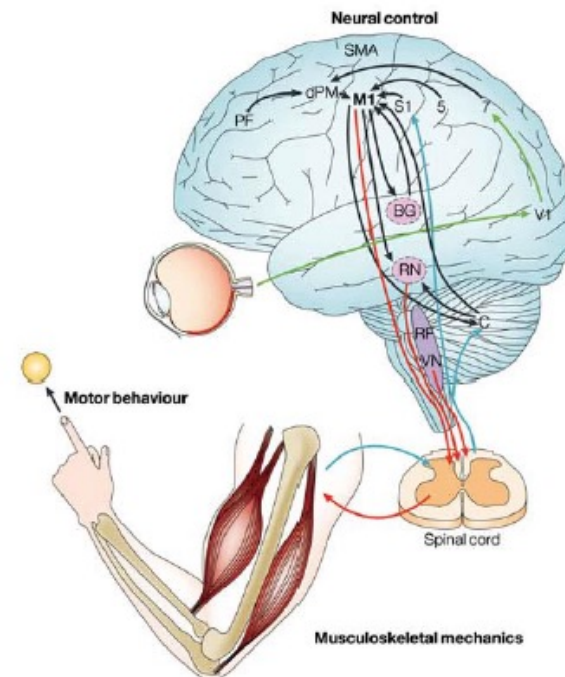


FIGURE 16.5 The motor unit

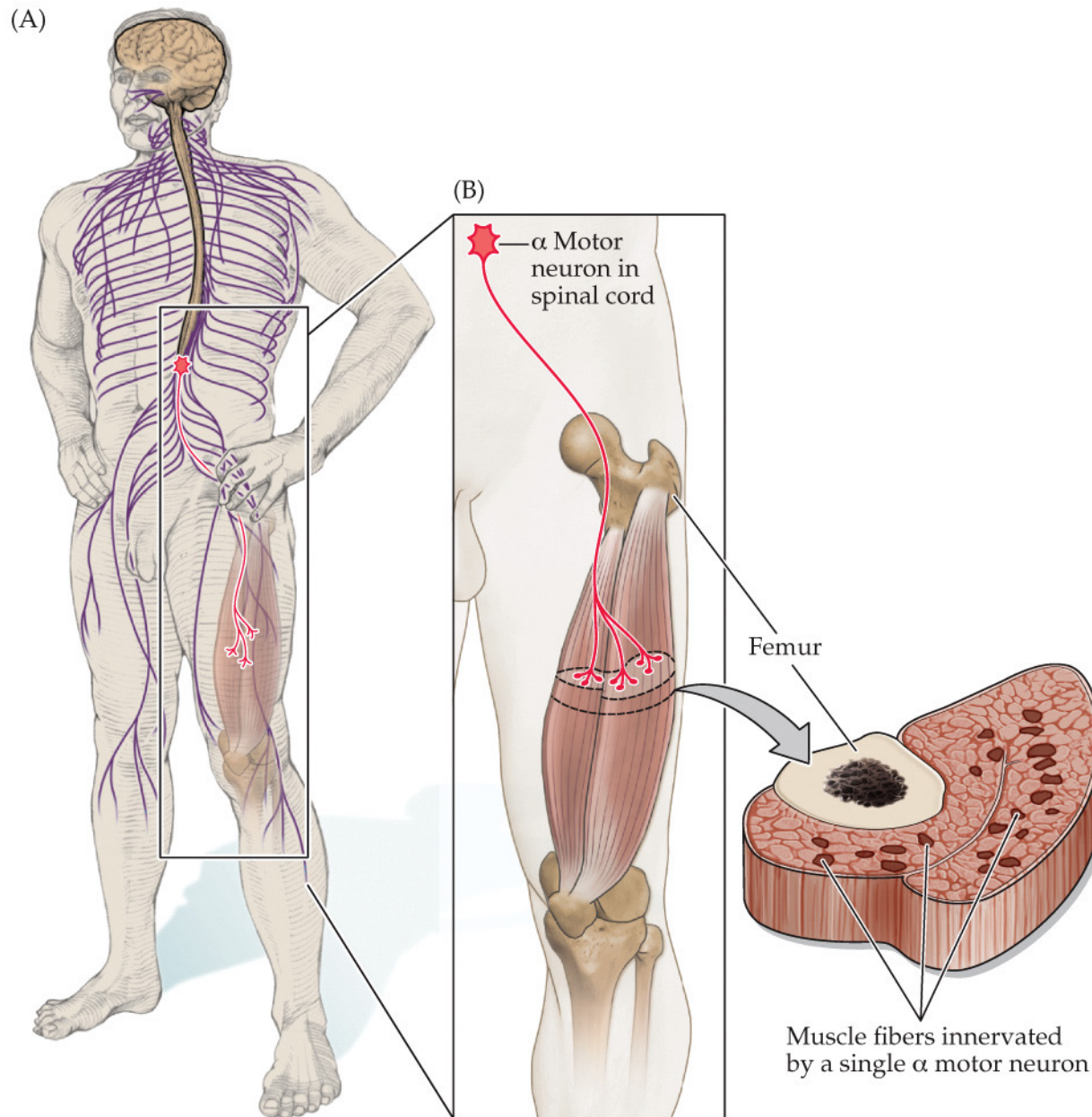


FIGURE 16.2 Distribution of lower motor neurons in the ventral horn of the spinal cord

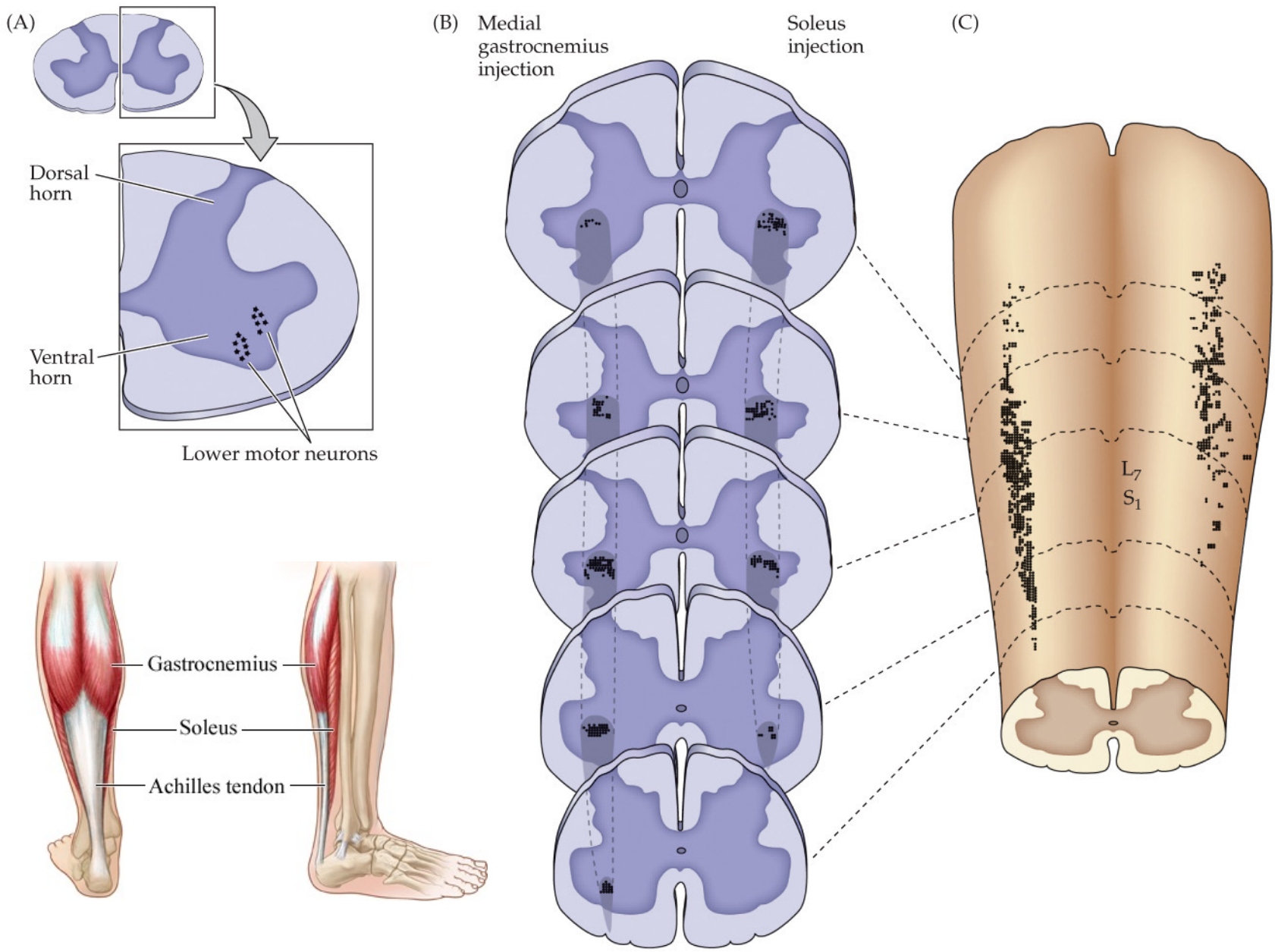
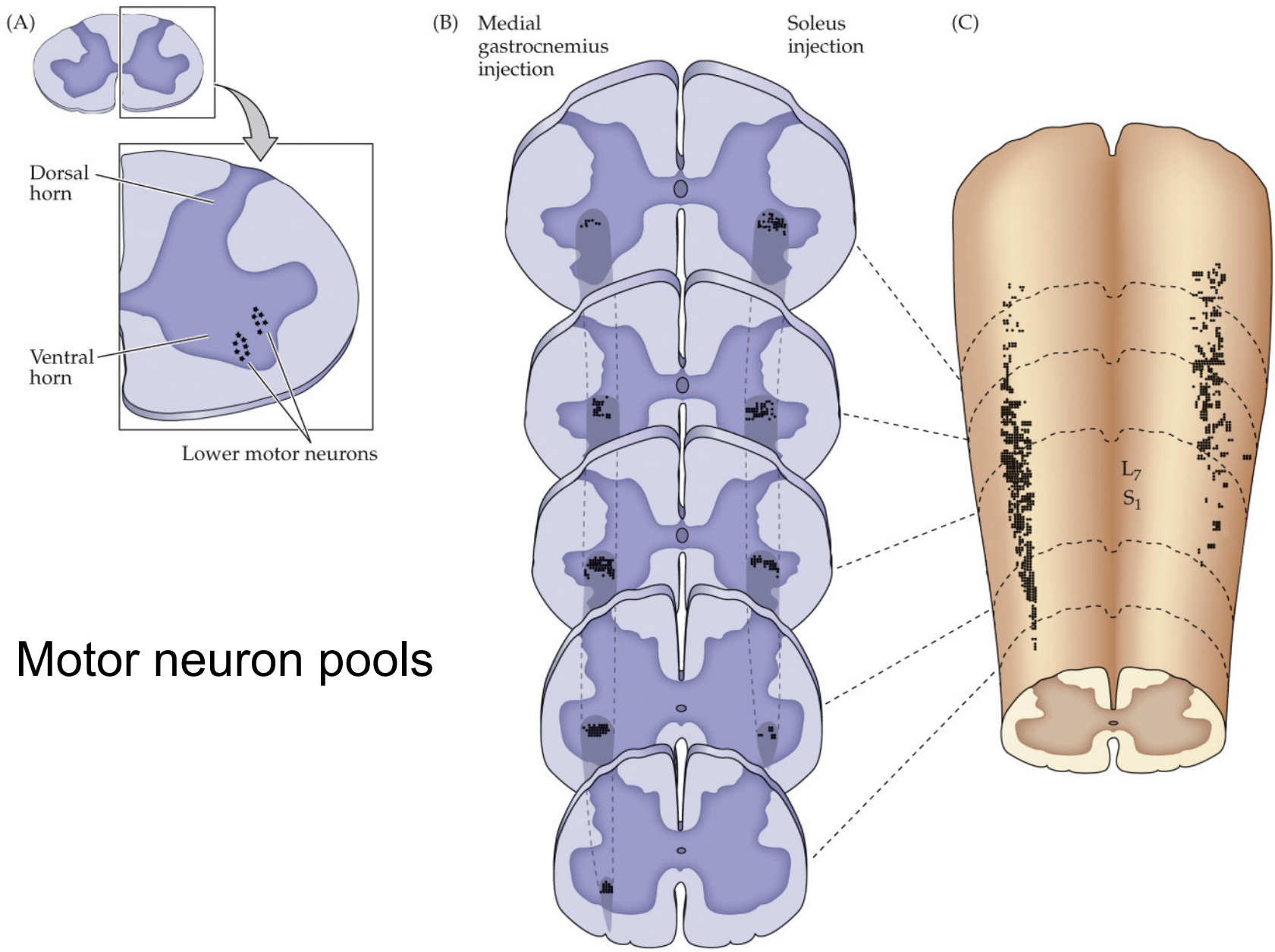


FIGURE 16.2 Distribution of lower motor neurons in the ventral horn of the spinal cord



Motor neuron pools



FIGURE 16.3 Somatotopic organization of lower motor neuron pools

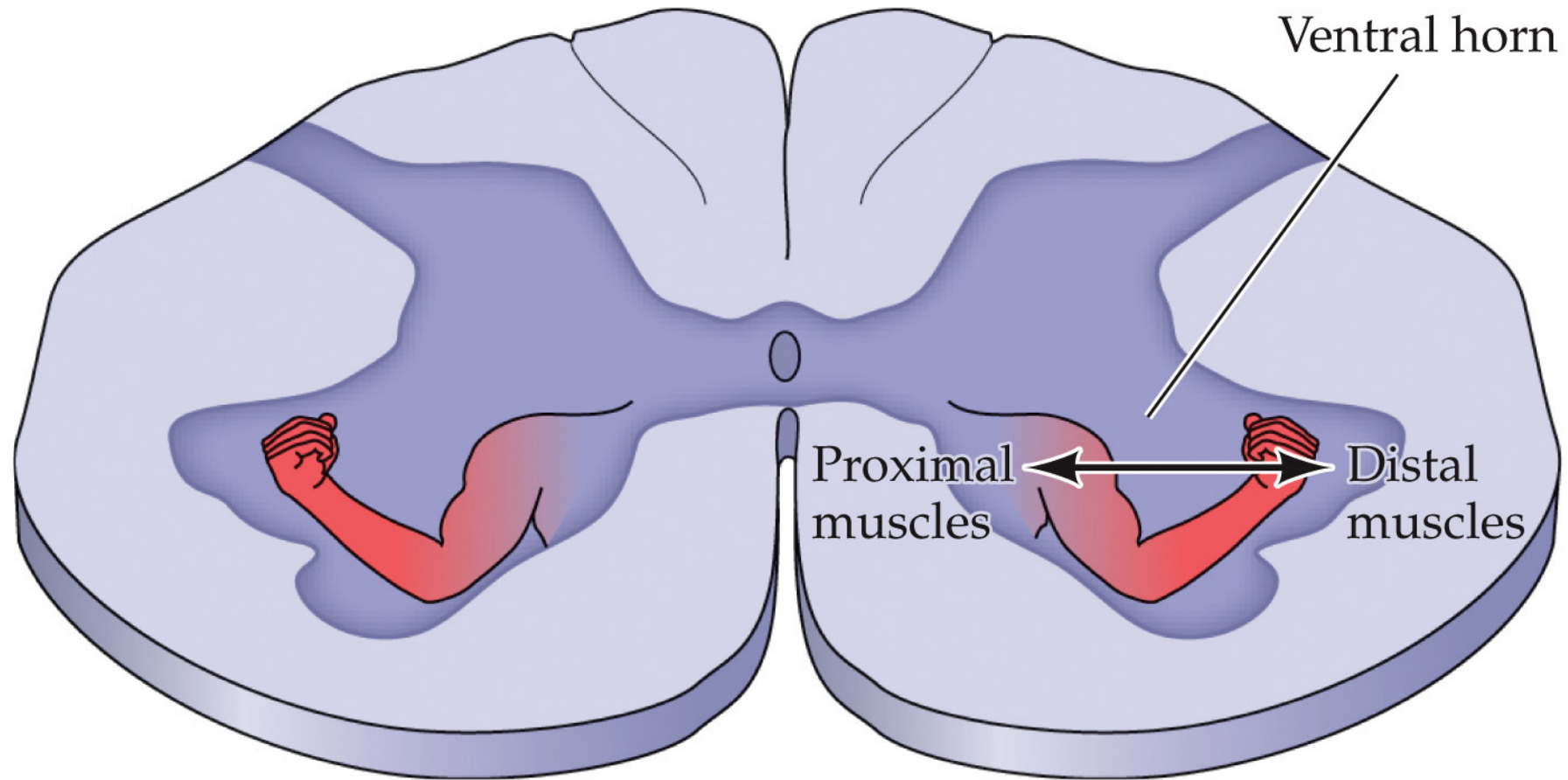
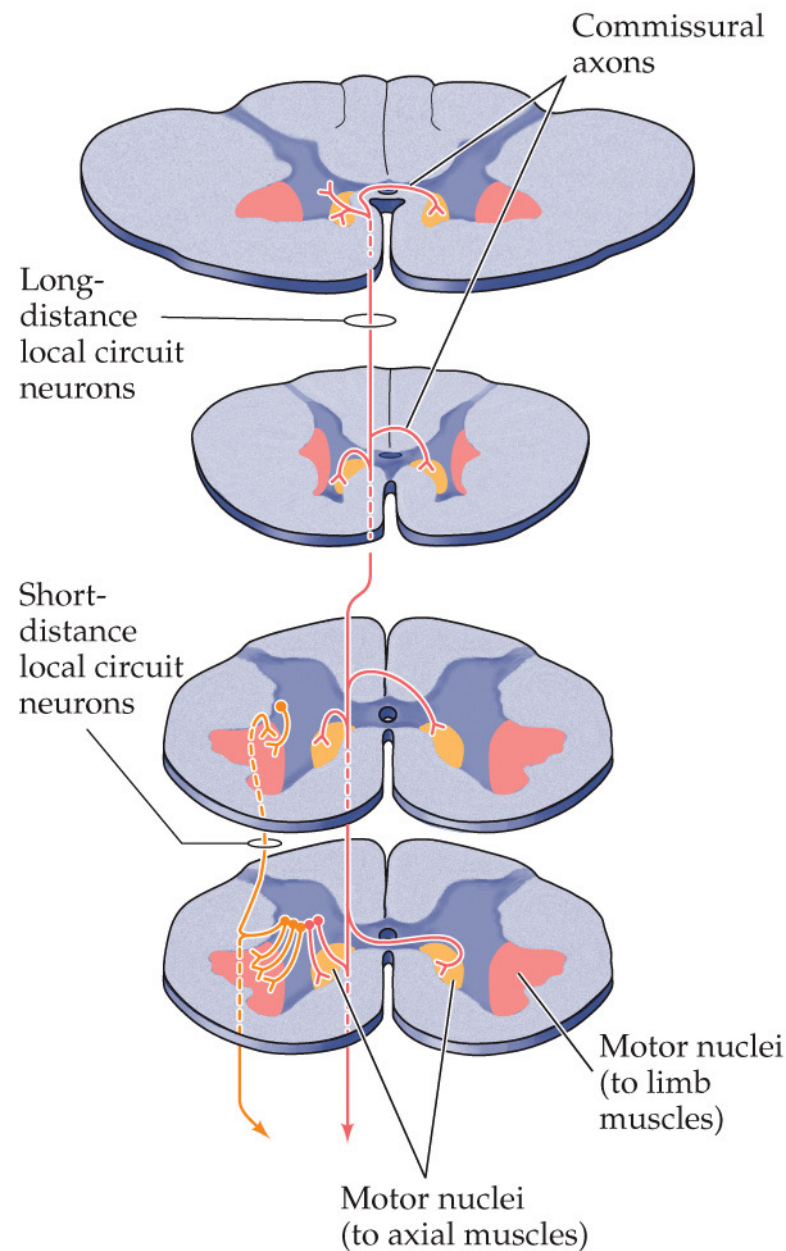
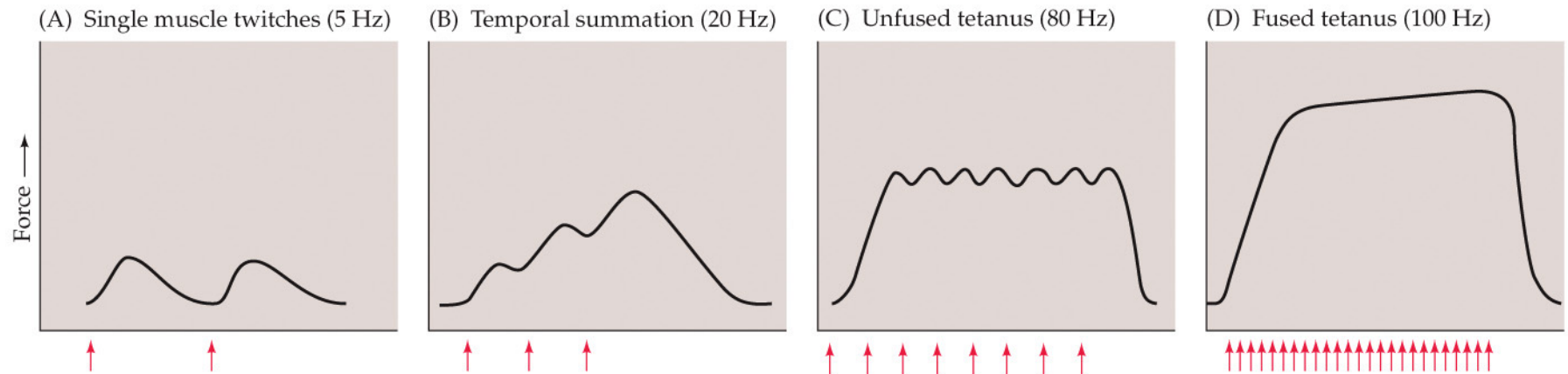


FIGURE 16.4 Local circuit neurons in the spinal cord gray matter



Twitch: The cycle of muscle contraction and relaxation resulting from a single  $\alpha$  motor neuron action potential

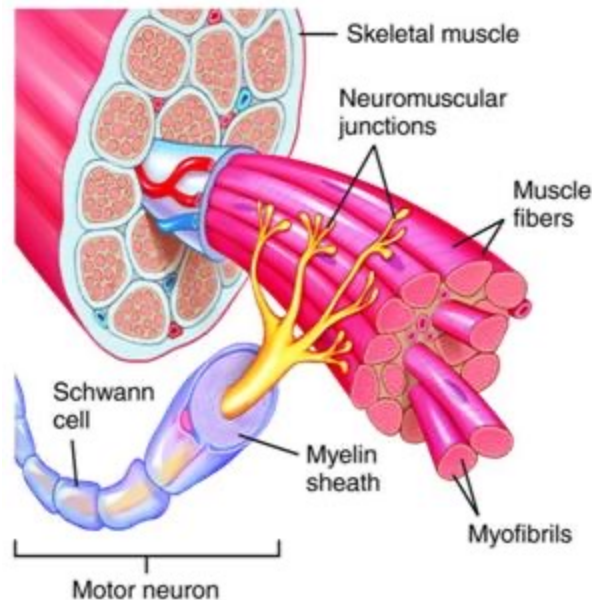


# Motor Unit

Single  $\alpha$  motor neuron and the muscle fibers that its axon innervates

Smallest unit of force generated by the motor system

Motor units and  $\alpha$  motor neurons vary in size





## Small alpha motoneurons

- Innervate few fibers
- Generates small forces
- Enable precise movements (i.e., fractionation of movement, eye movement)

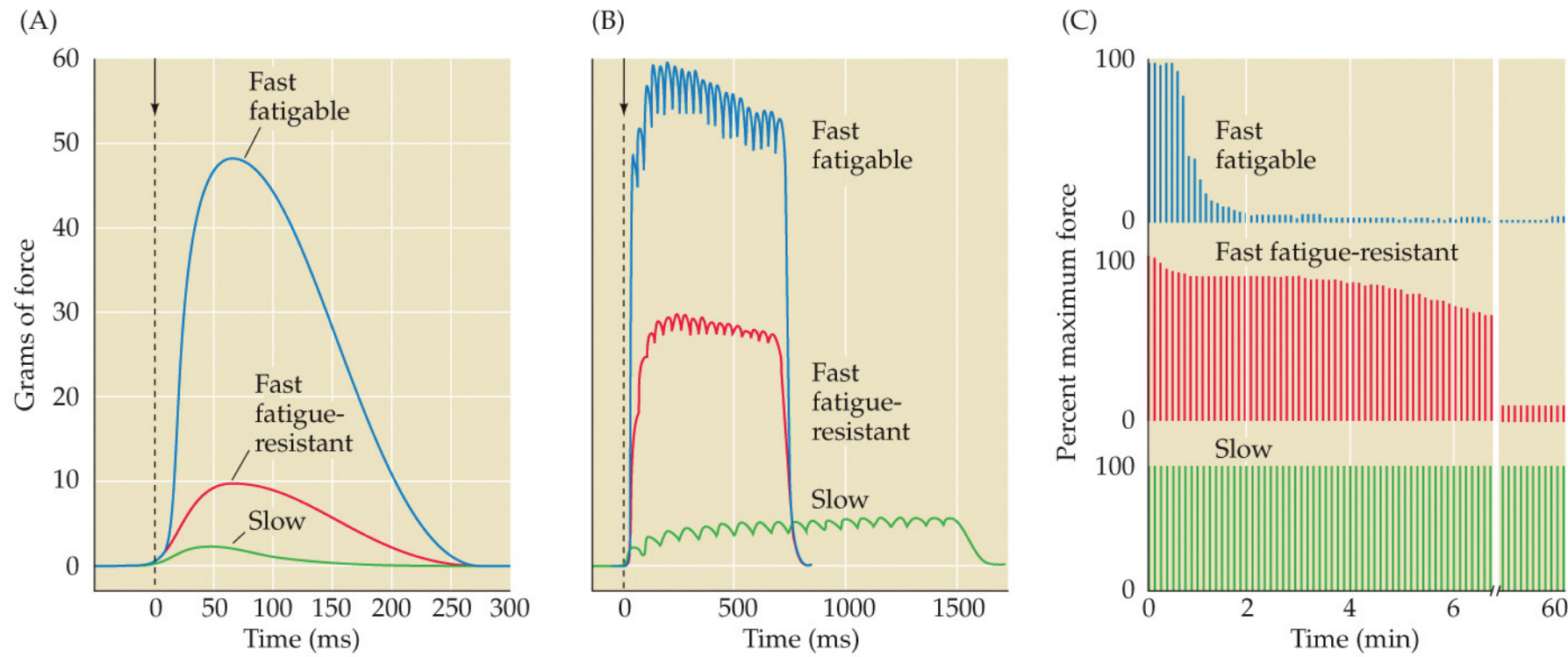


## Large alpha motoneurons

- Innervate many fibers
- Generate strong, powerful forces
- Ex: Gastrocnemius



FIGURE 16.6 Force and fatigability of the three different types of motor units



After Burke et al. (1973) *J. Physiol.* 234: 723–748.

**NEUROSCIENCE 6e, Figure 16.6**

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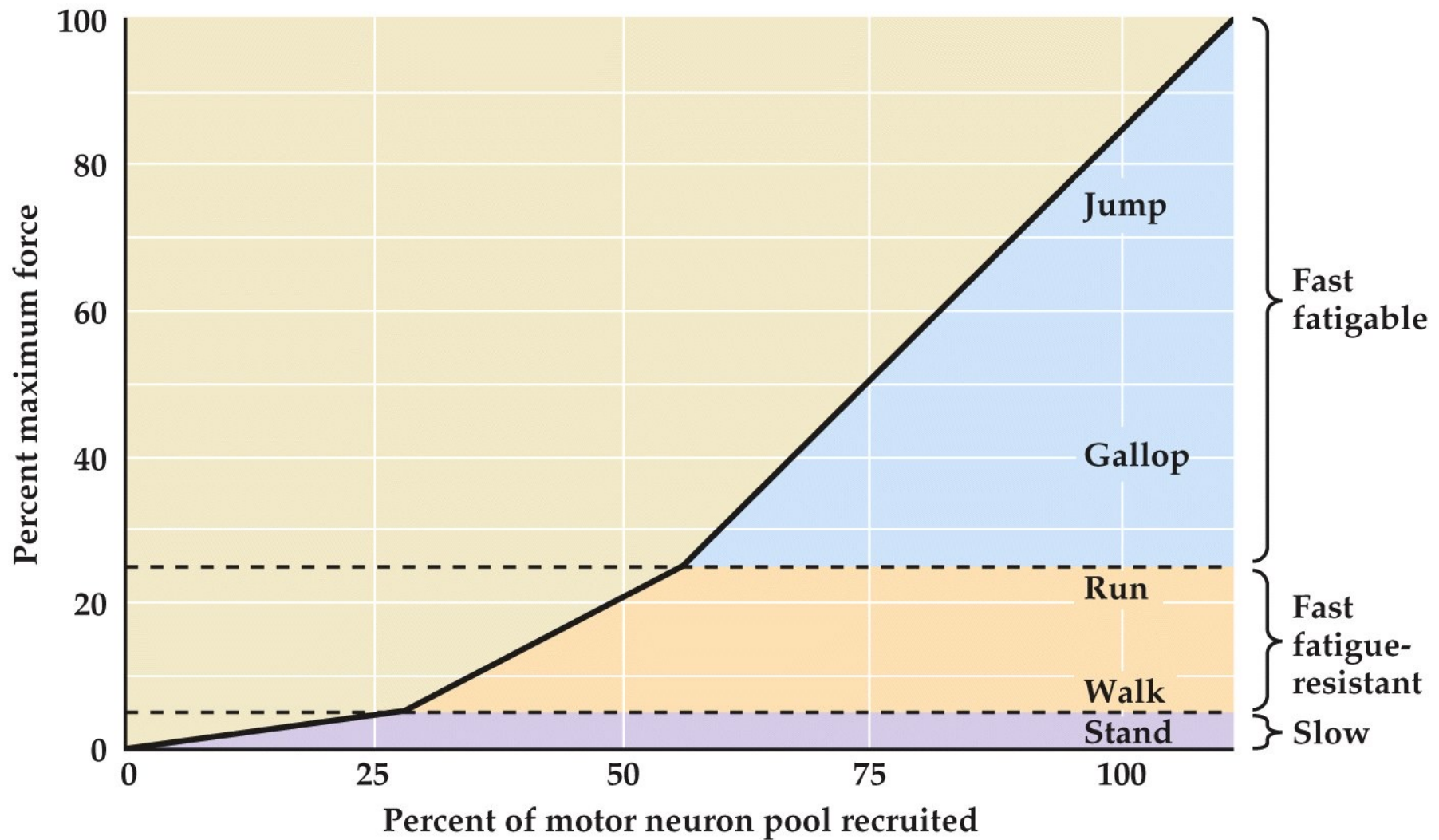
# Types of motor units

	Slow	Fast Fatigue Resistant	Fast Fatigable
Innervated by:	Small $\alpha$ motor neurons	I N T E R M E D I A T E	Large $\alpha$ motor neurons
Made of:	Small red muscle fibers		Larger pale muscle fibers
Fatigue:	Resistant to fatigue		Easily fatigued
Speed of contraction:	Slow		Fast
Force generated:	Small		Large
Used for:	Posture		Running, jumping

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# Motor neuron recruitment in the cat medial gastrocnemius muscle under different behavioral conditions



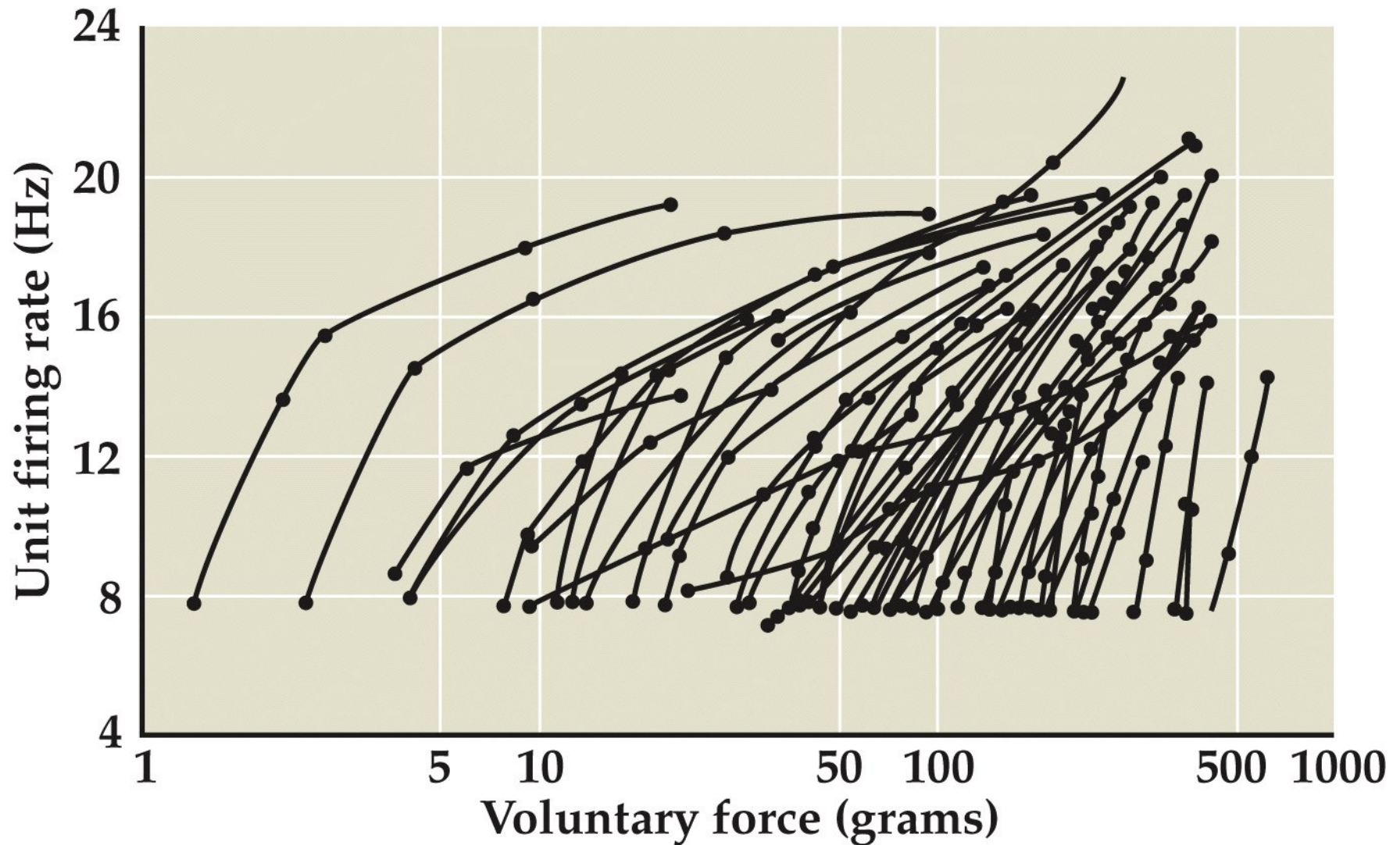
NEUROSCIENCE 5e, Figure 16.7

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SIZE PRINCIPLE



The number of active motor units and their rate of firing both increase with voluntary force



# Features of $\alpha$ motor neurons

	That innervate small motor units		That innervate large motor units
Axonal diameter	Smaller	C O N T I N U U M	Larger
Input resistance	Larger		Smaller
Excitability	Greater		Lesser
EPSP amplitude	Larger		Smaller
Duration of after-hyperpolarization	Longer		Shorter
	<ul style="list-style-type: none"> <li>-Easily depolarized</li> <li>-Slow rate of firing</li> <li>-Control slow muscle fibers needed for posture</li> </ul>		<ul style="list-style-type: none"> <li>-Difficult to depolarize</li> <li>-Fast rate of firing</li> <li>-Control fibers that produce max force used for jumping</li> </ul>

## Increase motor unit size, alpha motor neuron exhibits:

Increased	Decreased
Cell body size	Input resistance
Dendritic Complexity	Excitability
Short-term EPSP potentiation with repeated activation	Ia EPSP amplitude
Axonal diameter (i.e. faster conduction)	PSP decay constant
Number of axonal branches (i.e., more muscle fibers innervated)	Duration of after-hyperpolarization



