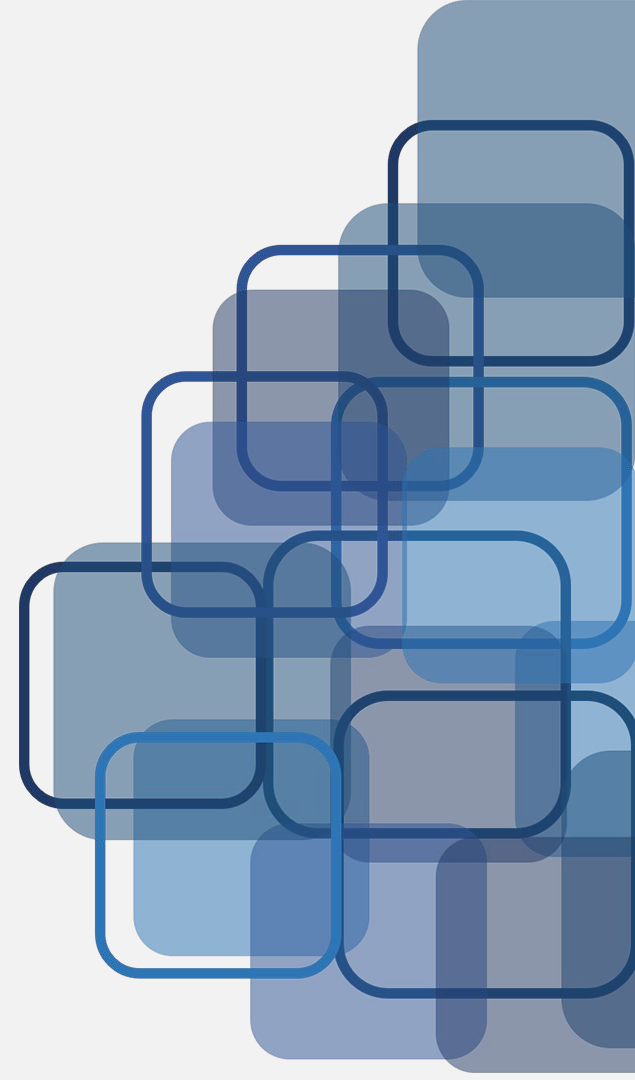


4

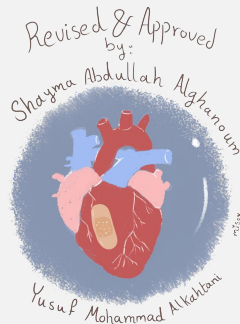
Motor unit



Editing file

physiology439@gmail.com

Red: Important
Black: In Male & Female slides
Blue: In male slides
Pink: In female slides
Gray: Notes & extra information



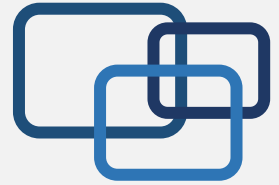
Objectives



- 01** Recognise the organization of the Nervous System
- 02** Identify the differences between central nervous system (CNS) & peripheral nervous system (PNS)
- 03** Discuss the functions and recruitment of the motor unit
- 04** Interpret the effect of motor units number on motor action performance

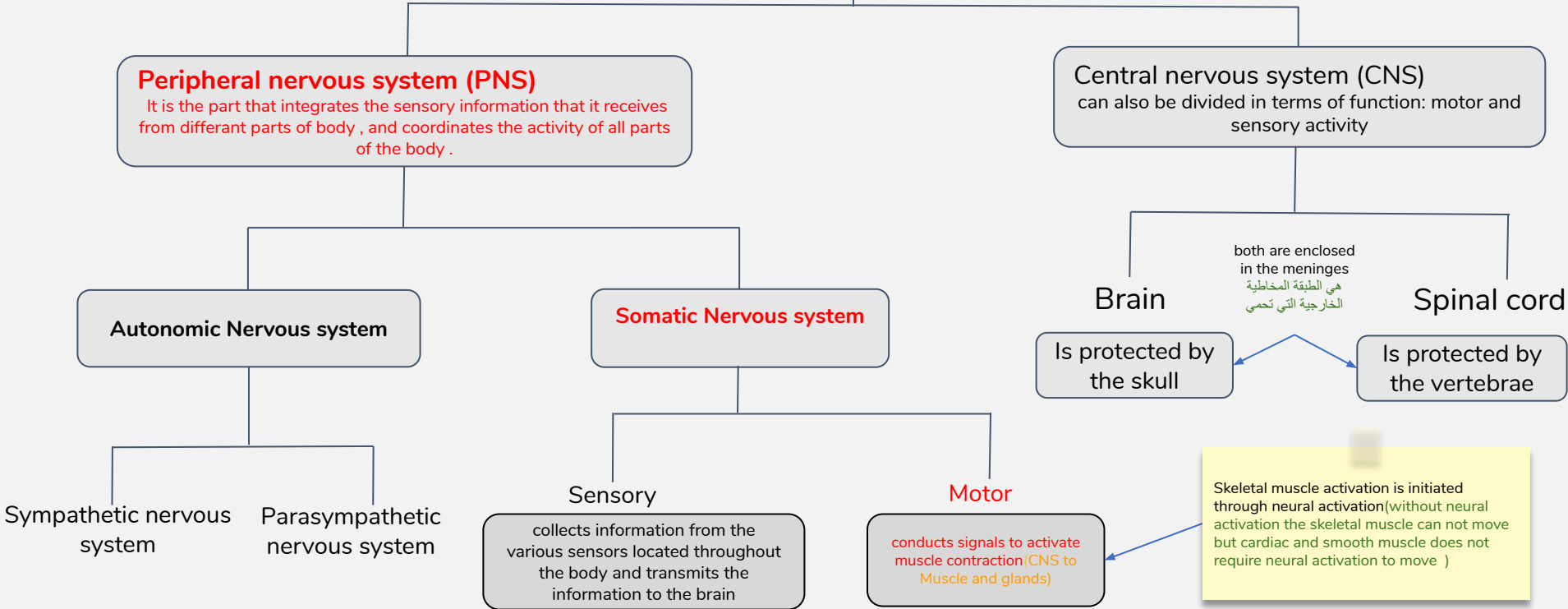


In foundation block we focused on ANS but in this lecture we are gonna focus on somatic Nervous system



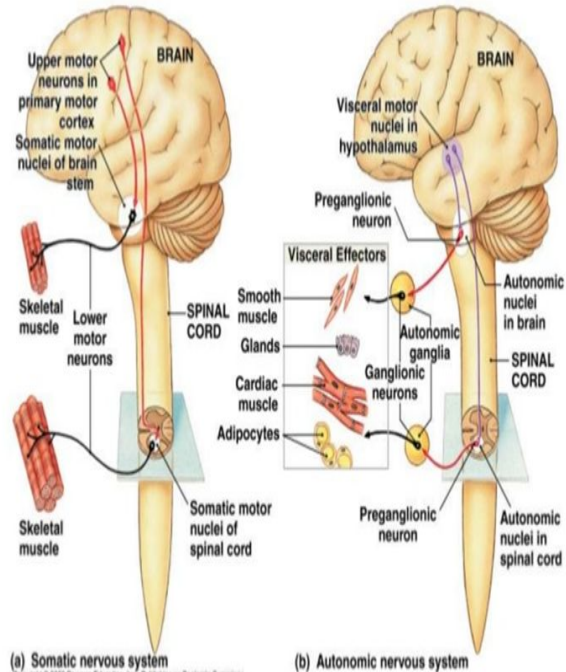
Nervous System

The nervous system can be divided into central (CNS) and peripheral (PNS)

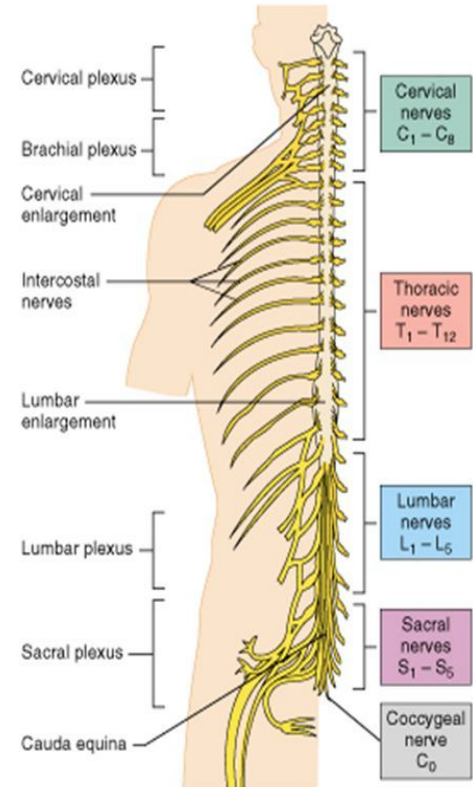


Organization of Nervous System

Somatic vs. Autonomic

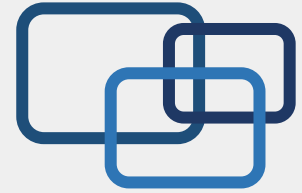


Copyright © 2008 Pearson Education, Inc., Publishing as Benjamin Cummings.



Copyright © 2001 Benjamin Cummings, an imprint of Addison Wesley Longman, Inc.

Neurons



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

Cell body : contains nucleus

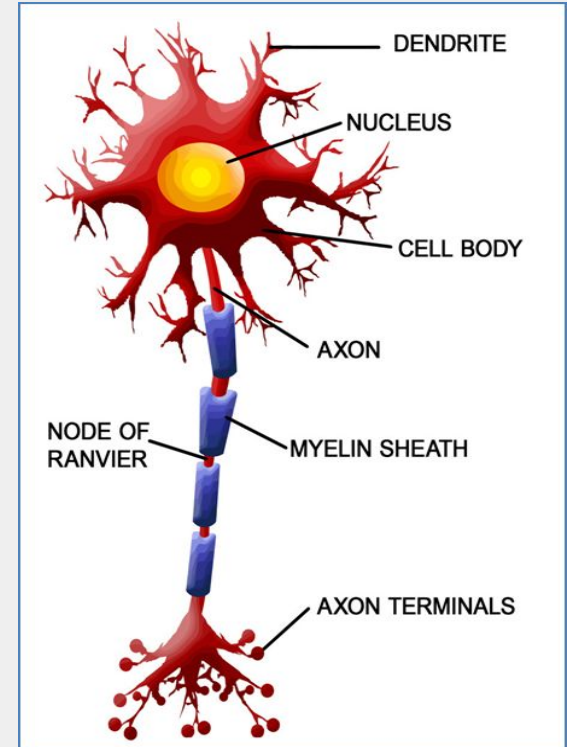
Dendrites : receive signals

Axon : consist of myelination and nodes of ranvier

Axon terminals : release neurotransmitters to conduct signals

Synaptic end bulbs : part of axon terminals and contains neurotransmitters

Neurotransmitter : Acetylcholine (ACH)



α -Motor neuron in the anterior horn cell



A nerve is made of a group of axons of neurons

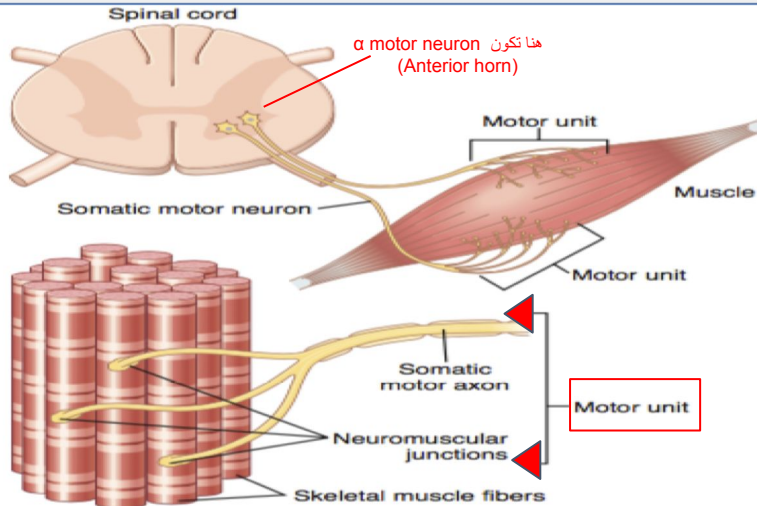
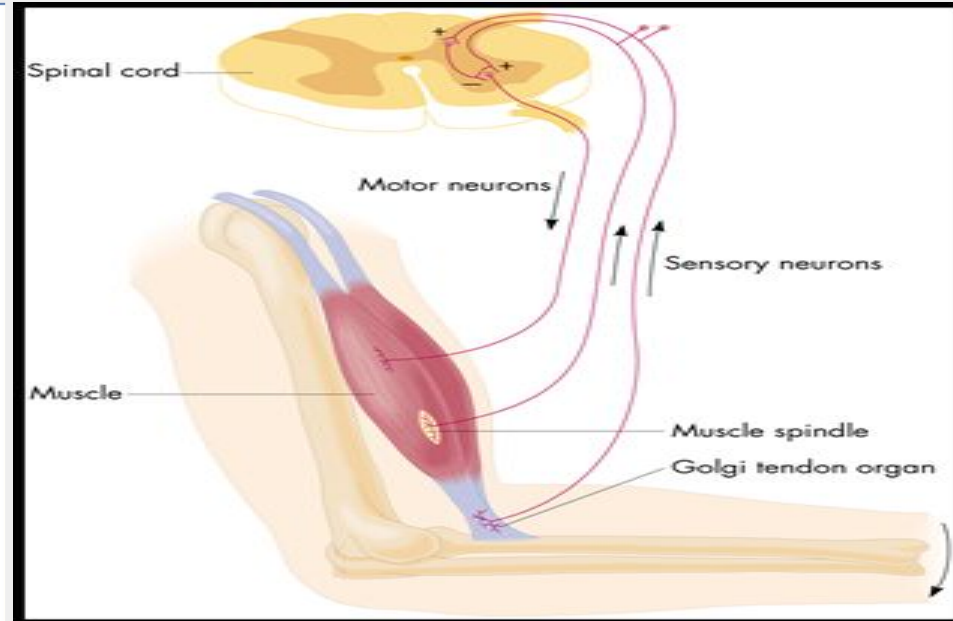


Figure 6-14. A motor unit consists of a motor neuron and the group of skeletal muscle fibers it innervates. A single motor axon may branch to innervate several muscle fibers that function together as a group. Although each muscle fiber is innervated by a single motor neuron, an entire muscle may receive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



What is a Motor unit ?



01

It is the α -motor neuron in the **anterior horn cell (AHC)** and all the muscle fiber it innervates (supplies)
(do not mix between AHC and ACH)

02

All of these muscle fibers will be of the same type (either **fast twitch** or **slow twitch**)

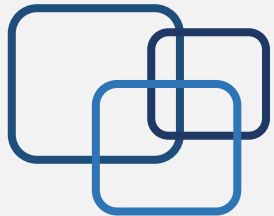
03

-Each muscles consist of a number of motor units.
(each muscle is controlled by more than 1 motor units)

-The group of motor units supplying a single muscle are **Motor Unit Pool**.

04

When a motor neuron is activated, all of the muscle fibers innervated by the motor neuron are stimulated and contract
(innervated means supply an organ with nerve)



Continue ..



The number of muscle fibers in a motor unit (innervated by 1 motor neuron) varies

06

1–**Gastrocnemius** :2,000 muscle fibers per one motor neuron

2–**Extraocular** muscles :it is the six muscle that control the movement of the eye < 10 muscle fibers per one motor neuron

Gastrocnemius:عضلة الساق

Extraocular muscle :
عضلات العين

07

3-Leg muscles :600 muscle fibers per one motor neuron.

4-Some laryngeal muscles (2-3 muscle fibers per MU)

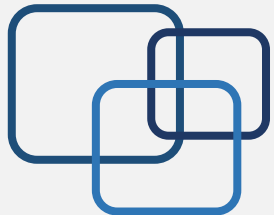
08

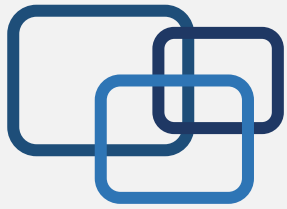
The average all over the body is
80-100/MU

09

Ratio of muscle fibers to motor neurons affects the precision of movement.

small number is associated with more precise movements and vice versa
والعكس صحيح





Precise movement

كل ما زادت ال motor units
وقلت ال muscle fibers زادت
دقة حركة العضلة

01

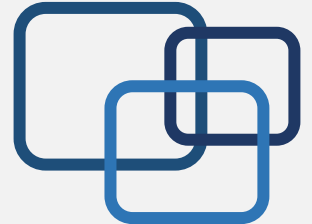
Groups of motor units often work together to help the contractions of a single muscle .

02

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 Hand and eye muscles)

03

Less precise movements are carried out by muscles composed of **fewer** motor units with many fibers per unit (e.g Trunk muscles)



Force Produced By

A Single Motor Unit is Determined by :

1) Number of muscle fibers in the unit

This will lead to**

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

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

- The number of muscle fibers in a motor unit **determines the size of the motor unit and ultimately the force produced** by the activation of that motor unit.
- Larger number of muscle fibers in a motor unit = larger motor unit = greater contraction , and vice versa.

Muscle Contraction

Different magnitudes of force (graded response) depends on force summation which means the adding together of individual **twitch*** contraction to increase the intensity of overall muscle contraction.

- force summation occurs in two ways** (=The two ways the nervous system increases force production through) :

2) Frequency summation (**rate coding**)

1) Multiple fiber summation

*Muscle Twitch: is a brief contraction followed by relaxation in the muscle caused by a single action potential. (ر عشة) (short duration) (no purposeful movement)

**are also the 2 types of summation.

الفكرة Motor unit تغذي 4 مسل فايبرز ووحدة ثانية تغذي 20 لو شغلت الأولى 4 مرات صاروا متساوين لو عندي كذا تغلظت على نقص العدد

Multiple Fiber Summation

(Recruitment of Motor Units)

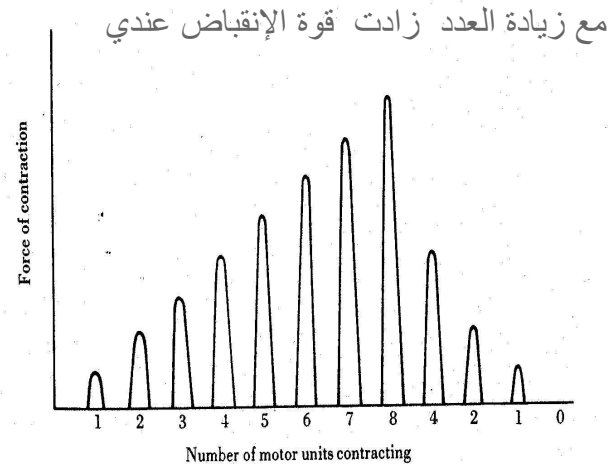
Definition: It is the summation of individual muscle fiber contractions that happen simultaneously. by increasing the number of motor units contracting simultaneously = increase the summation = increase the force produced.

Recruitment (توظيف) of motor units: is the progressive activation of a muscle by successive recruitment of contractile units (motor units) to accomplish increasing degrees of contractile strength (force).

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

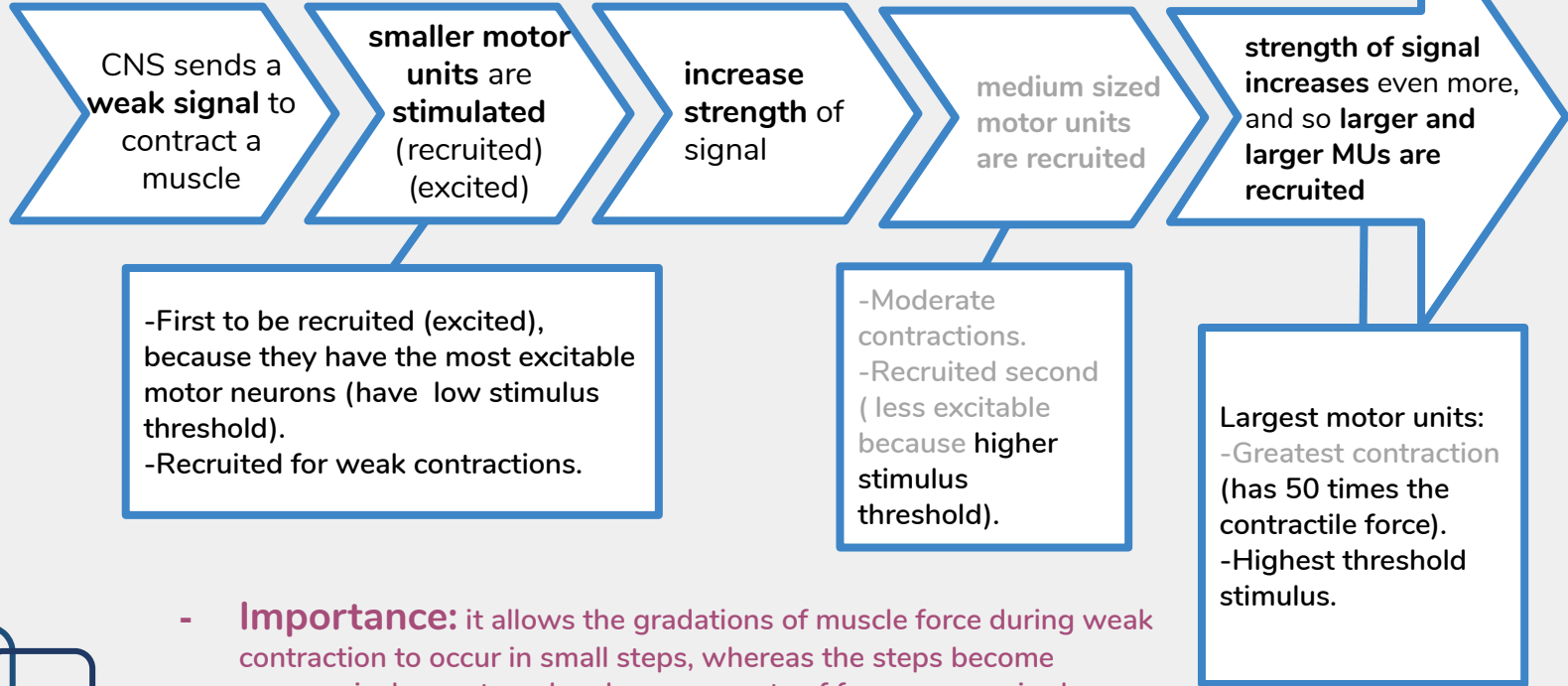
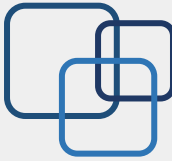
The higher the motor unit recruitment (more motor neurons are stimulated resulting in more muscle fibers being activated), the stronger the muscle contraction.

Recruitment of motor units follows a principle called the size principle.*

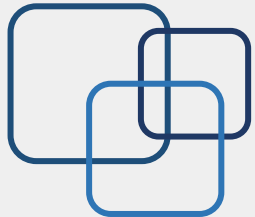


*Or we can say exhibit a phenomenon called the size principle.

The Size Principle:



- **Importance:** 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.
- **Cause:** the smaller motor units are driven by small motor nerve fibers, and the small motor neurons in the spinal cord are more excitable than the larger ones, so naturally they are excited first.



Multiple Fiber Summation:

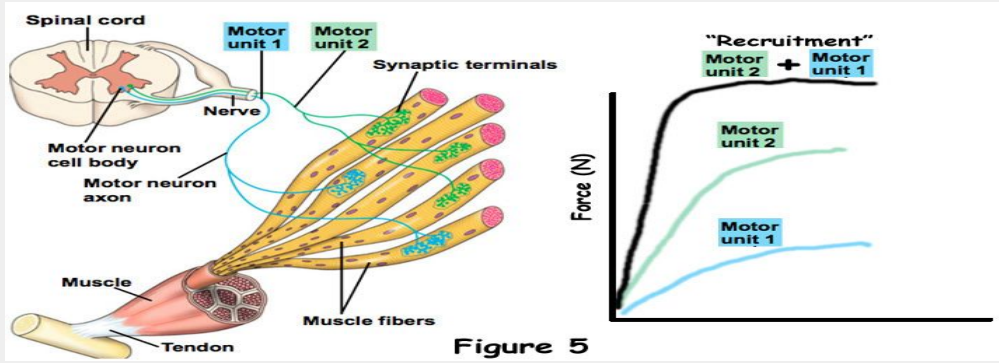


Figure 5

Types of alpha motor neurons

MUs receive common neural input and are recruited according to their sizes. (Henneman's Size principle)

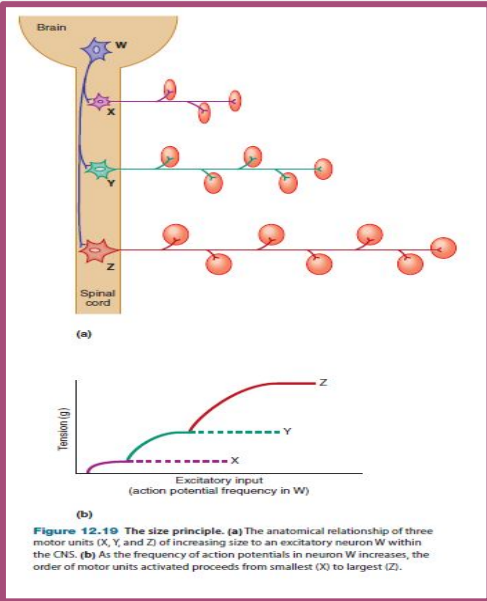
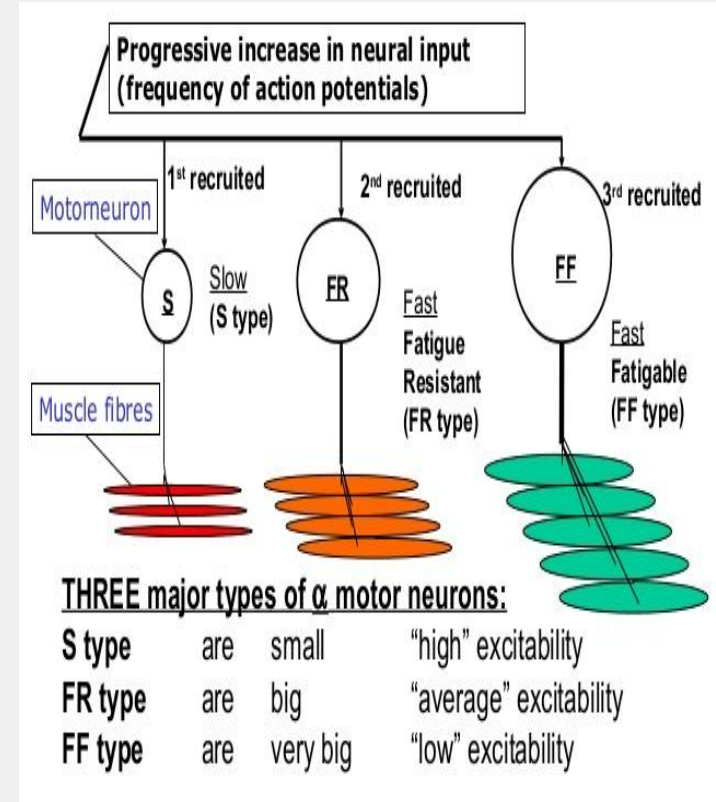


Figure 12.10 The size principle. (a) The anatomical relationship of three motor units (X, Y, and Z) of increasing size to an excitatory neuron W within the CNS. (b) As the frequency of action potentials in neuron W increases, the order of motor units activated proceeds from smallest (X) to largest (Z).

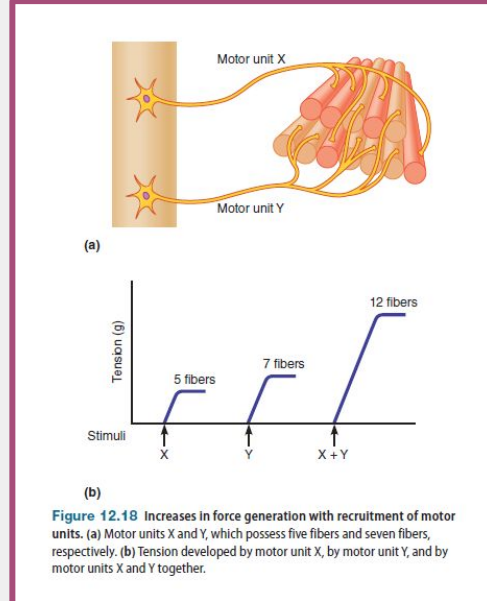
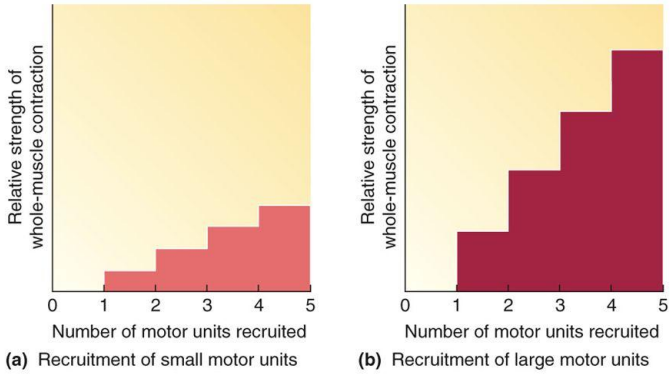
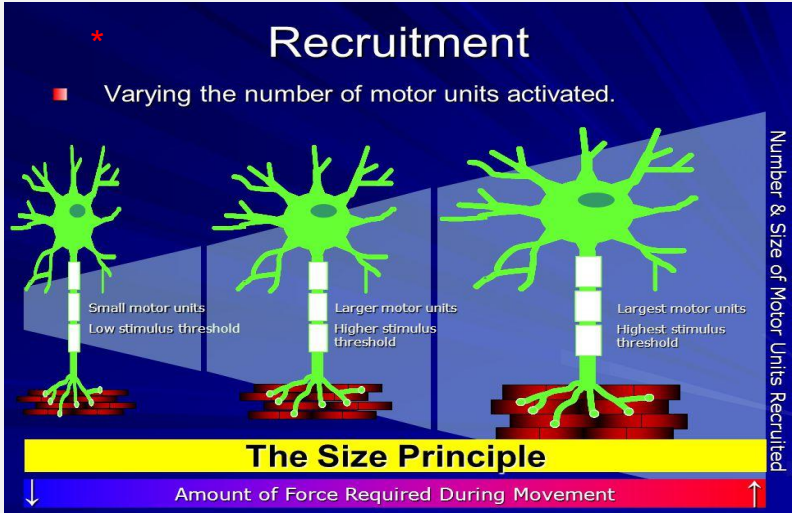
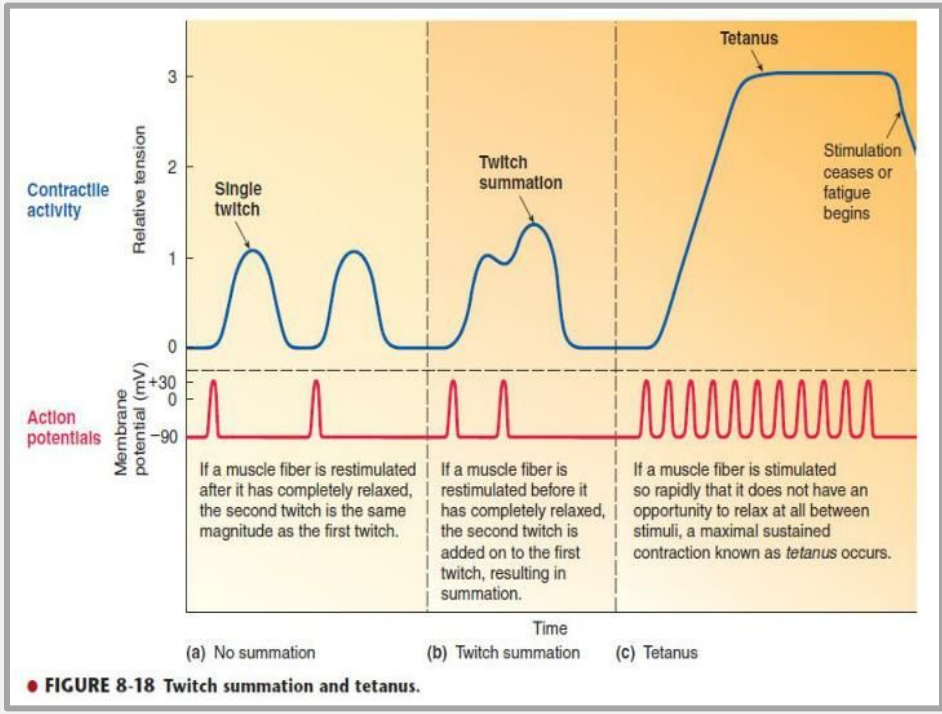


Figure 12.18 Increases in force generation with recruitment of motor units. (a) Motor units X and Y, which possess five fibers and seven fibers, respectively. (b) Tension developed by motor unit X, by motor unit Y, and by motor units X and Y together.

* Motor Unit Recruitment

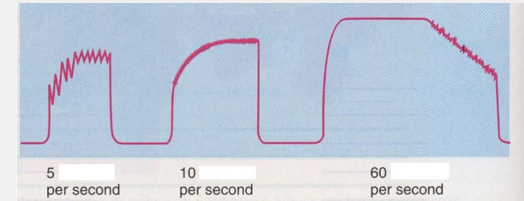
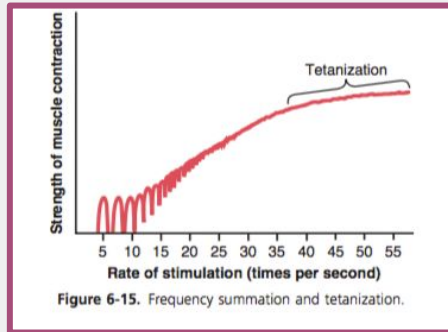


frequency Summation:



Frequency Summation (rate coding) and Tetanization

- **Definition:** is the increase of force of contraction by increasing the frequency of contractions- increasing the rate at which the action potentials stimulate the muscle fiber.
 - frequency summation can lead to tetanization (tetanus: is the prolonged contraction of a muscle caused by rapidly repeated stimuli, it has 2 types: fused or complete tetanus, unfused or incomplete tetanus).
 - **Rate coding:** refers to the motor unit firing rate.
 - Active motor units can discharge at higher frequencies to generate greater tensions.
 - As the frequency increases, there comes a point when each new contraction occurs before the preceding one is over.
 - If AHCs fire at very fast rates → fast MUPs → stronger contraction.
 - Thus the total strength of contraction rises progressively with increasing frequency (Increasing frequency of action potentials resulting in stronger force of contraction).
- Example: Two twitches from 2 action potentials add together to produce greater tension(force) in the fiber than produced by a single action potential.



Frequency Summation (rate coding) and Tetanization

frequency increases ↓

Rate Coding (Frequency)		Result
Slow	<ul style="list-style-type: none"> - Individual twitch contractions occurring one after another at low frequency of stimulation. - When the anterior horn cell (AHC) fires at slow rates, motor unit potentials (MUPs) will be at slow rate & the force of muscle contraction is weak. 	<u>No summation</u> (because repeated APs are separated by long intervals of time and so muscle fibers have time to relax completely between stimuli.)
Faster	<ul style="list-style-type: none"> - Muscle fiber is restimulated before it has completely relaxed, the second twitch is added on to the first twitch. - Sustained contraction. - Happens on a daily basis. 	<ul style="list-style-type: none"> - Results in twitch summation (unfused or incomplete tetanus).
Even Faster	<ul style="list-style-type: none"> - No relaxation occurs between the stimuli. - Sustained contraction. - Not common. 	<ul style="list-style-type: none"> - Results in summation (fused or complete tetanus). - Muscles fatigue very quickly

- 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 none role



Motor Units Follows “all-or-none” principle

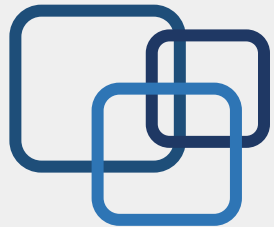
impulse from motor neuron will cause contraction in all muscle fibers it innervates or none



In an electrodiagnostic testing (EMG, electromyography) 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.

S U M M A R Y

- The number of muscle fibers in a motor unit determines the size of the motor unit and ultimately the force produced by the activation of that motor unit.
- Different magnitudes of force (graded response) depends on:
 1. multiple fibers summation.
 2. frequency summation.
- The higher the motor unit recruitment (more motor neurons are stimulated), the stronger the muscle contraction.
- Frequency summation: is the increase of force of contraction by increasing the rate at which the action potentials stimulate the muscle fiber (the frequency of contractions).
- Major three types of alpha motor neuron S Type , FR Type , FF type
- Two ways the nervous system increases force production is through
 - 1- Recruitment of new motor units .
 - 2- Increasing stimulation frequency (rate coding).
- The number of muscle fibers within each motor unit can vary. group of motor units supplying a single muscle are Motor Unit Pool



MCQs

Q1: what is affected by ratio of muscle fibers to its motor neuron

- | | | | |
|----------------|---------------------|--------------|------------------------------|
| A) Contraction | B) Action potential | C) precision | D) Initiation of contraction |
|----------------|---------------------|--------------|------------------------------|

Q2 : Which of the following determines a strong muscle contraction?

- | | | | |
|-------------------------------------|-------------------------------------|--------------------------------------|--|
| A) Slow firing rate of motor neuron | B) High recruitment of motor neuron | C) Activation of single motor neuron | D) Activates a small number of muscle fibers |
|-------------------------------------|-------------------------------------|--------------------------------------|--|

Q3 :Which ONE of the following muscles has the smallest motor unit?

- | | | | |
|------------------|--------------|---------------|-----------|
| A) Gastrocnemius | B) Laryngeal | C) Pectoralis | D) Soleus |
|------------------|--------------|---------------|-----------|

Q4 :CNS sends a signal to contract a muscle, first to be stimulated are:

- | | | | |
|----------------------|-----------------------|------------------------|-------------------------|
| A) small motor units | B) medium motor units | C) largest motor units | D) all at the same time |
|----------------------|-----------------------|------------------------|-------------------------|

Q5 :Active motor units can discharge at _____ frequencies to generate greater tensions.

- | | | | |
|-----------|----------|----------|--------------|
| A) higher | B) lower | C) minor | D) separated |
|-----------|----------|----------|--------------|

Q6 : Smaller muscles (e.g: first dorsal interosseous) when contracting rely more on:

- | | | | |
|-------------------------------|----------------|---------------------------|--------------------------------------|
| A) recruitment of motor units | B) rate coding | C) muscle fiber summation | D) number of muscle fibers in a unit |
|-------------------------------|----------------|---------------------------|--------------------------------------|

SAQ

Q1: The nervous system can increase force production in two ways:

Q2: **explain** what causes the size principle.

MCQs key answer :
6B
5A
4A
3B
2B
1C

SAQ answer key :
1): A) Recruitment of new motor units
B) increasing stimulation frequency
2) the smaller motor units are driven by small motor nerve fibers, and the small motor neurons in the spinal cord are more excitable than the larger ones because they have lower stimuli threshold than the ones innervating larger MUs, and so small motor units are stimulated first then larger and larger MUs.



THANK
you 😊

TEAM LEADERS

Abdulrahman Alswat

Haya Alanazi

REVIEWED BY

👉 Meshal Alhamed

Ghada Alothman

TEAM MEMBERS

- 👉
- ▶ Mishal Althuanyan
 - ▶ Basel Fakeeha
 - ▶ Mohammad Beyari
 - ▶ Abdulaziz Alsuhaime
 - ▶ Mohammad Alsalman
 - ▶ Abdulrahman Addweesh
 - ▶ Morshed Alharbi
 - ▶ Ahmad Alkhayatt
 - ▶ Abdulaziz Alguligah
 - ▶ Omar Alhalabi

- ▶ Sumo Alzeer
- ▶ Noura Alshathri
- ▶ Renad Alhomaidi
- ▶ Yasmin Alqarni
- ▶ Lama Alahmadi
- ▶ Alaa Alsulmi
- ▶ Farah Albakr
- ▶ Hind Almotywea
- ▶ Sarah Alqahatani
- ▶ Duaa Alhumoudi