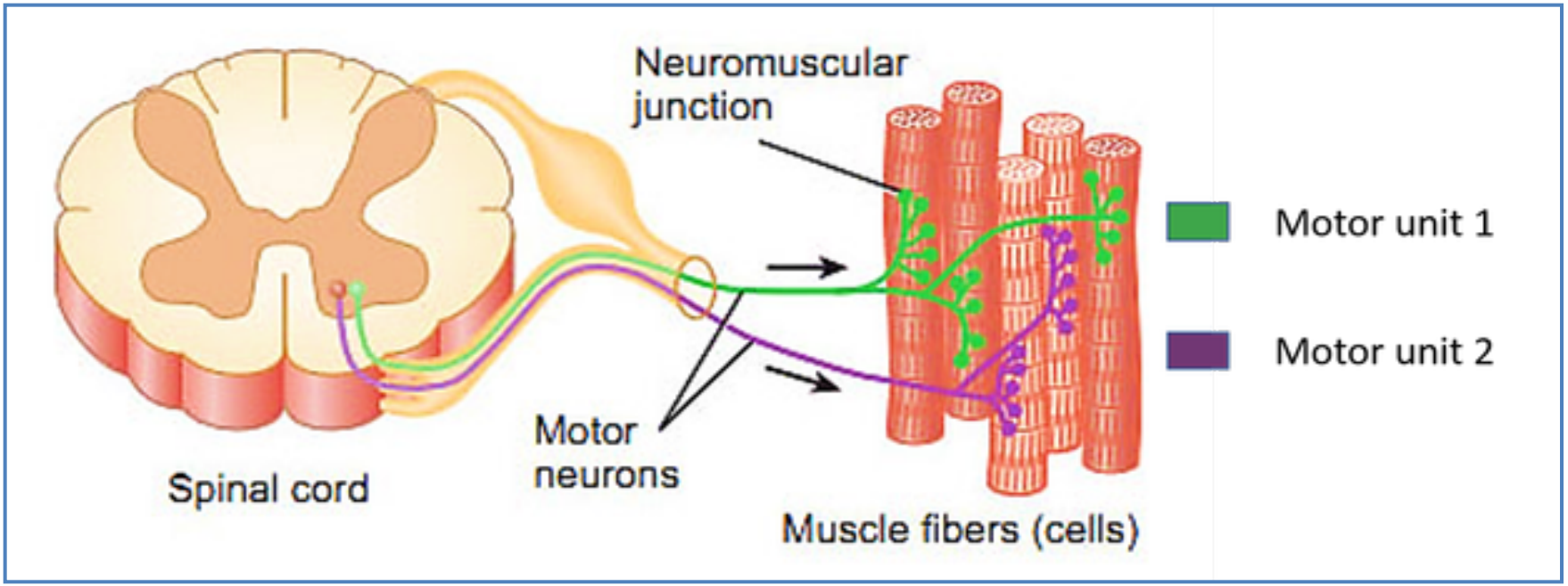
Motor Unit



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Objectives

At the end of this lecture you should be able to:

1-Recognize the organization of the nervous system.

2-Detect the differences between central nervous system (CNS) and the peripheral nervous system (PNS).

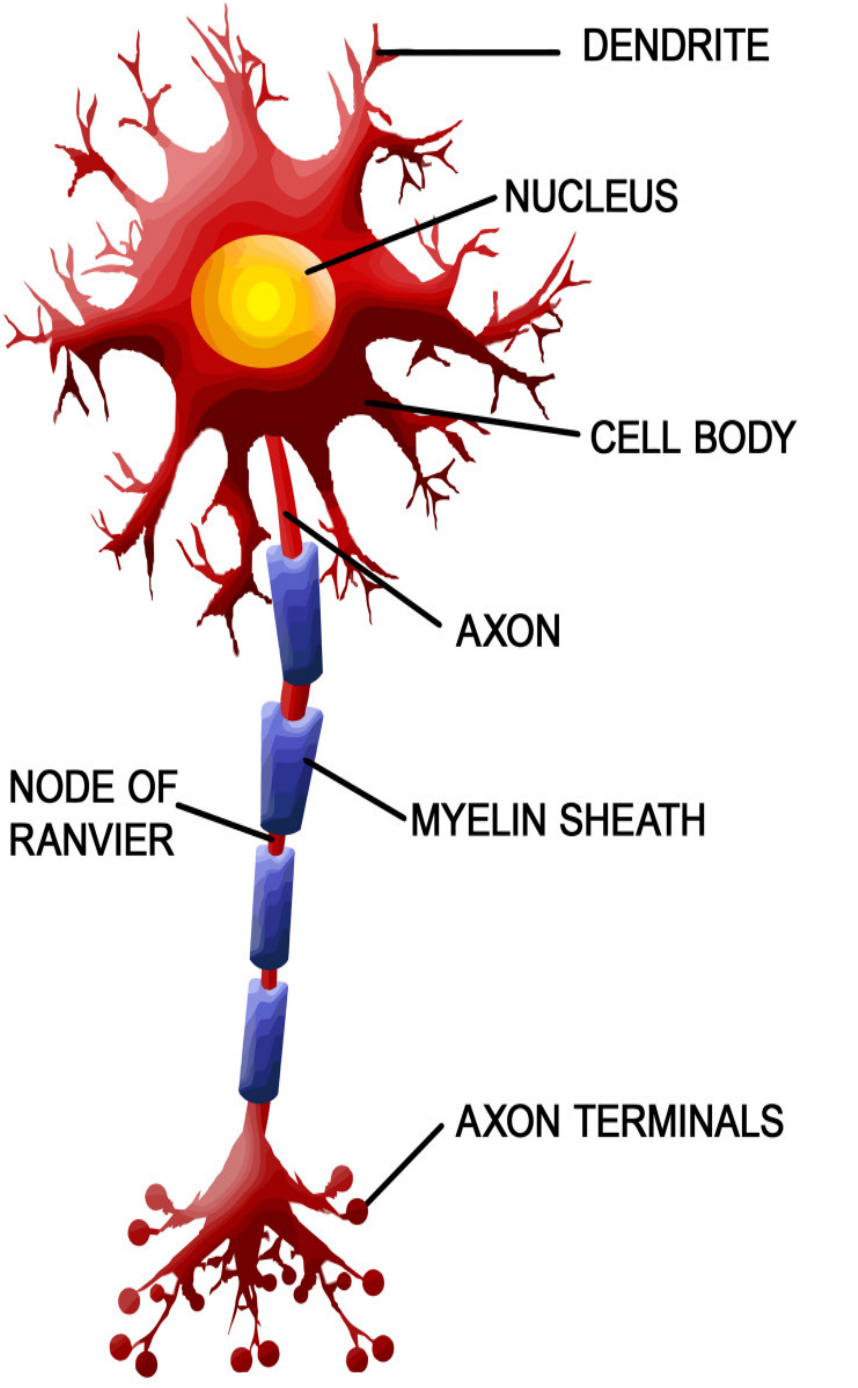
3-Discuss the functions and recruitment of the motor unit.

4- Interpret the effect of motor units number on motor action performance.

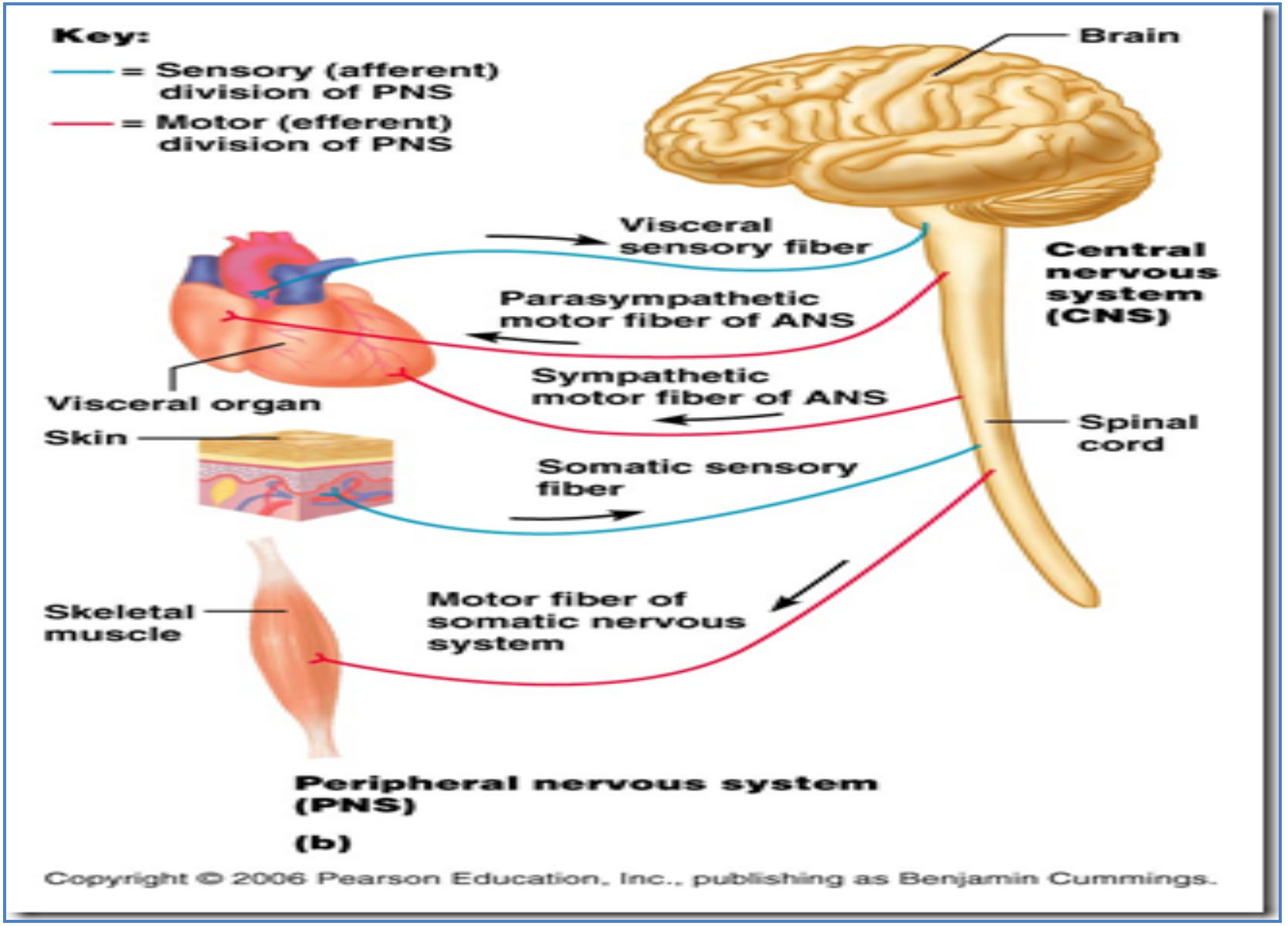
Neurons

The building unit of the nervous system is the neuron which has

- Cell body
  - Nucleus
- Dendrites
- Axon
  - Myelination
  - Nodes of Ranvier
- Axon terminals
- Synaptic end bulbs
- Neurotransmitter
  - Acetylcholine (ACH)



Organization of Nervous System



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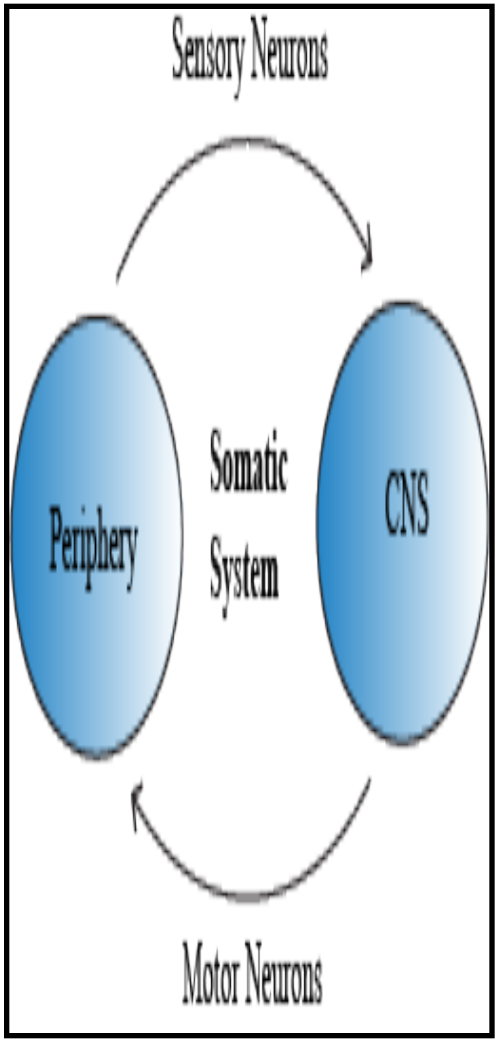
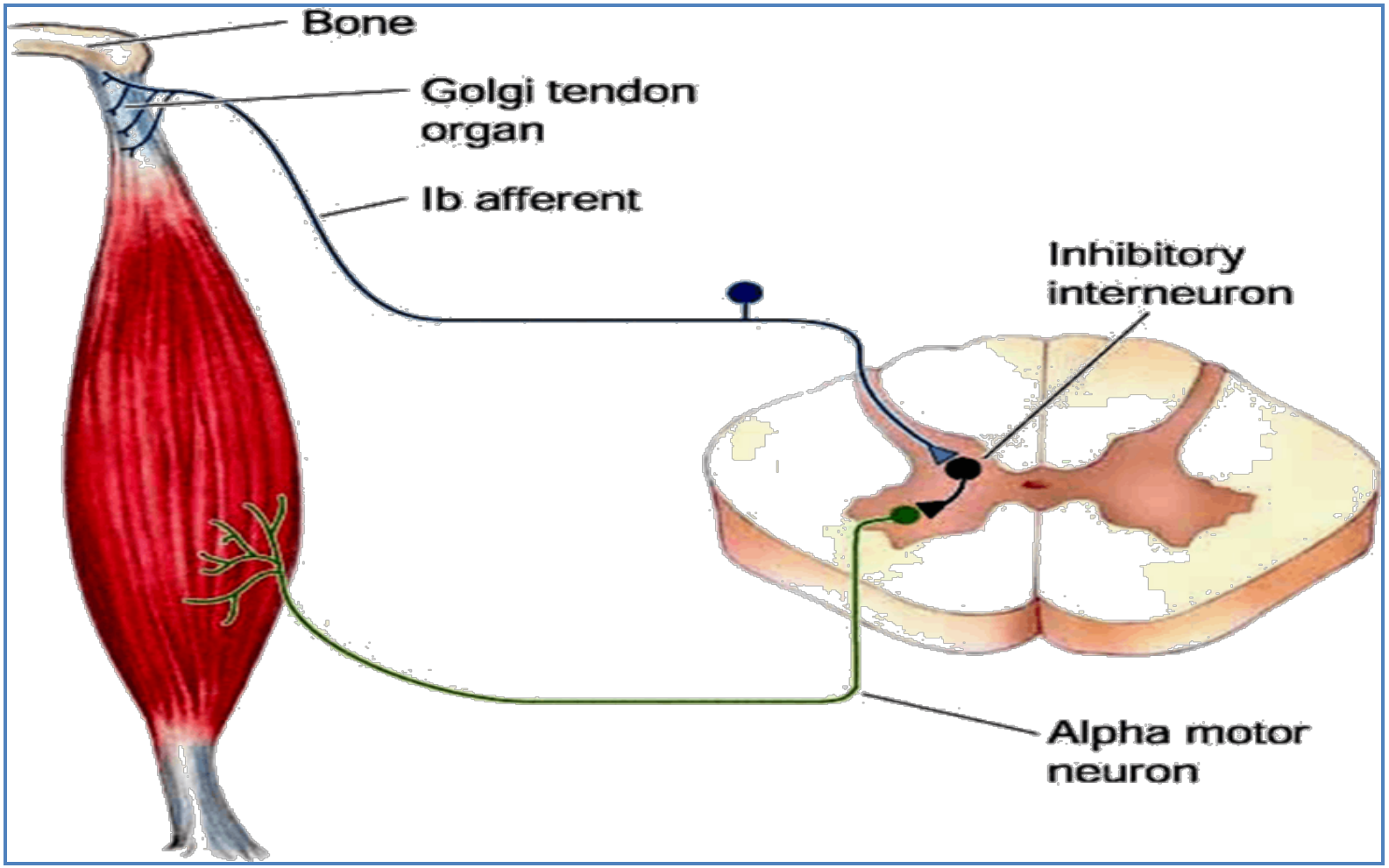
Nerve-Muscle Interaction

- The nervous system can be divided into central (CNS) and peripheral (PNS).
- PNS can be divided in terms of function into motor and sensory activities.
- **Sensory Neurons**: collects information from the various receptors located throughout the body and transmits them to the brain.
- **Motor Neurons**: conducts signals to activate muscle contraction.
- Skeletal muscle activation is initiated through neural activation.
- **A nerve is made up of a group of axons of neurons.**



α-motor neuron in the anterior horn cell



Motor Unit

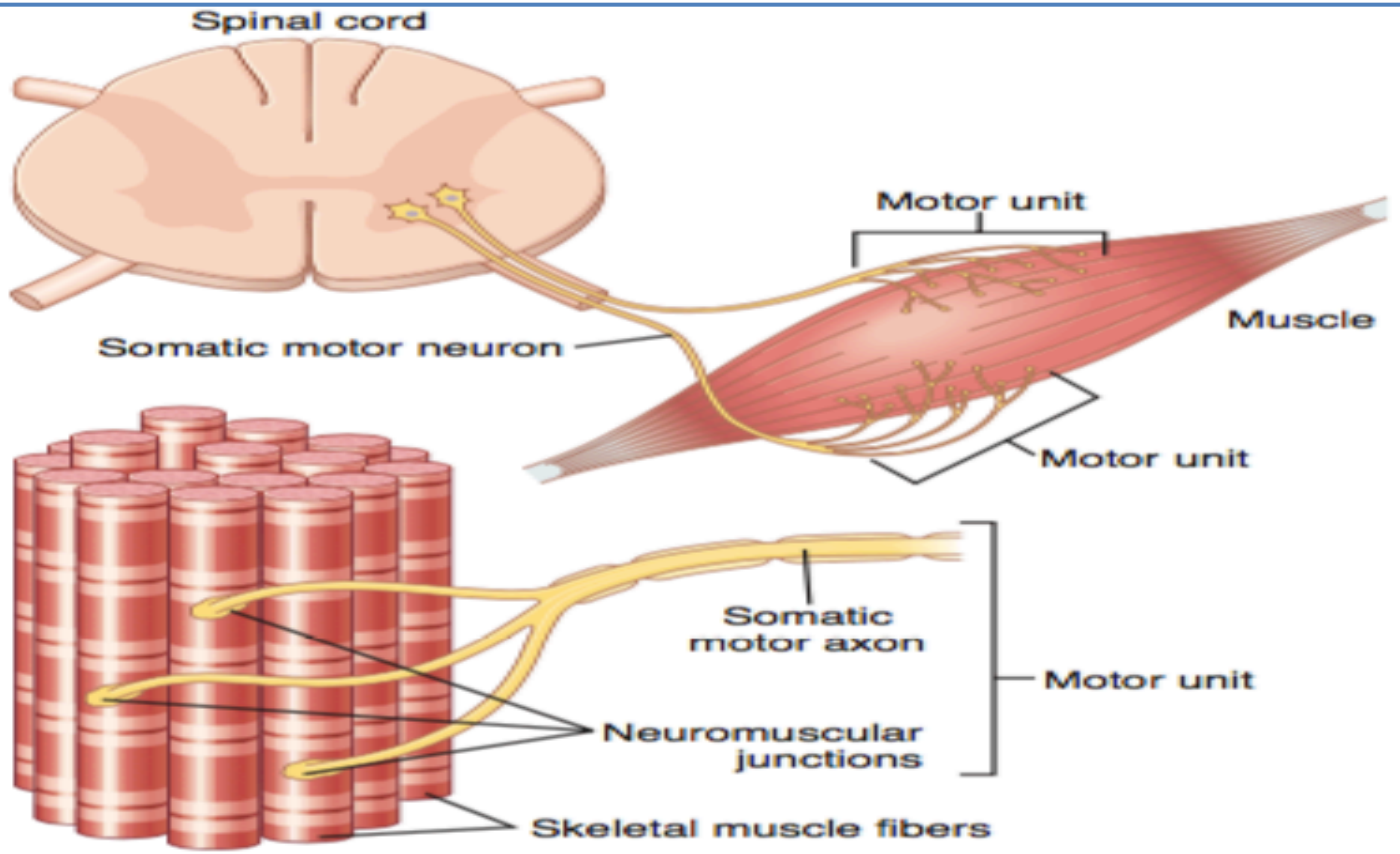
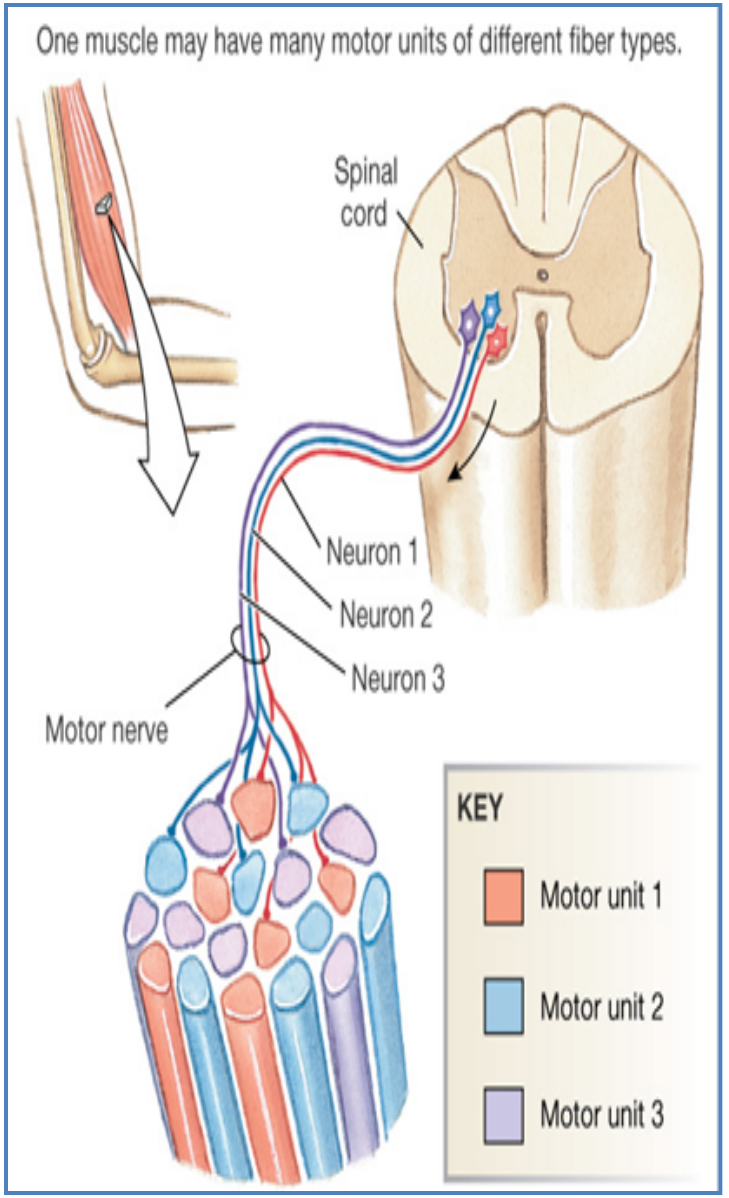


Figure 6-14. A motor unit consists of a motor neuron and the group of skeletal muscle fibers it innervates. A single motor axon may branch to innervate several muscle fibers that function together as a group. Although each muscle fiber is innervated by a single motor neuron, an entire muscle may receive input from hundreds of different motor neurons.

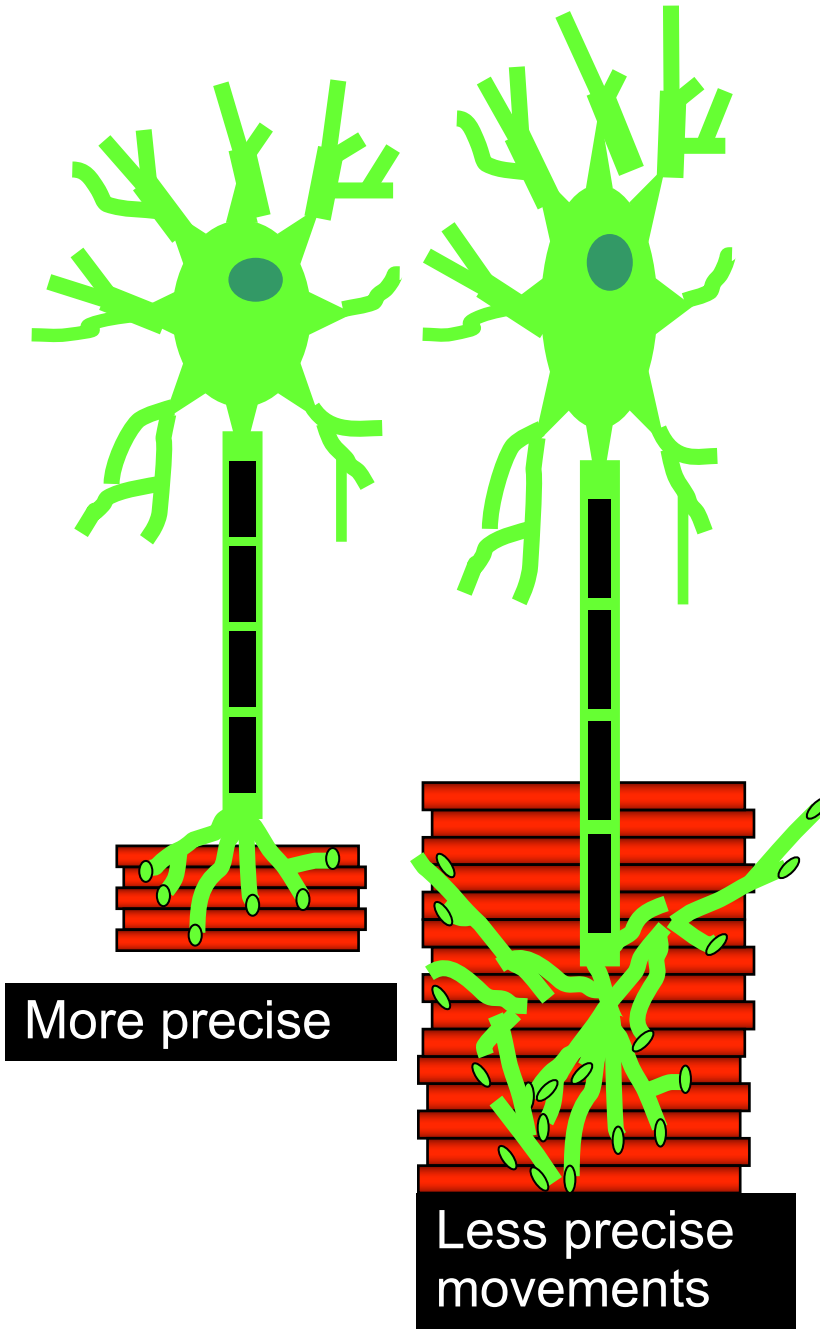
What is a Motor Unit ?

- It is the α-motor neuron in the anterior horn cell (AHC) and all the muscle fibers it innervates (supplies).
- All of these muscle fibers will be of the same type (either fast twitch or slow twitch).
- Each muscle consist of a number of motor units.
- When a motor neuron is activated, all the muscle fibers it innervates are stimulated and will contract.

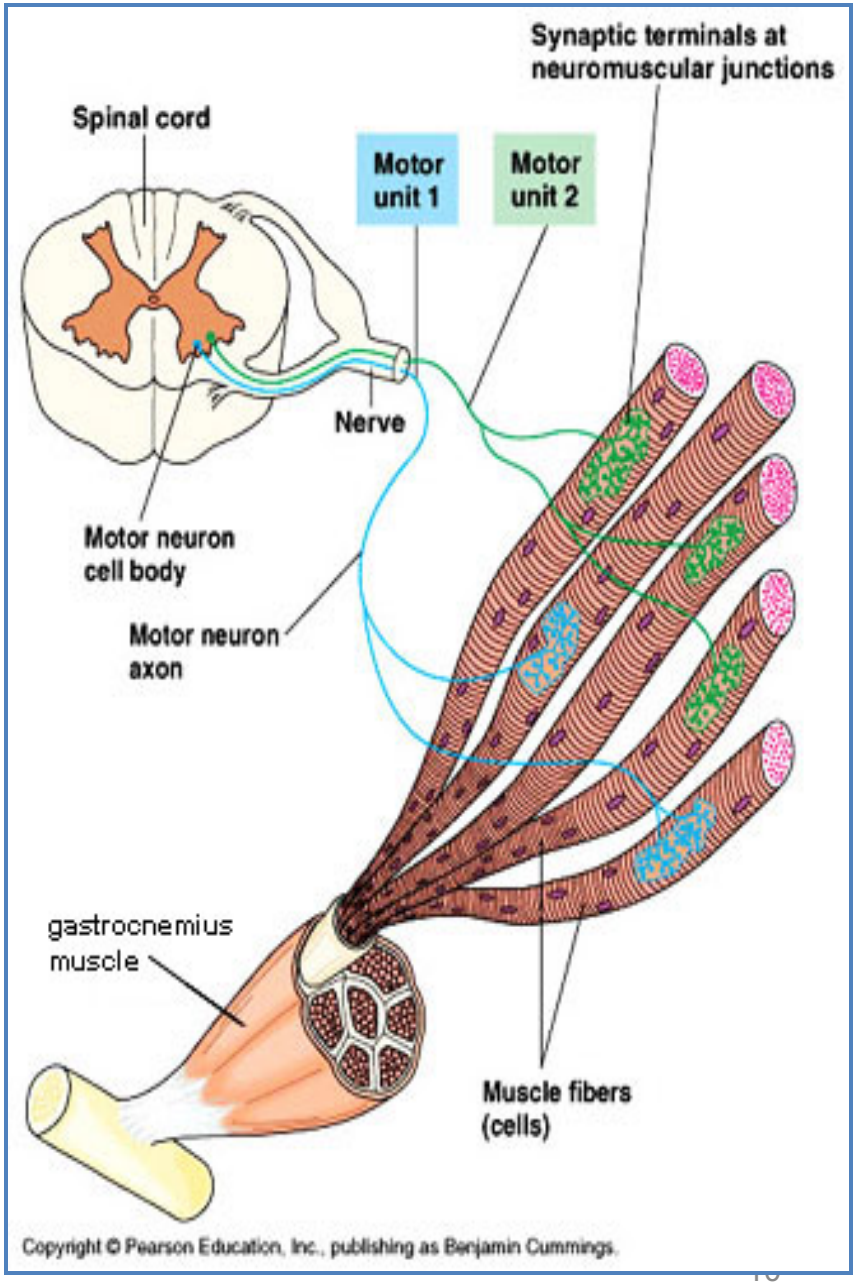


Motor Unit (MU)

- The number of muscle fibers in a motor unit innervated by one motor neuron varies.
- Leg muscles :600 muscle fibers per motor neuron.
- Extra ocular muscles < 10 muscle fibers per motor neuron.
- Some laryngeal muscles (2-3 muscle fibers per MU.
- The average all over the body is 80-100/MU
- Ratio of muscle fibers to motor neurons affects the precision of movement i.e small number is associated with more precise movements and vice versa.



- Group of motor units often work together to help the contractions of a single muscle and are called ***Motor Unit Pool.***
- Muscles needed to perform **precise movements** generally consist of a large number of motor units and few muscle fibers in each motor unit e.g Hands and eyes muscles
- **Less precise movements** are carried out by muscles composed of fewer motor units with many fibers per unit e.g Trunk muscles.



- The force produced by a single motor unit is determined by →

(1) the number of muscle fibers in the unit and

(2) the frequency with which the muscle fibers are stimulated by their innervating axon.

- Generally, this allows a 2 to 4-fold change in force.

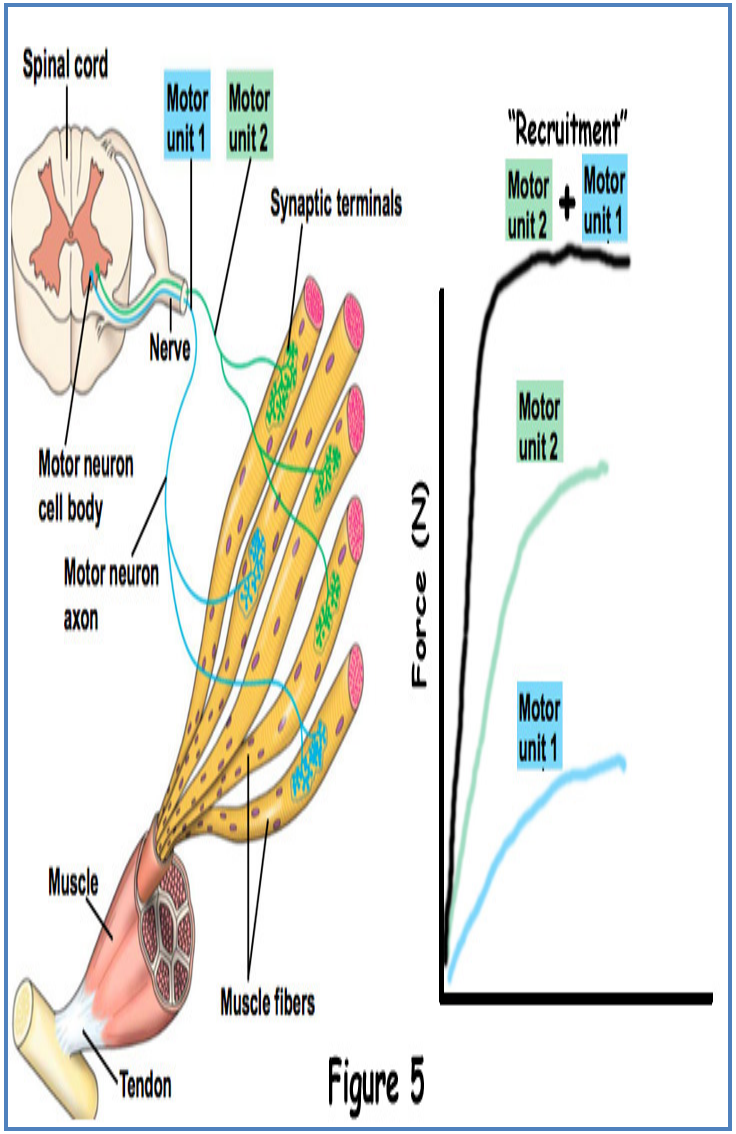
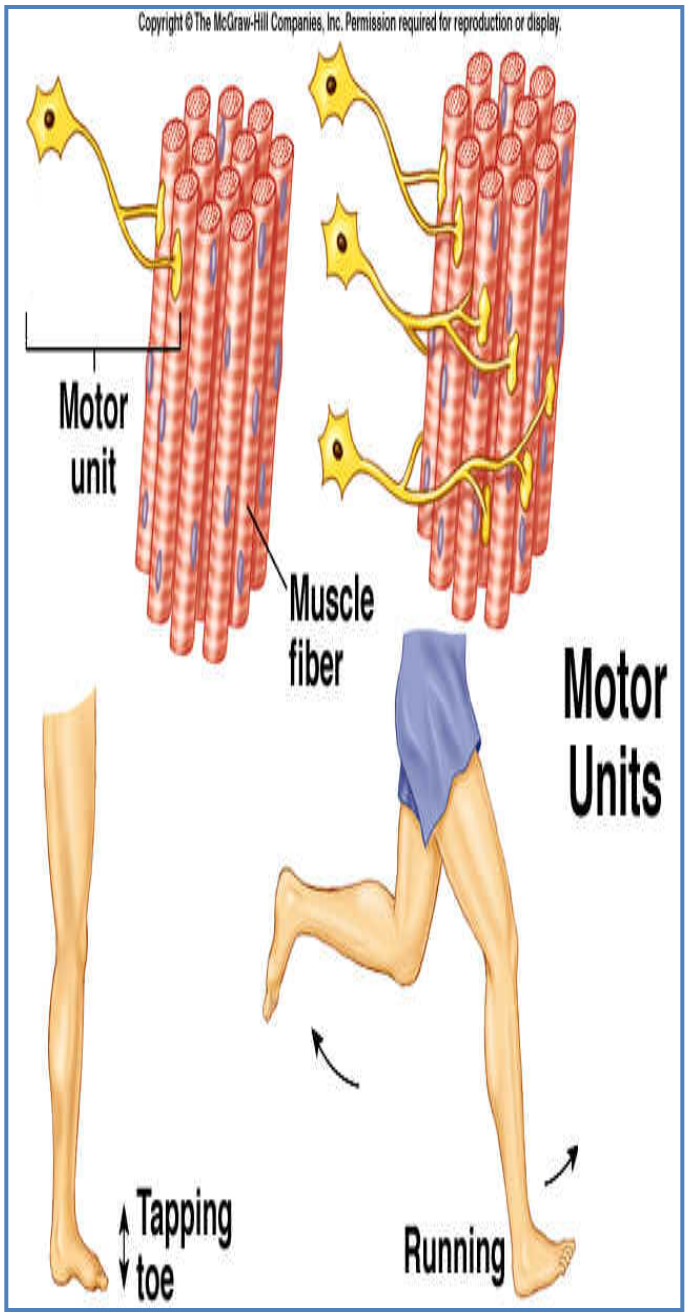


Figure 5

The activation of one motor neuron will result in a weak muscle contraction.

- The activation of more motor neurons will result in more muscle fibers being activated, and therefore a stronger muscle contraction.
- The higher the motor unit recruitment, the stronger the muscle contraction .



Muscle Contractions of Different Force—
Force Summation.

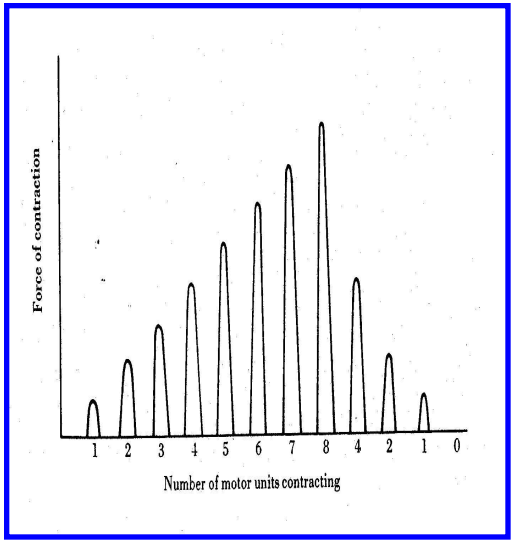
Summation *:*means the adding together of individual twitch contractions to increase the intensity of overall muscle contraction.

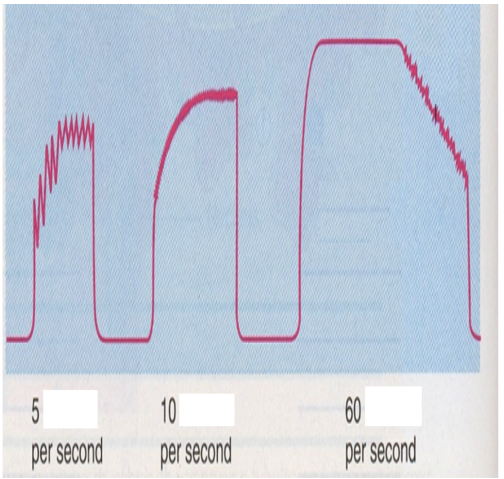
Summation occurs in two ways:

1-by increasing the number of motor units contracting simultaneously, which is called *multiple fiber summation* (***Recruitment*** of motor units).

2-by increasing the frequency of contraction, which is called ***frequency summation (rate coding)*** and can lead to *tetanization.*

Rate coding :refers to the motor unit firing rate. Active motor units can discharge at higher frequencies to generate greater tensions.





Multiple Fiber Summation (Recruitment of motor Units)

- When the central nervous system sends a weak signal to contract a muscle, the smaller motor units of the muscle may be stimulated in preference to the larger motor units.
- Then, as the strength of the signal increases, larger and larger motor units begin to be excited as well, with the largest motor units often having as much as 50 times the contractile force of the smallest units. This phenomenon, called **the *size principle.***,

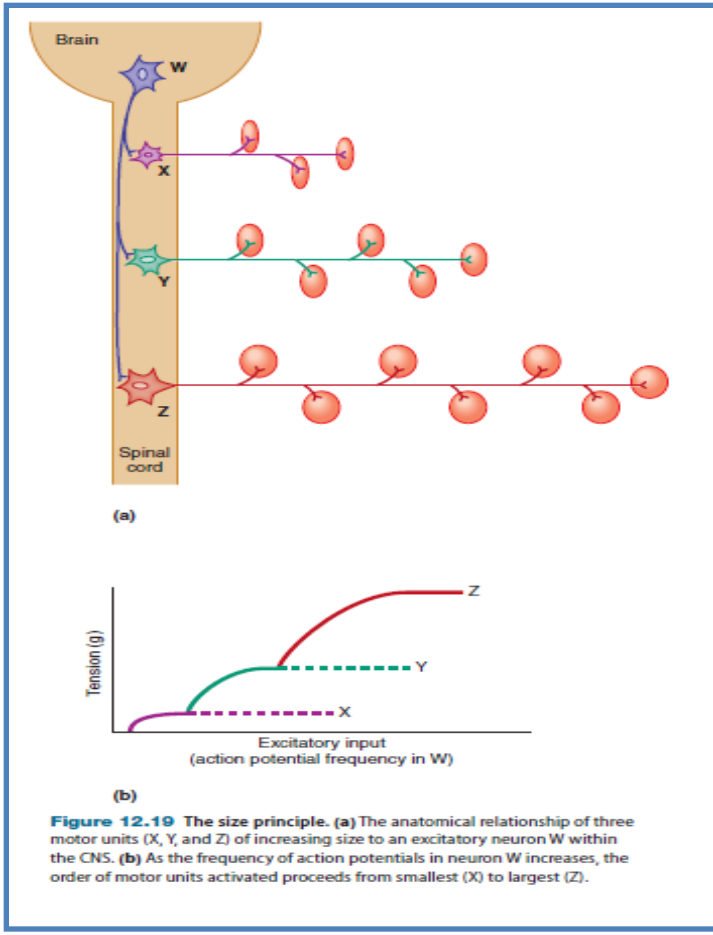


Figure 12.19 **The size principle.** **(a)** The anatomical relationship of three motor units (X, Y, and Z) of increasing size to an excitatory neuron W within the CNS. **(b)** As the frequency of action potentials in neuron W increases, the order of motor units activated proceeds from smallest (X) to largest (Z).

The size principle

- The size principle is important because it allows the gradations of muscle force during weak contraction to occur in small steps, whereas the steps become progressively greater when large amounts of force are required.
- This size principle occurs because the smaller motor units are driven by small motor nerve fibers, and the small motoneurons in the spinal cord are more excitable than the larger ones, so naturally they are excited first.

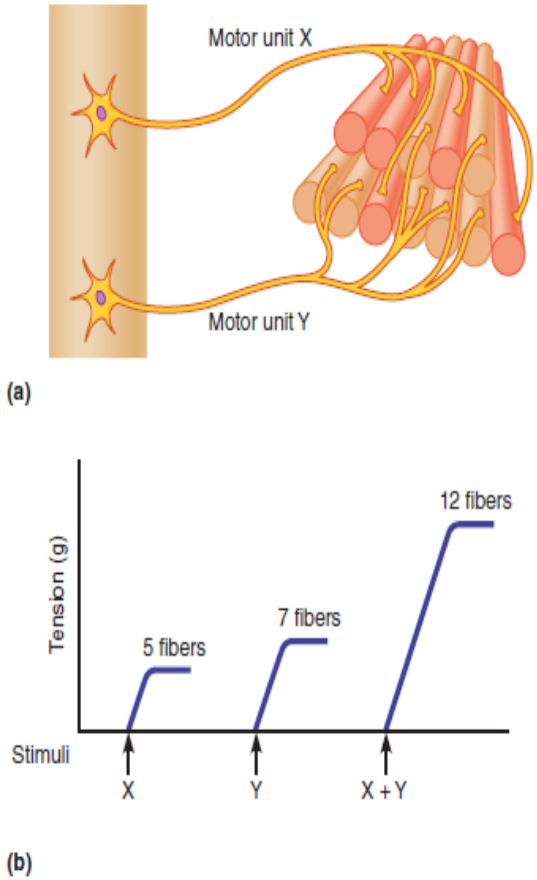
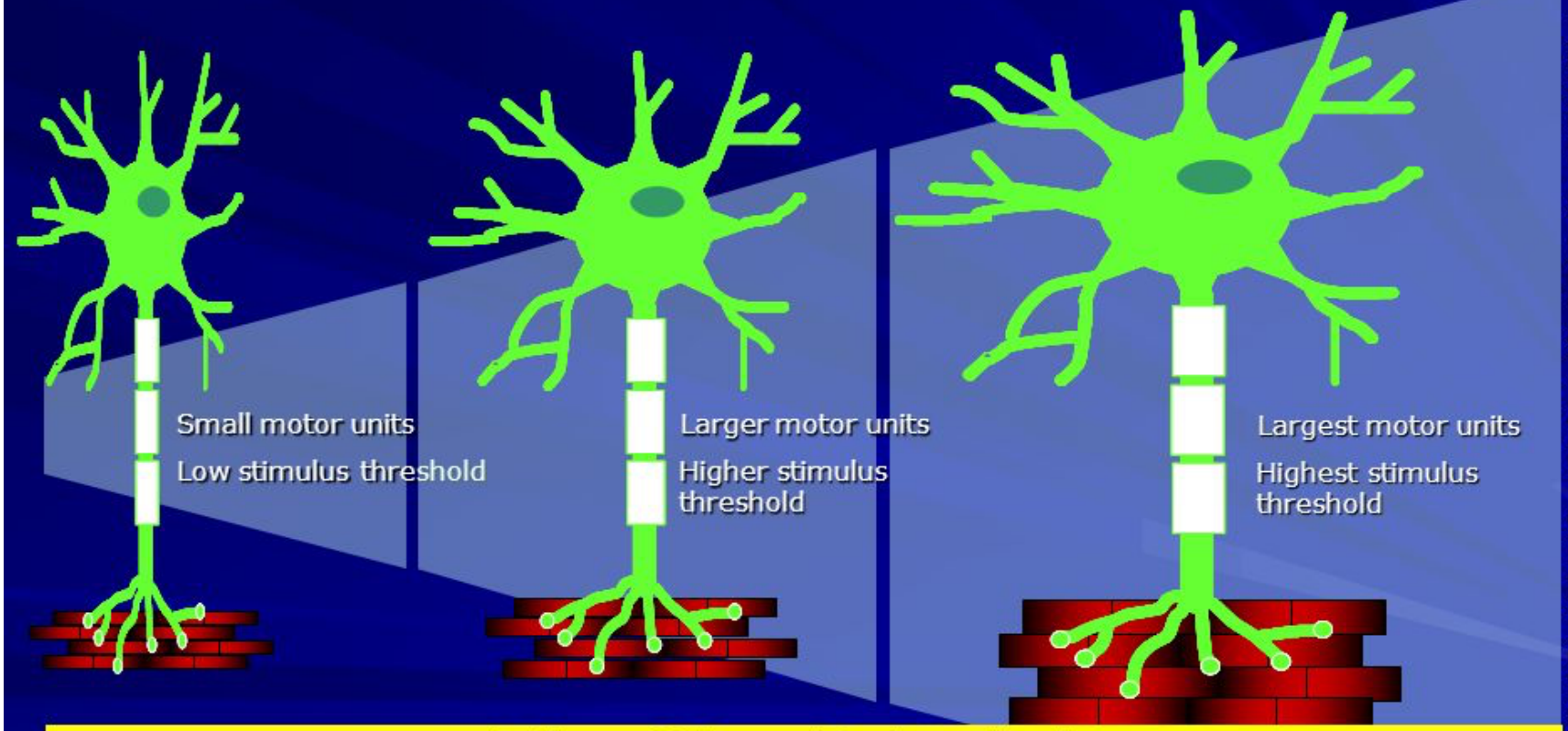


Figure 12.18 **Increases in force generation with recruitment of motor units.** (a) Motor units X and Y, which possess five fibers and seven fibers, respectively. (b) Tension developed by motor unit X, by motor unit Y, and by motor units X and Y together.

Recruitment

- Varying the number of motor units activated.



The Size Principle

↓ Amount of Force Required During Movement ↑

Motor Unit Recruitment

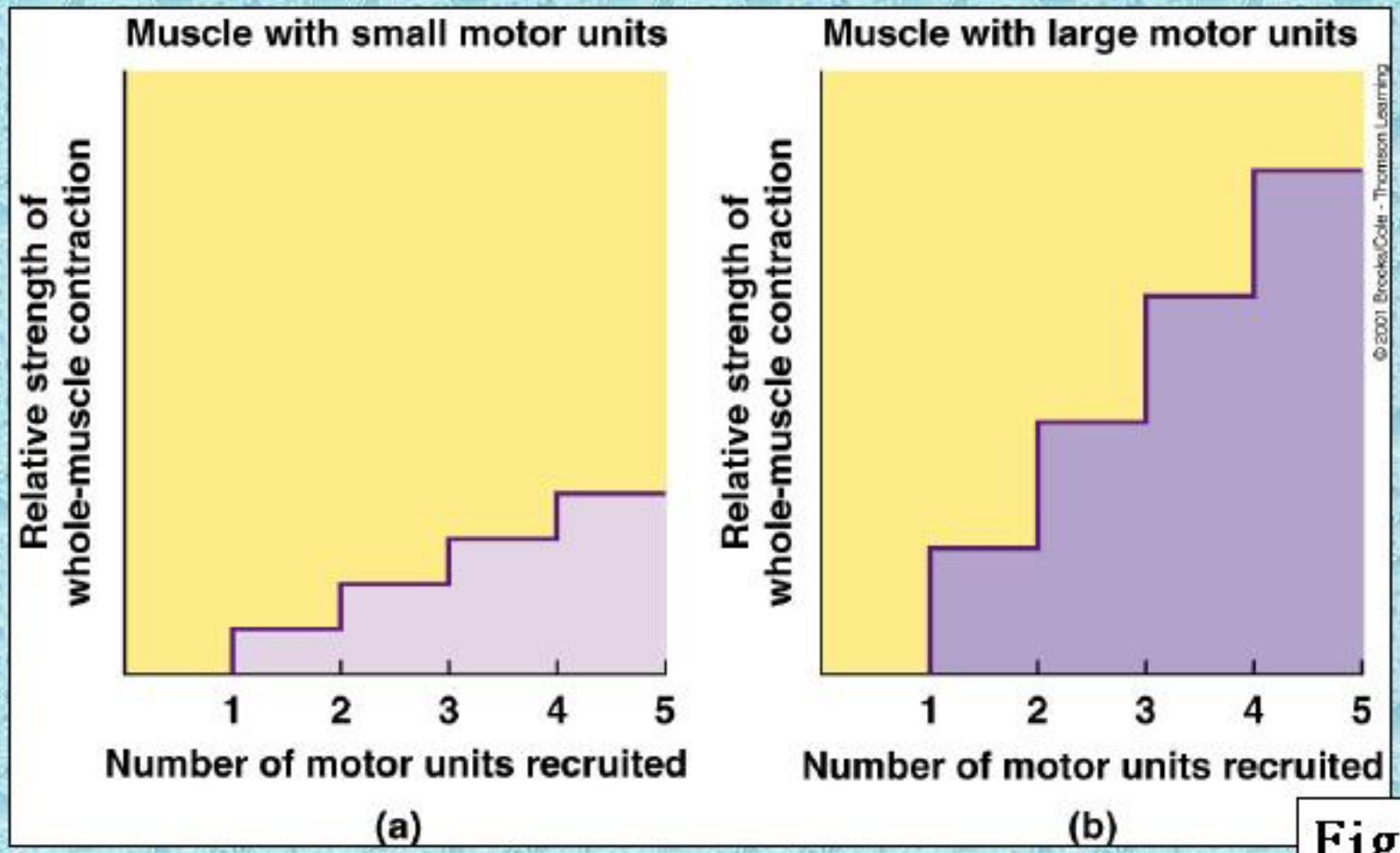


Fig 8-16

Motor Unit Recruitment Increases the Strength of Muscle Contraction

Frequency Summation (rate coding) and Tetanization.

- Individual twitch contractions occurring one after another at low frequency of stimulation.
- As the frequency increases, there comes a point when each new contraction occurs before the preceding one is over.
- When the AHC fires at slow rates, motor unit potentials (MUPs) will be at slow rate & the force of muscle contraction is weak.
- If AHCs fire at very fast rates → fast MUPs → stronger contraction.
- Thus the total strength of contraction rises progressively with increasing frequency.

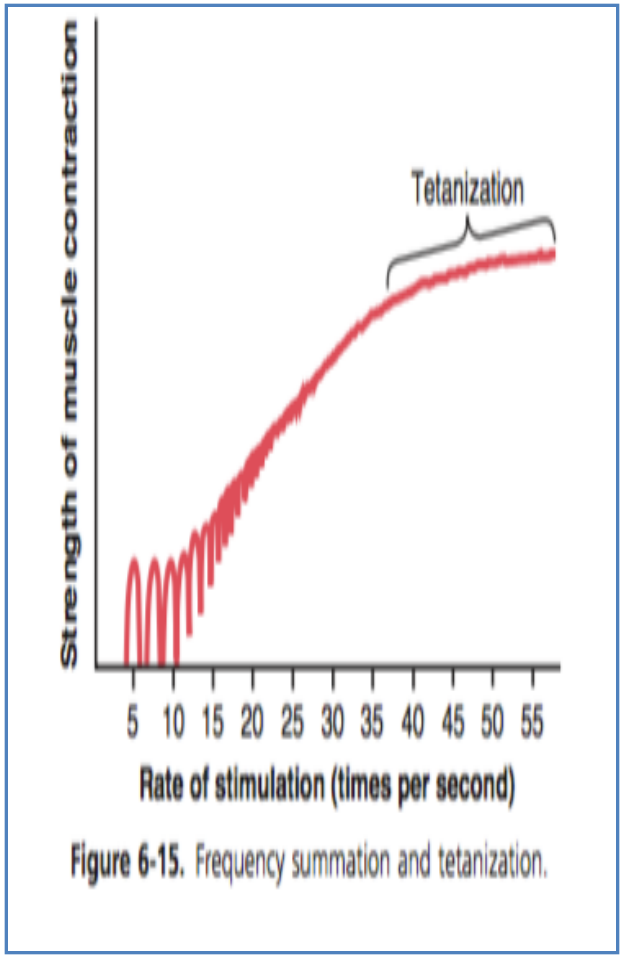
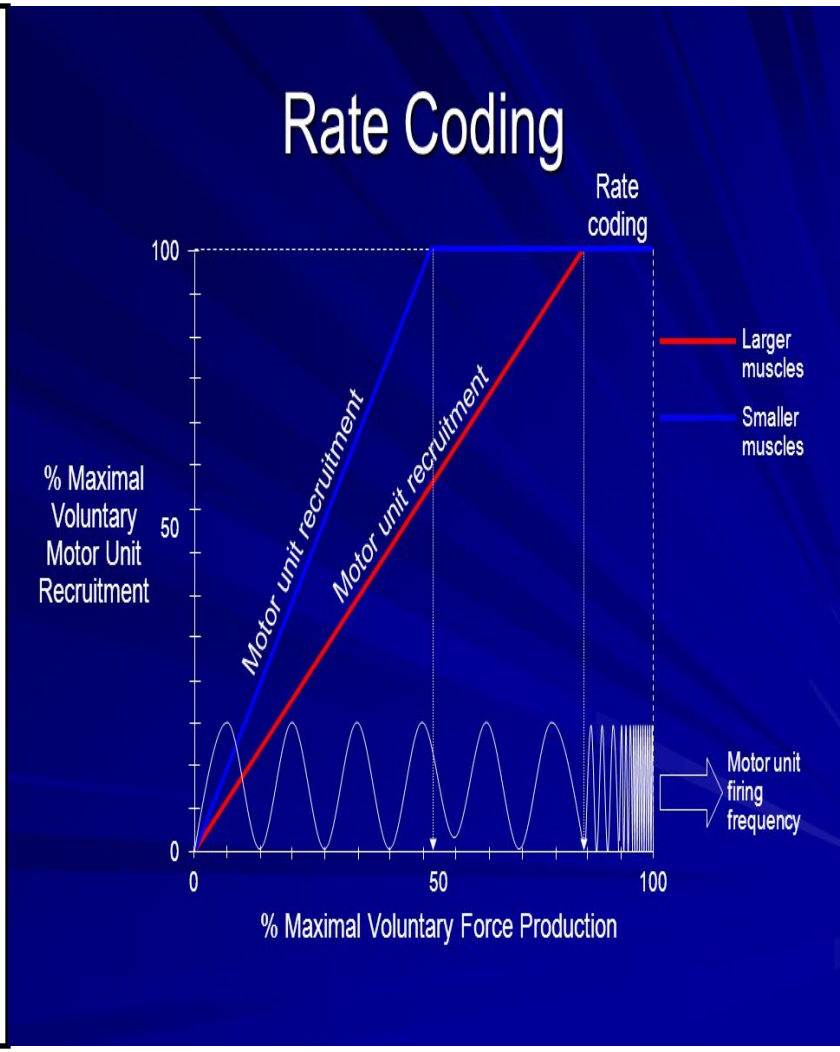


Figure 6-15. Frequency summation and tetanization.

Recruitment versus rate coding

- –Smaller muscles (e.g: first dorsal interosseous) rely more on rate coding.
- –Larger muscles of mixed fiber types (e.g: deltoid) rely more on recruitment.



All or non role

- Motor Unit Follows "all-or-none" principle – impulse from motor neuron will cause contraction in all muscle fibers it innervates or none.
- In an electrodiagnostic testing e.g electromyography (EMG) for a patient with weakness, careful analysis of the motor unit action potential (MUAP) size, shape, and recruitment pattern can help in distinguishing a myopathy from neuropathy.