BMD ENG 301
Quantitative Systems Physiology
(Nervous System)

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.

Motor System Lecture Plan

- 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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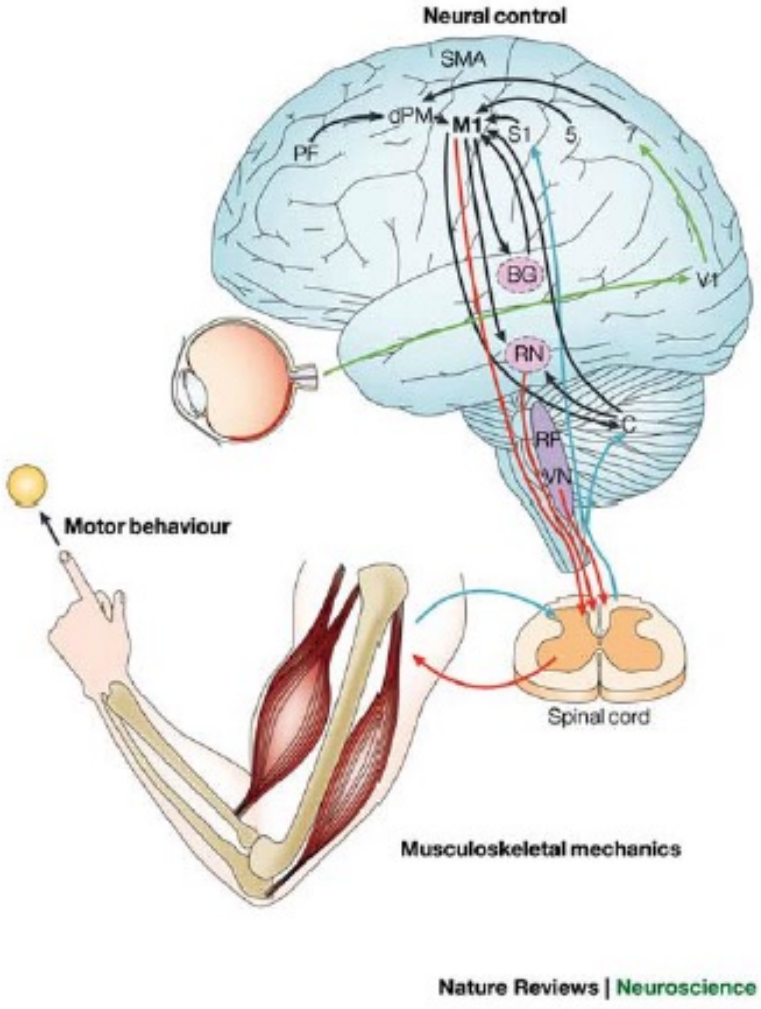
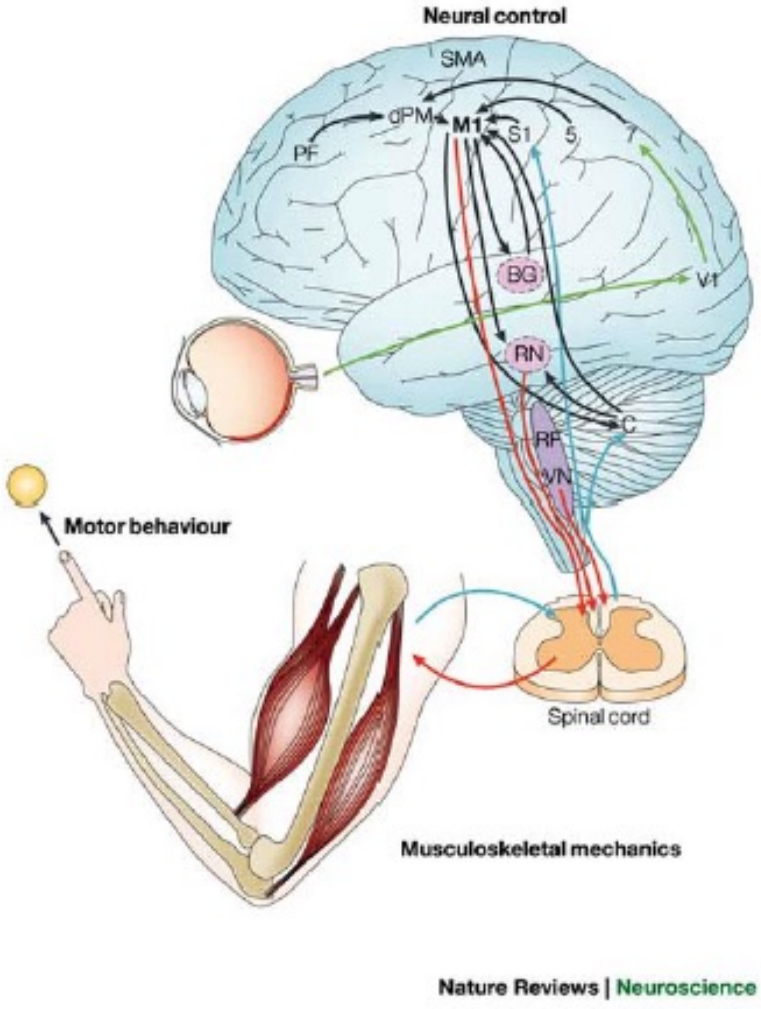


dPM: dorsal pre-motor cortex
M1: primary motor cortex
PF: prefrontal cortex
SMA: supplementary motor area
S1: primary somatosensory cortex
V1: primary visual cortex

BG: basal ganglia
C: cerebellum

RF: reticular formation
RN: red nucleus
VN: vestibular nucleus

What is missing?



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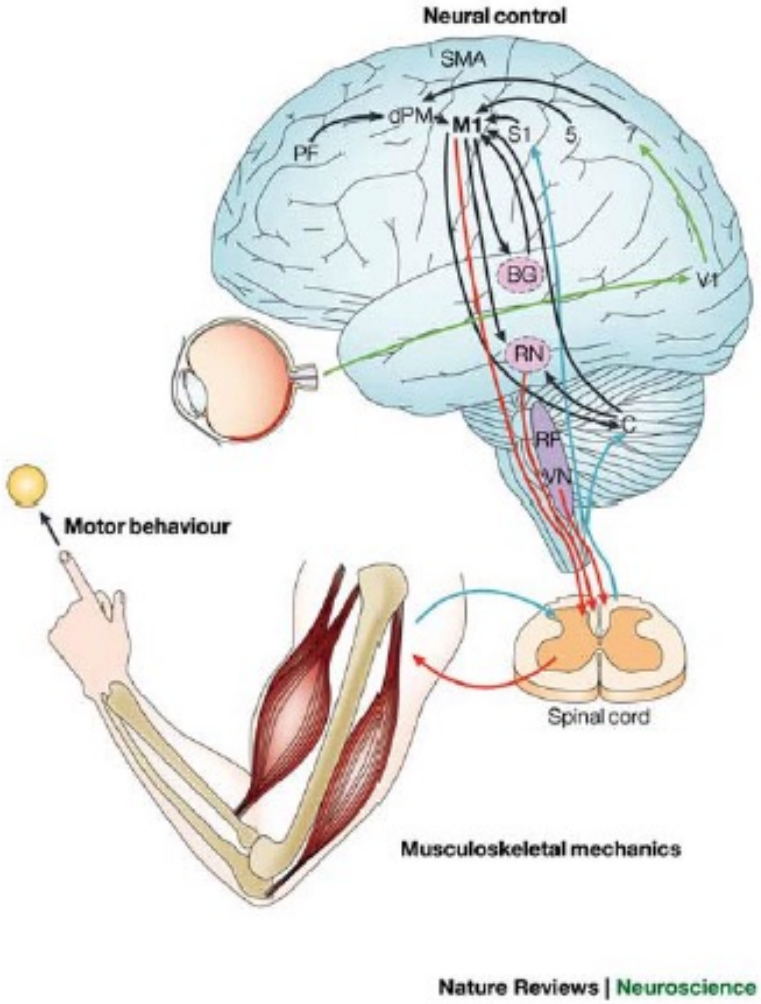
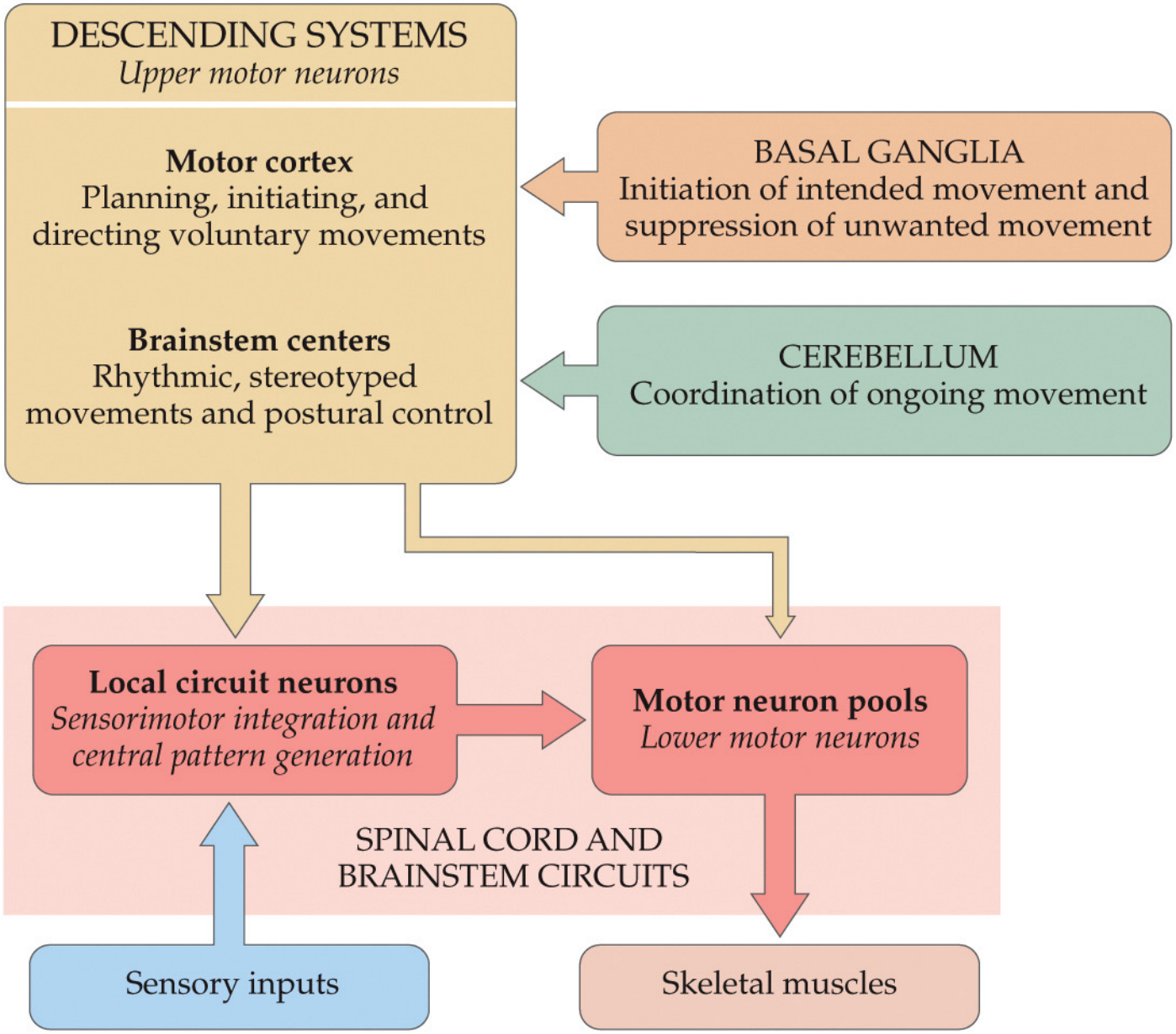
Thalamus



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

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



NEUROSCIENCE 6e, Figure 16.1

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

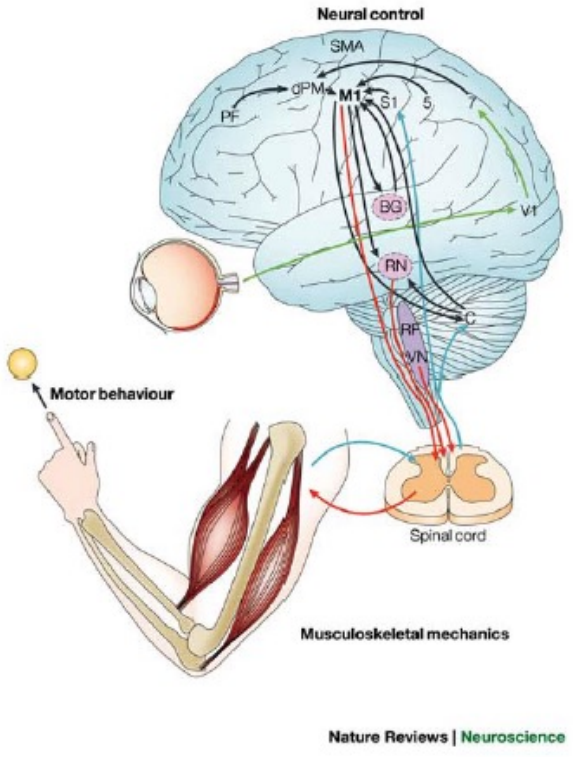
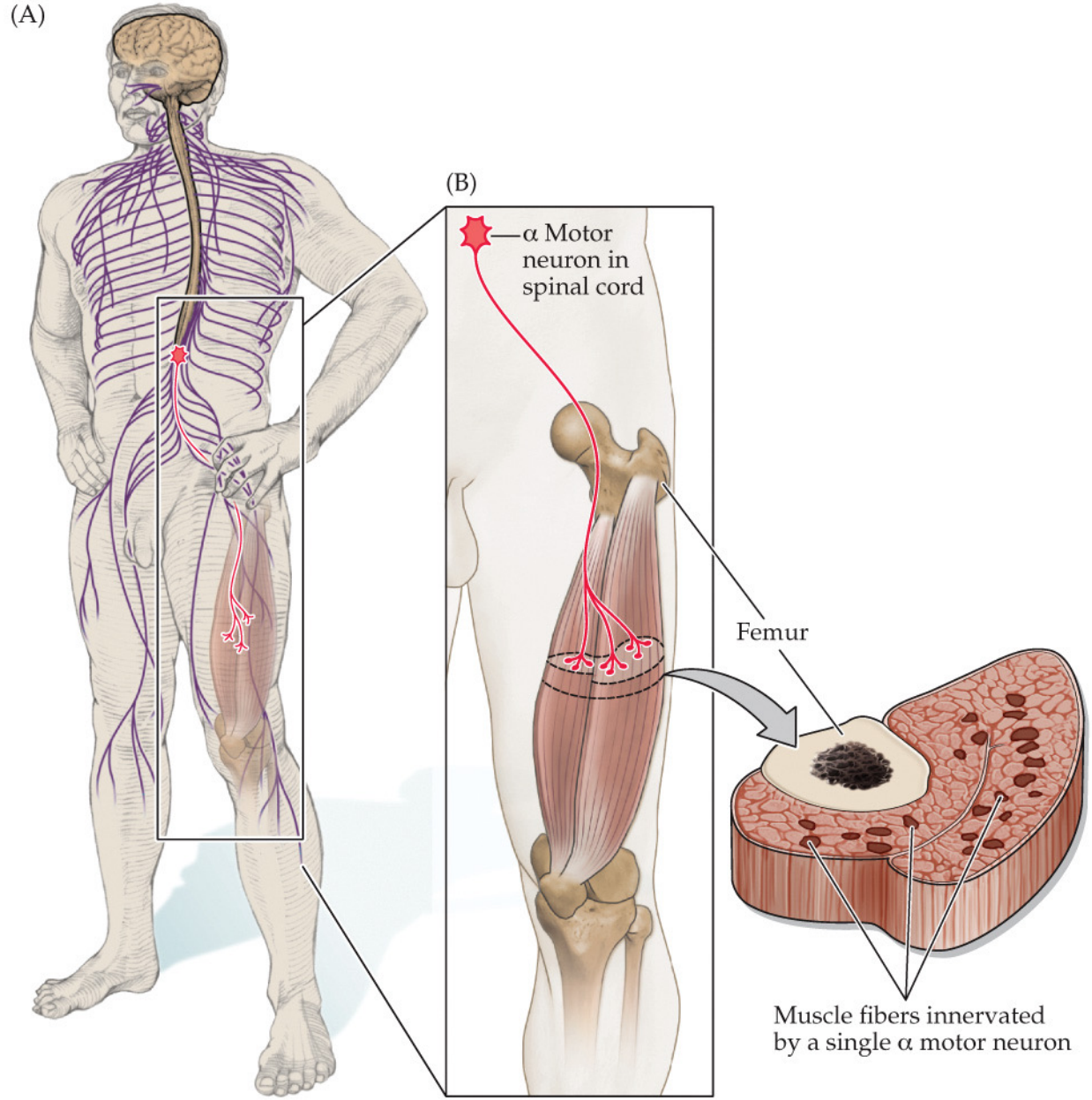
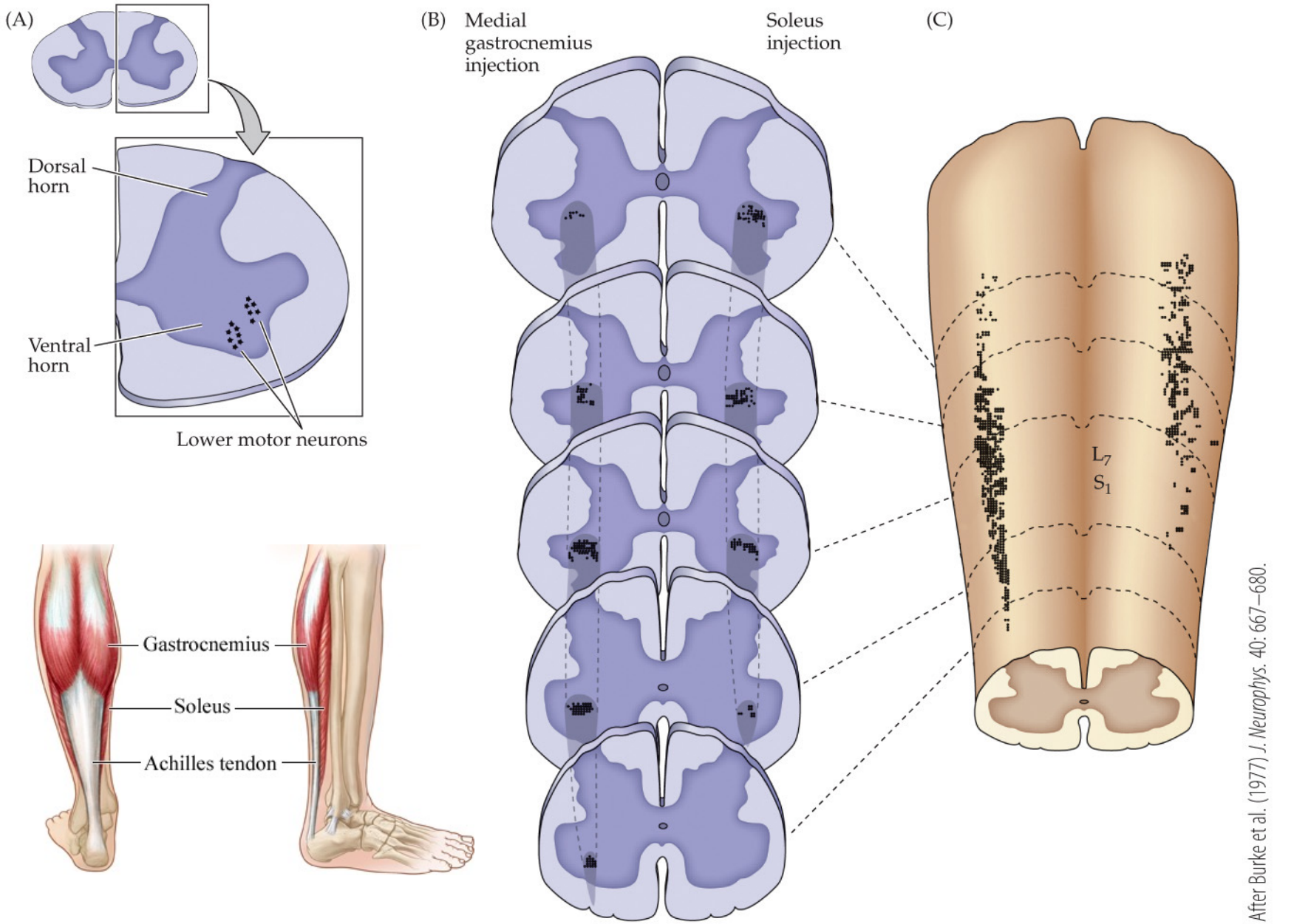


FIGURE 16.5 The motor unit



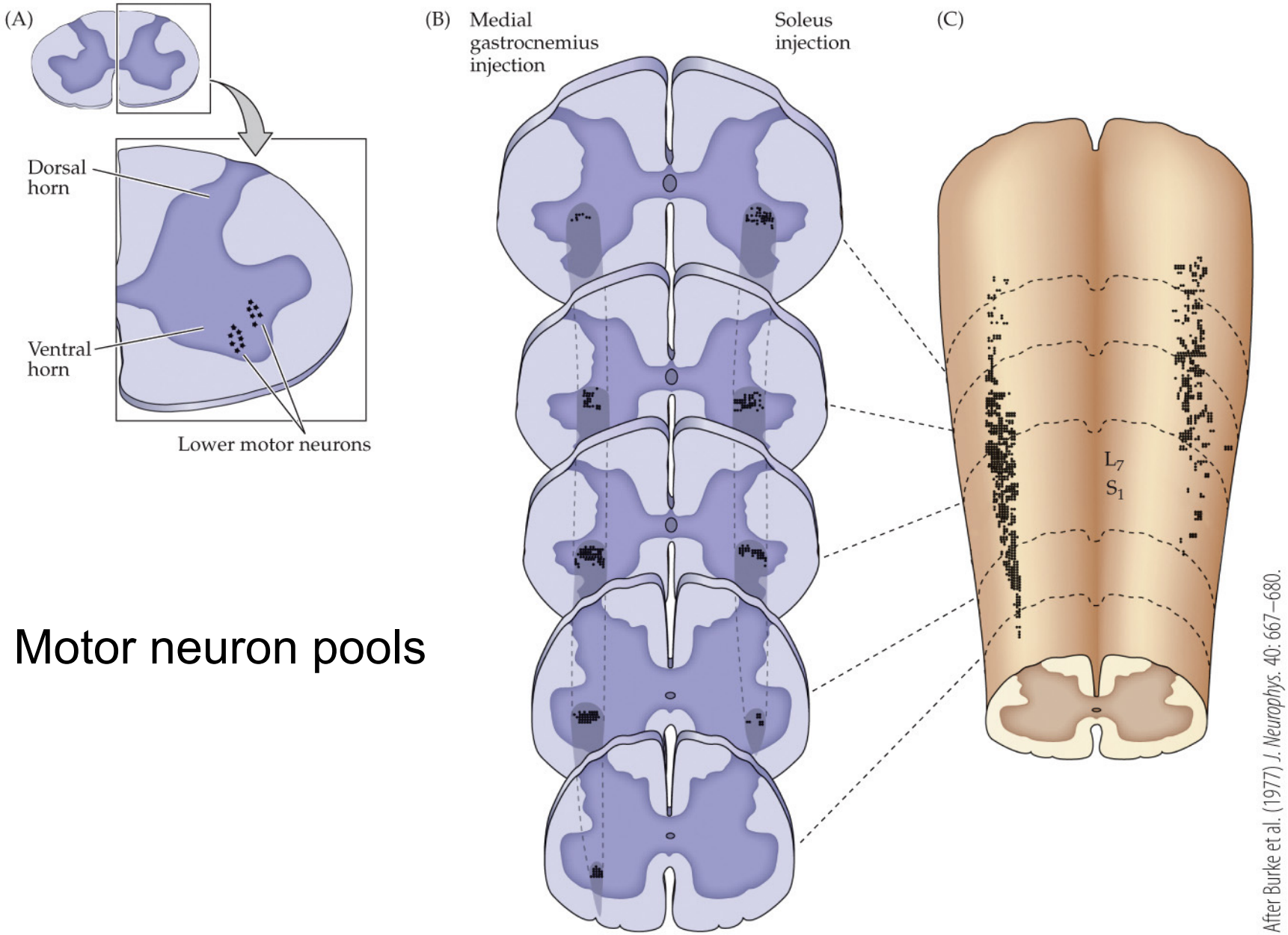
NEUROSCIENCE 6e, Figure 16.5

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



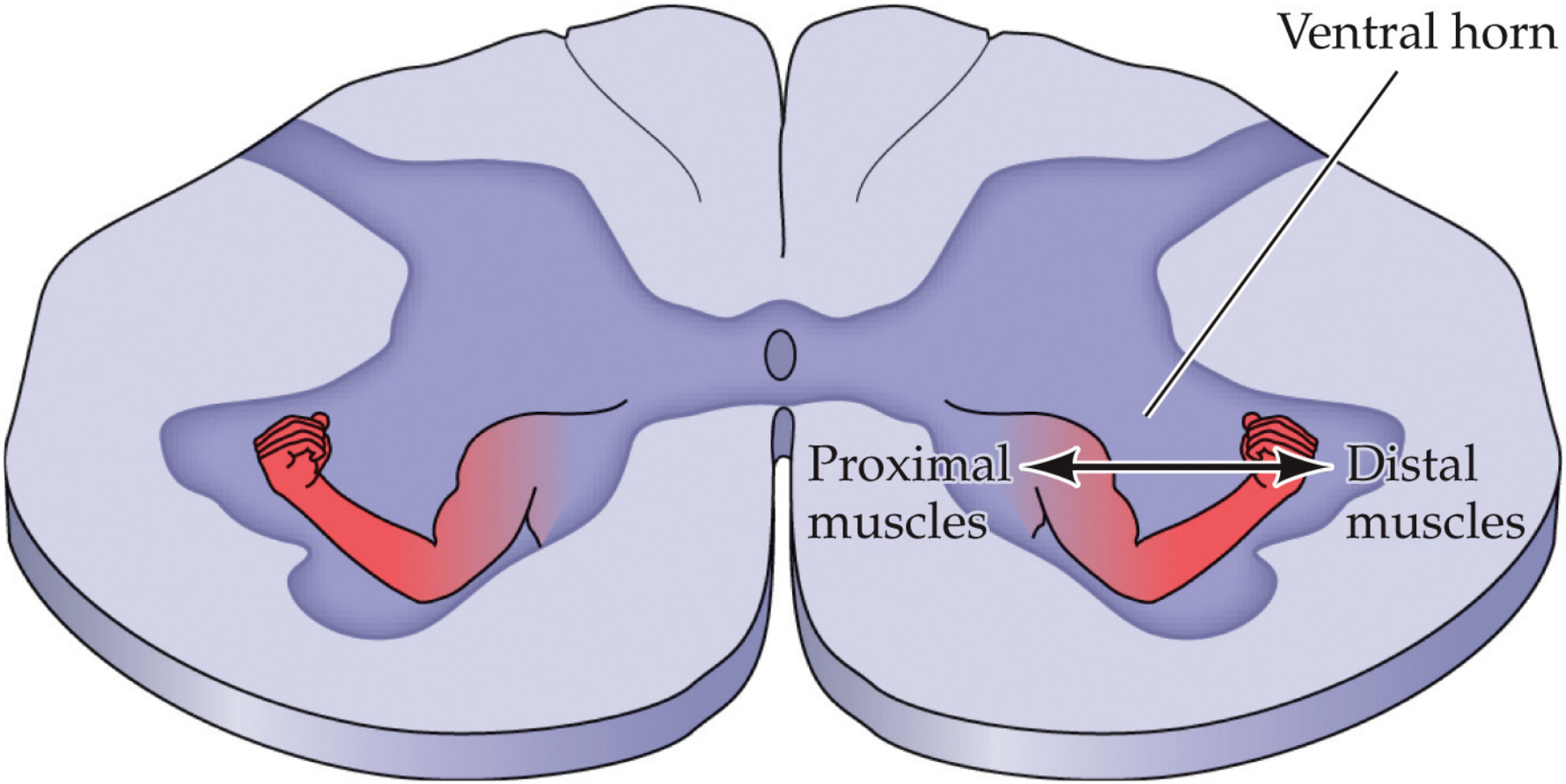
NEUROSCIENCE 6e, Figure 16.2

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



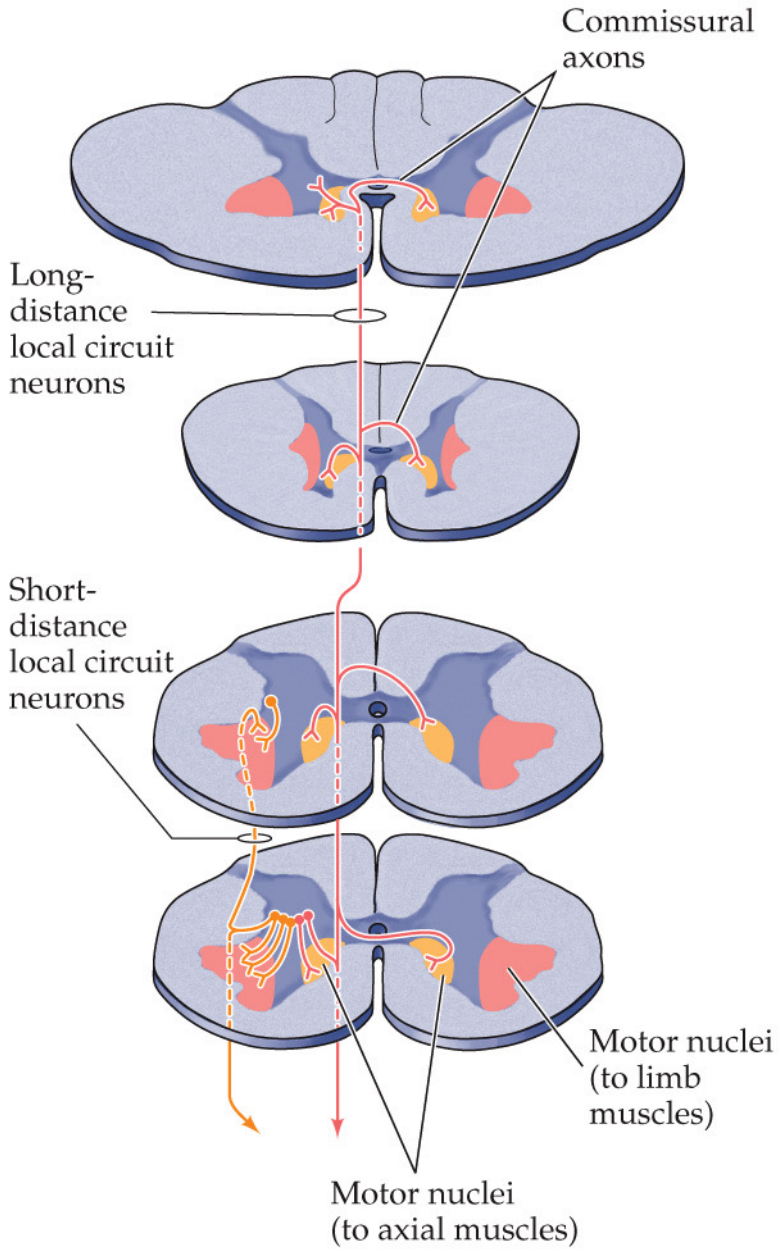
Motor neuron pools

FIGURE 16.3 Somatotopic organization of lower motor neuron pools



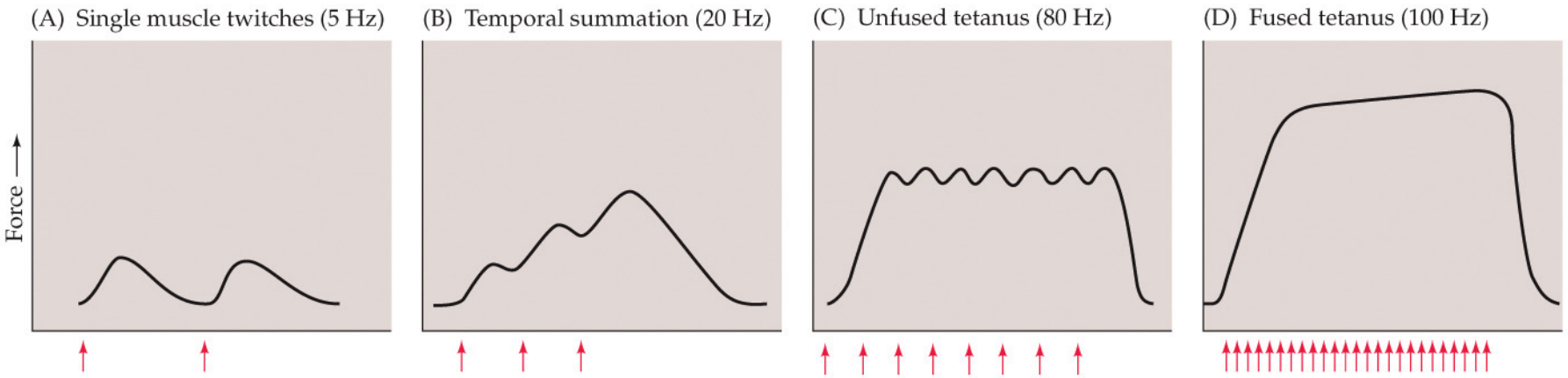
NEUROSCIENCE 6e, Figure 16.3

FIGURE 16.4 Local circuit neurons in the spinal cord gray matter



NEUROSCIENCE 6e, Figure 16.4

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



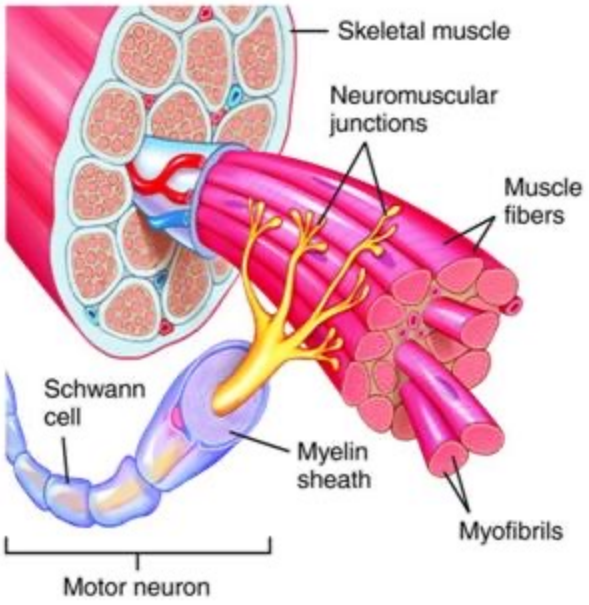
NEUROSCIENCE 6e, Figure 16.8

Motor Unit

Single α motor neuron and the muscle fibers that its axon innervates

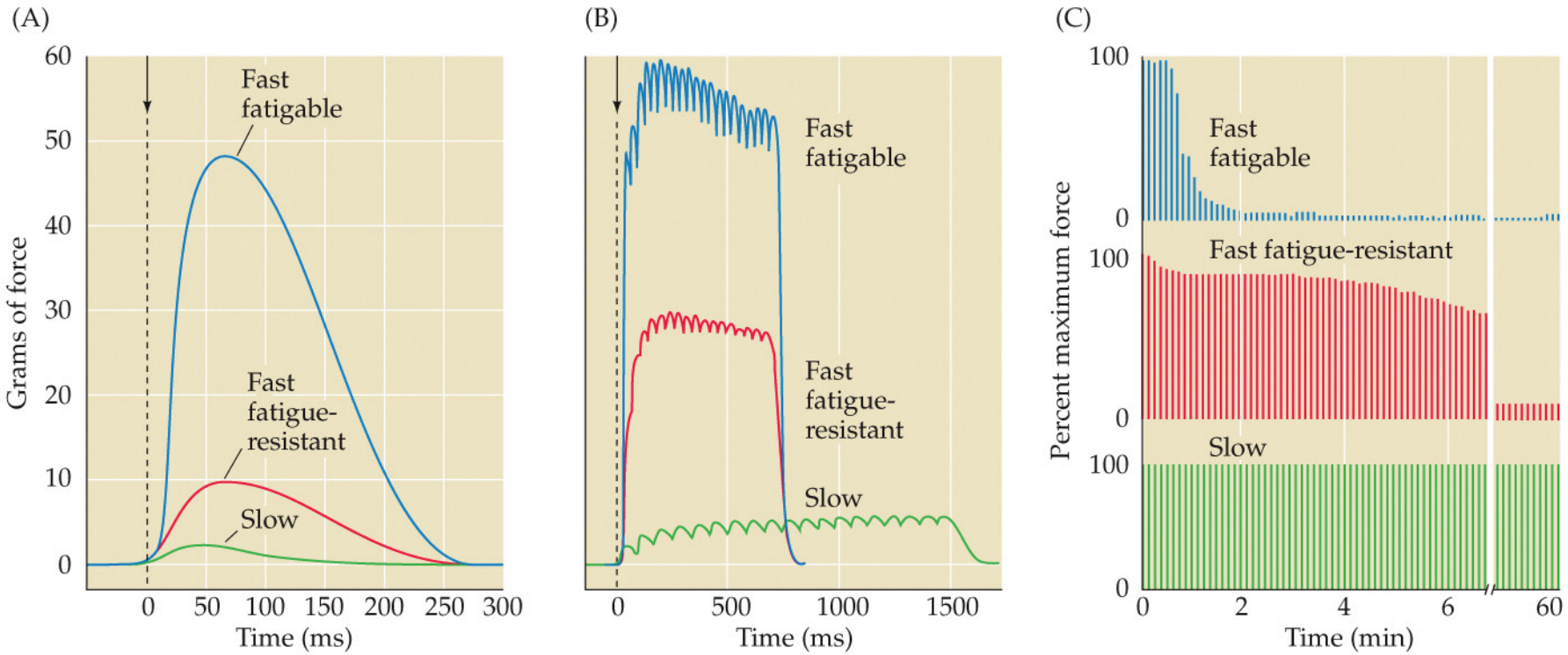
Smallest unit of force generated by the motor system

Motor units and α 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**

Types of motor units

	Slow	Fast Fatigue Resistant	Fast Fatigable
Innervated by:	Small α motor neurons	INTERMEDIATE	Large α 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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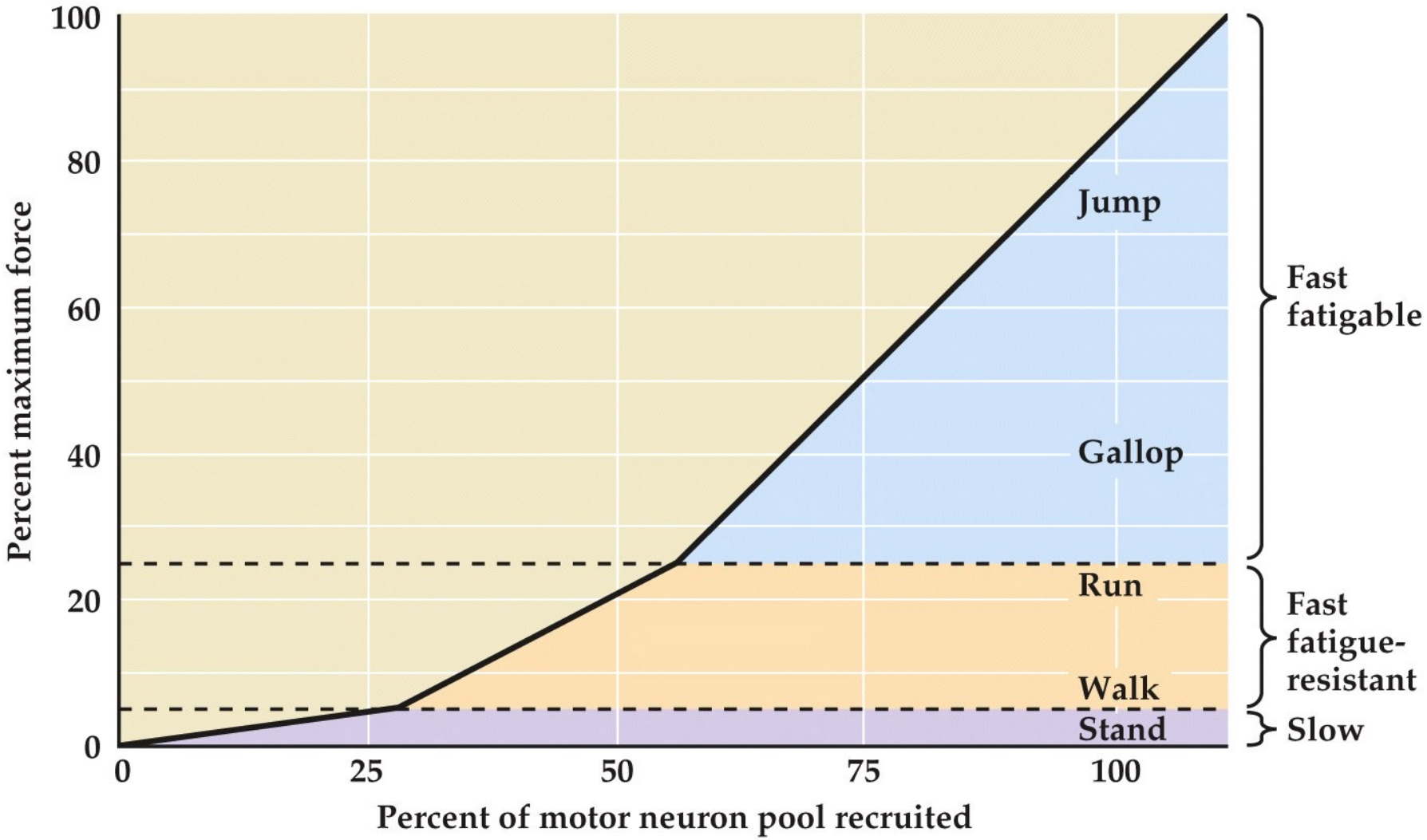
Motor neuron recruitment in the cat medial gastrocnemius muscle under different behavioral conditions



NEUROSCIENCE 5e, Figure 16.7

SIZE PRINCIPLE