SNS COLLEGE OF TECHNOLOGY

(AN AUTONOMOUS INSTITUTION)

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Department of Biomedical Engineering

Course Name: 19BMB201 –Diagnostic and Therapeutic Equipment

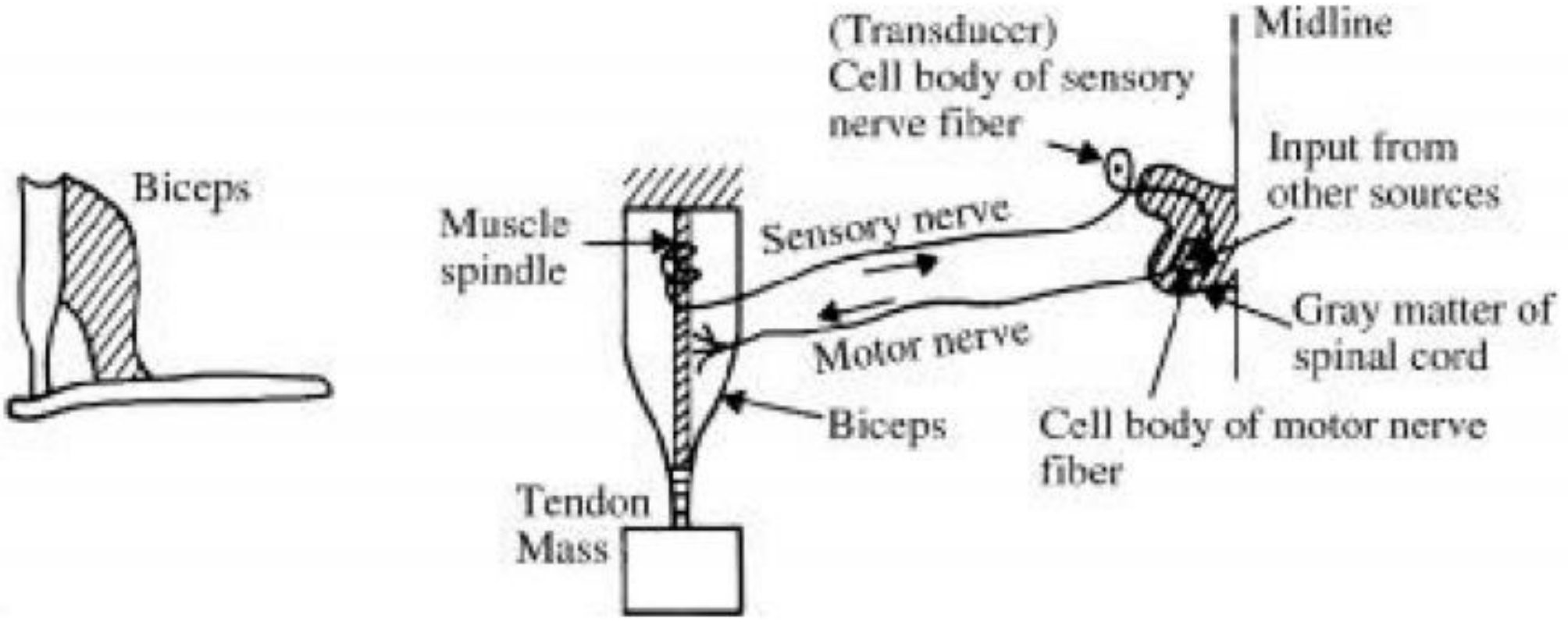
II Year : V Semester

Topic : UNIT 2-Electromyography

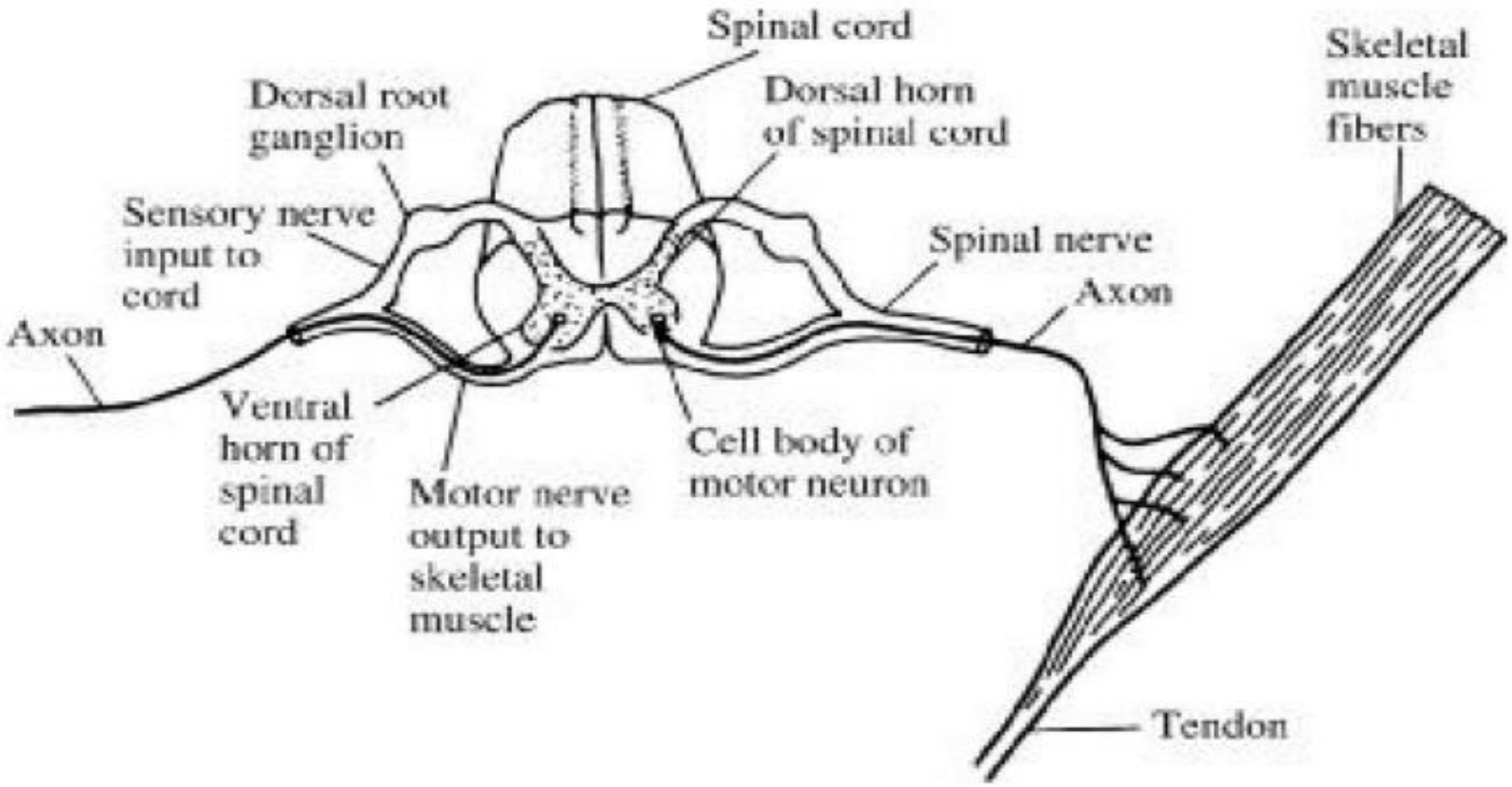
Outline

- Muscle Moment – Moment Arm
- Review of Muscle Contraction Physiology
- Physiological Basis of EMG
- Methods of EMG Collection
- Limitations & Uses
- Journal of Electromyography and Kinesiology (full-text in Science Direct)

The Reflex Arc



Single Motor Unit (SMU)



What is EMG

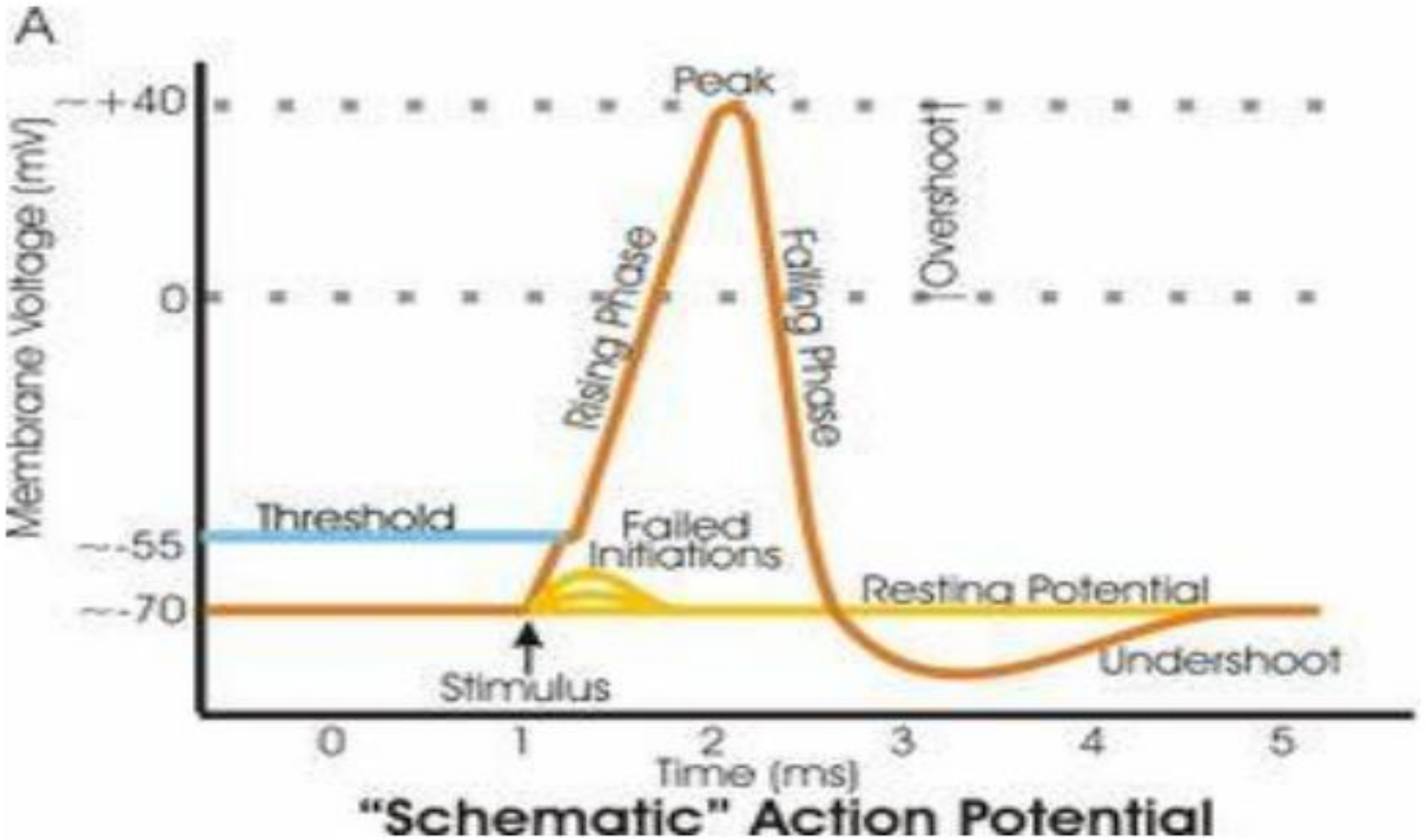
- Muscle contraction due to a change in the relative sliding of thread-like molecules or filaments
    - Actin and Myosin
- Filament sliding is triggered by electrical phenomenon (ACTION POTENTIAL, AP)
- The recording of muscle APs is called electromyography (EMG)
    - The record is known as an electromyogram

Action Potential (AP)

• Cell membrane separates intracellular from extracellular space, diffusion barrier which restricts ION flow. Concentration of ions different inside vs. outside of cell membrane, results in an electrical potential difference known as a MEMBRANE POTENTIAL. Typical magnitude of membrane potential is -60 and -90 mV (interior of cell is negatively charged compared to the outside) when the muscle cell is in resting state.

• When sufficient neurotransmitters are deposited at the motor endplate, it opens up Na+ gates, causing an influx of Na+ ions, causing a rapid depolarization of the membrane near the motor end plate. The membrane potential can change to +20 to +50 mV at the motor endplate within a fractions of a second, which starts (all or none) a cascade of events.

Action Potential (AP)

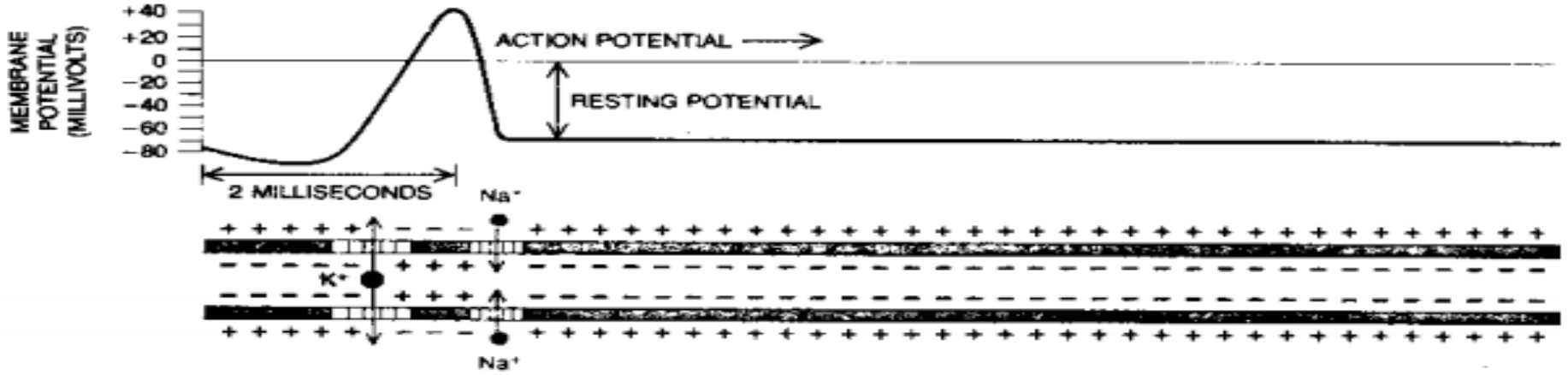


"Schematic" Action Potential

AP Continued

- This changed potential, sets up local currents in adjacent areas of membrane, which opens up more Na+ gates at the adjacent areas of the membrane, depolarizing those areas. The newly depolarized areas sets up electrical current with adjacent areas, and thus the depolarization wave propagates along the entire length of the muscle cell.

- Shortly after depolarization, the membrane is again repolarized, by active transport (ATP expenditure) of ions across the membrane. As a result a repolarization wave follows the depolarization wave for the entire length of the muscle.



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Action Potential Summary

• Active response of excitable membranes in nerve and muscle fibers produced by sodium and potassium channels opening in response to a stimulus

• AP abide by the all-or-none principle

– If MP reaches threshold voltage then Na+ channels open at first (Which direction will Na+flow?)

– Na+ channels only open for 1 ms, this causes repolarization (K+ channels also open during this time to speed up return of resting membrane potential)

– AP propagation along muscle fibers

• AP propagation velocity dependent upon:

(1) diameter of fibers (faster for thick – fast twitch)

(2) [K+] in extracellular fluid, ie chemical environment.

Motor Unit Action Potential

- Typically, each motor neuron innervates several hundred muscle fibers (innervation ratio).

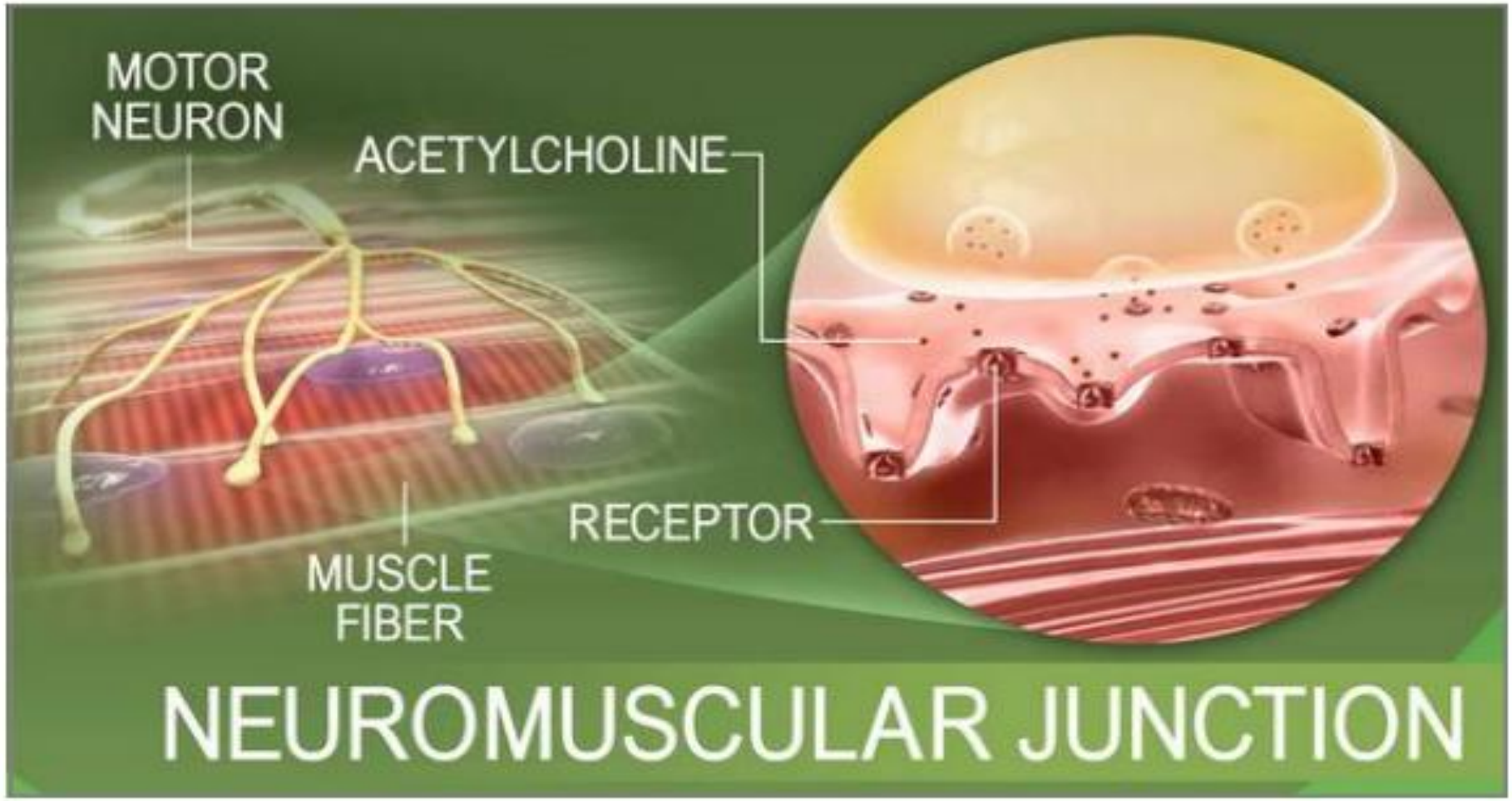
- Motor Unit Action Potential (MUAP) = summed electrical activity of all muscle fibers activated within the motor unit.

- Muscle force increased through higher recruitment and increased rate coding.

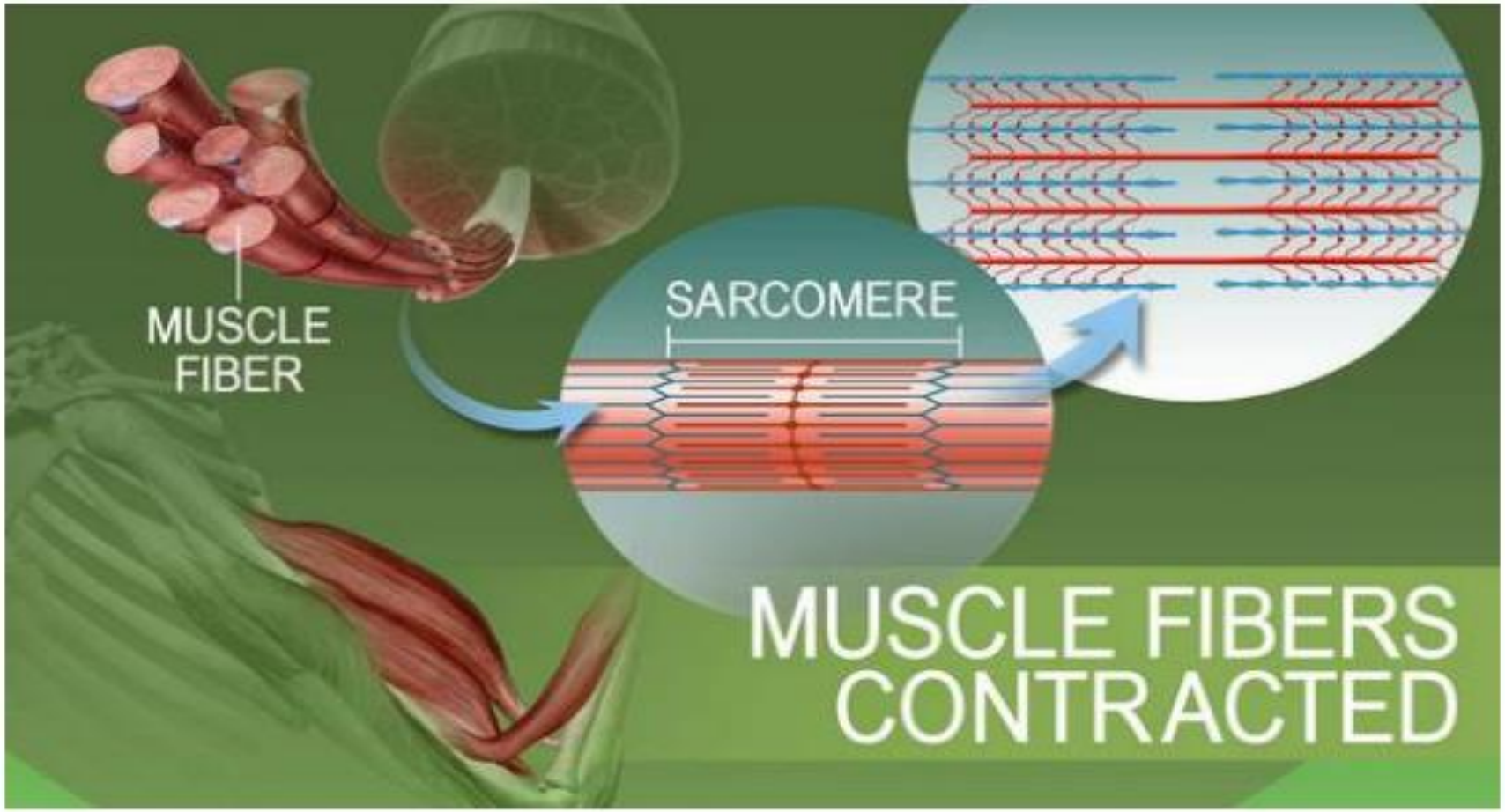
Mechanism of Muscle Contraction

(1) A message travels from the nervous system to the muscular system, triggering chemical reactions.
(2) The chemical reactions lead to the muscle fibers reorganizing themselves in a way that shortens the muscle--that's the contraction.
(3) When the nervous system signal is no longer present, the chemical process reverses, and the muscle fibers rearrange again and the muscle relaxes.

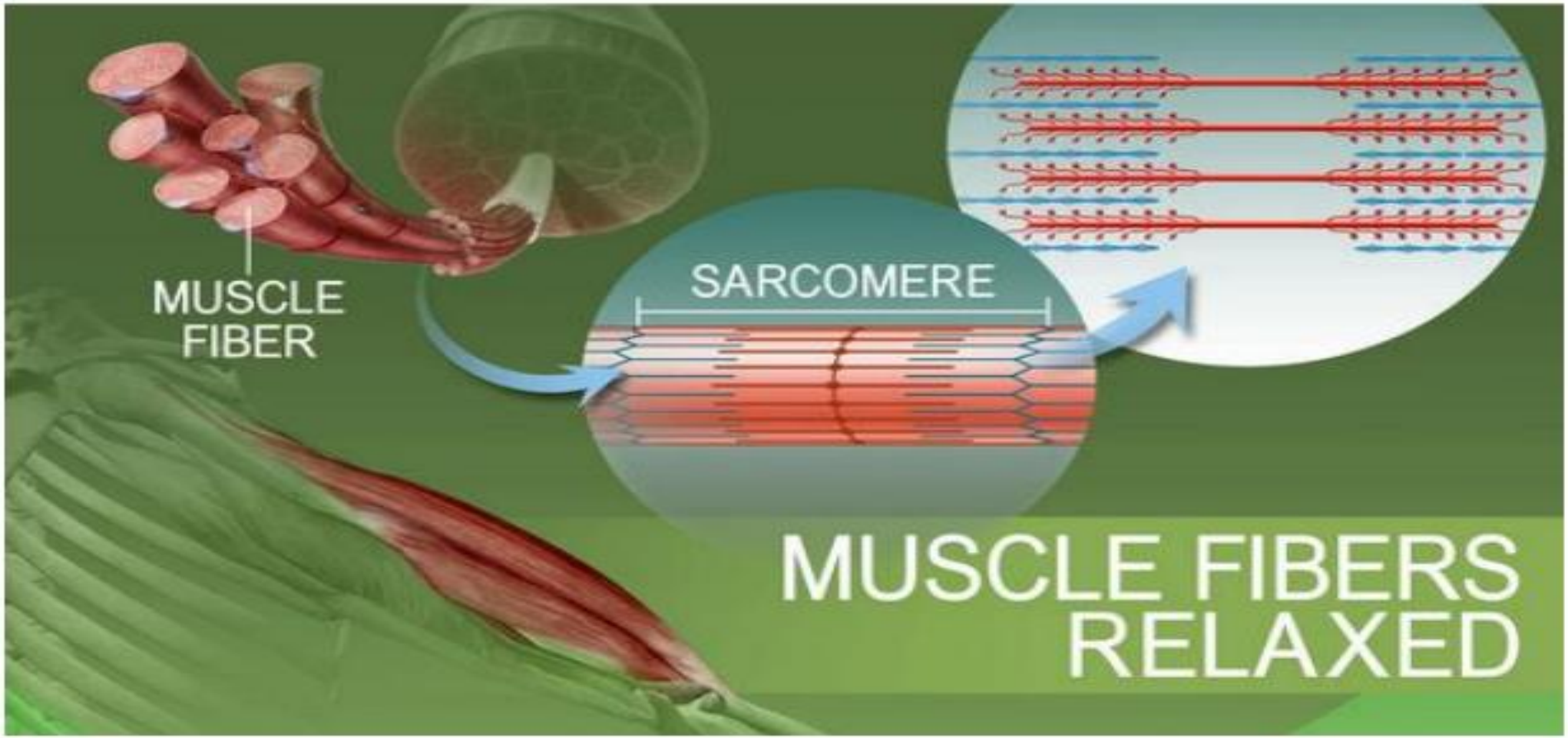
A Muscle Contraction Is Triggered When an Action Potential Travels Along the Nerves to the Muscles



Acetylcholine Is Released and Binds to Receptors on the Muscle Membrane

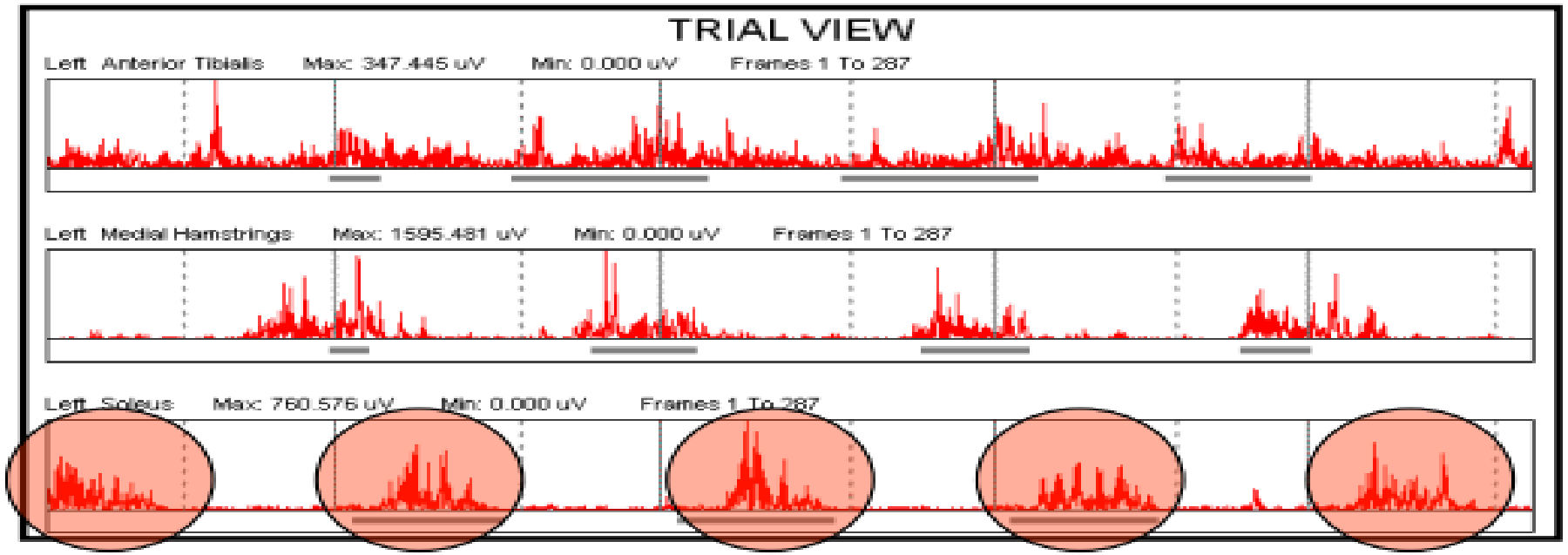


Muscle Fibers Relax When the Nervous System Signal Is No Longer Present



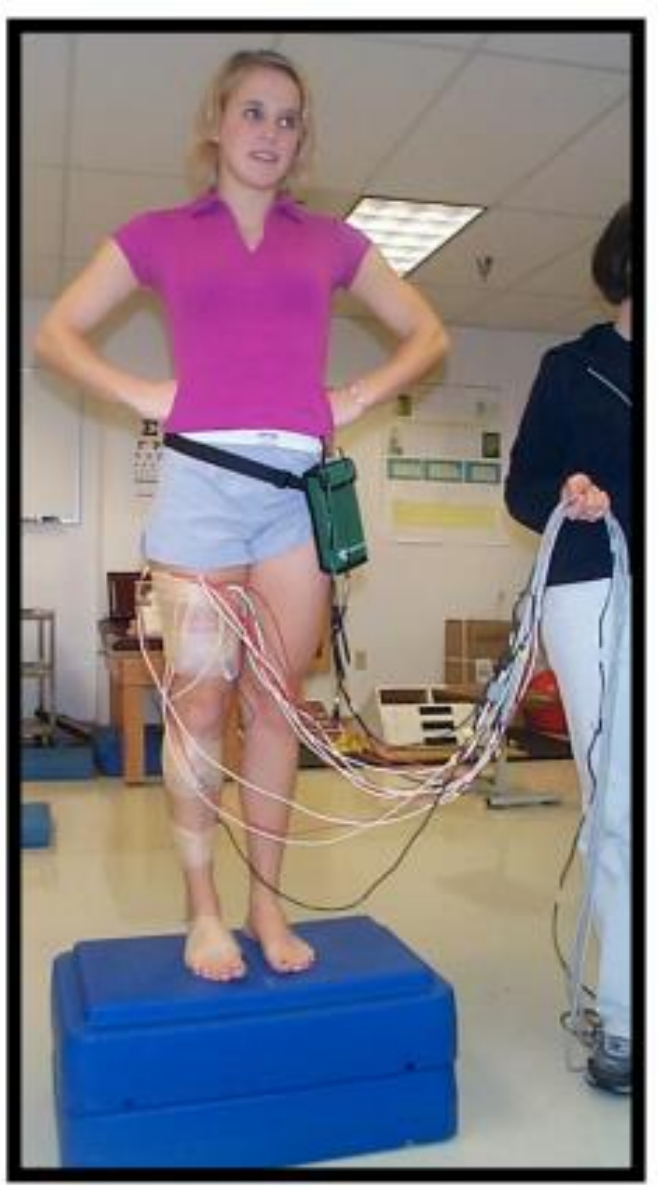
Recording Methodology

- Sweep of AP → similar to a wave
- Height of wave and the density of the wave can be recorded
- Represented graphically →electromyogram

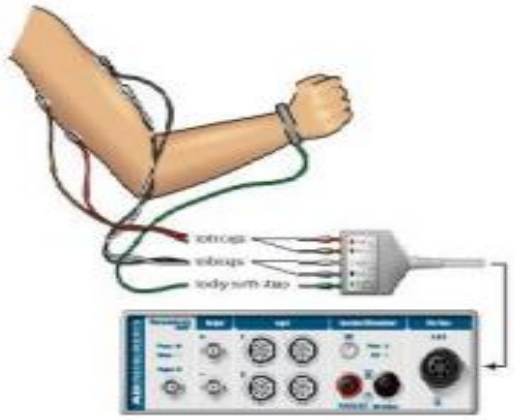


Recording Methodology

- Electrical potential difference measured between two points →bipolar electrode configuration used
- Bipolar Electrode Types
  - Fine Wire
  - Needle
  - Surface
    - – Most common, less invasive
    - – Silver-silver chloride electrodes
- Electrode Placement
- Overlying the muscle of interest in the direction of predominant fiber direction
- Subject is GROUNDED by placing an electrode in an inactive region of body



EMG Electrodes



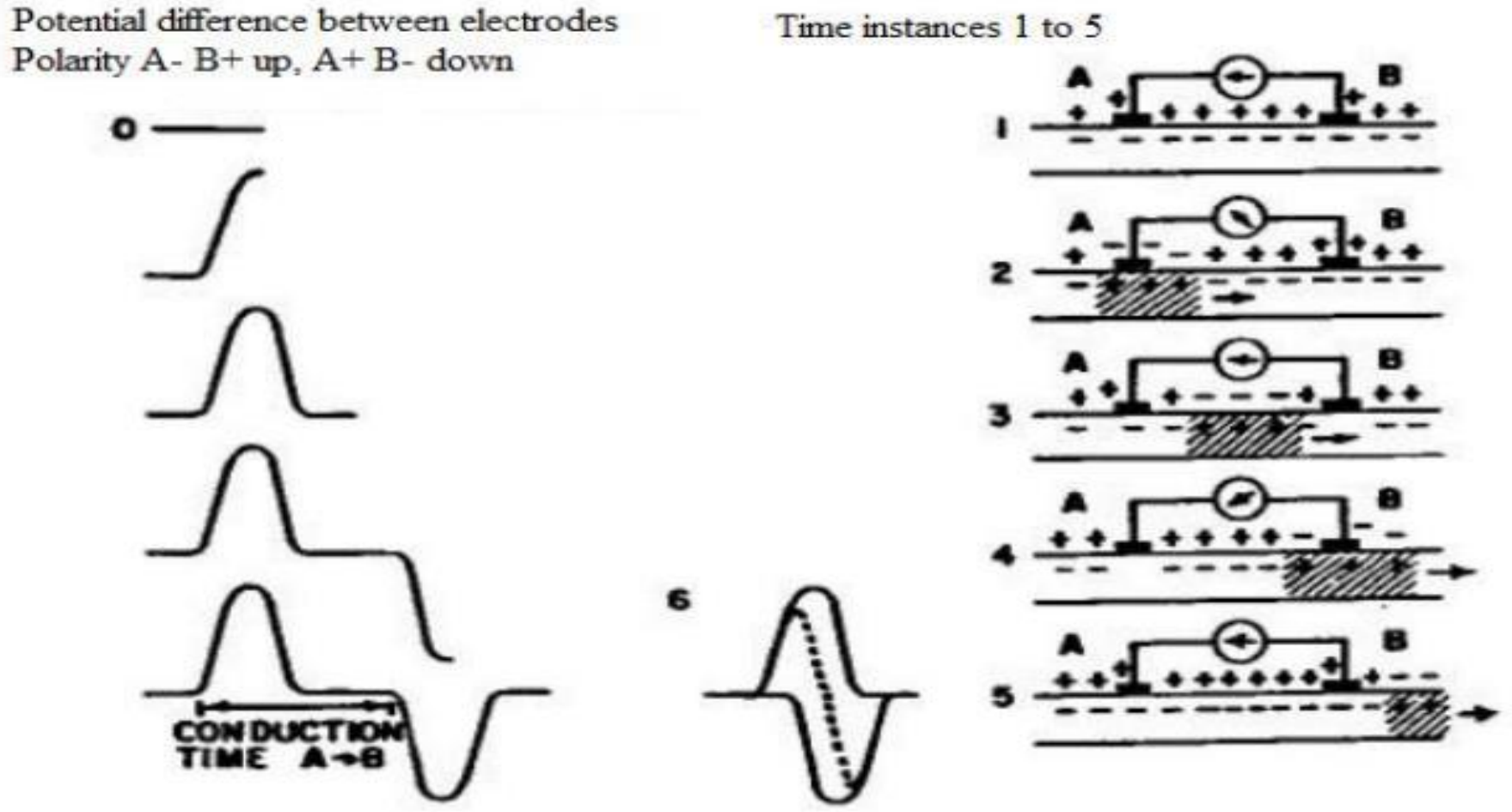
Surface Electrodes

Fine wire

Needle electrode

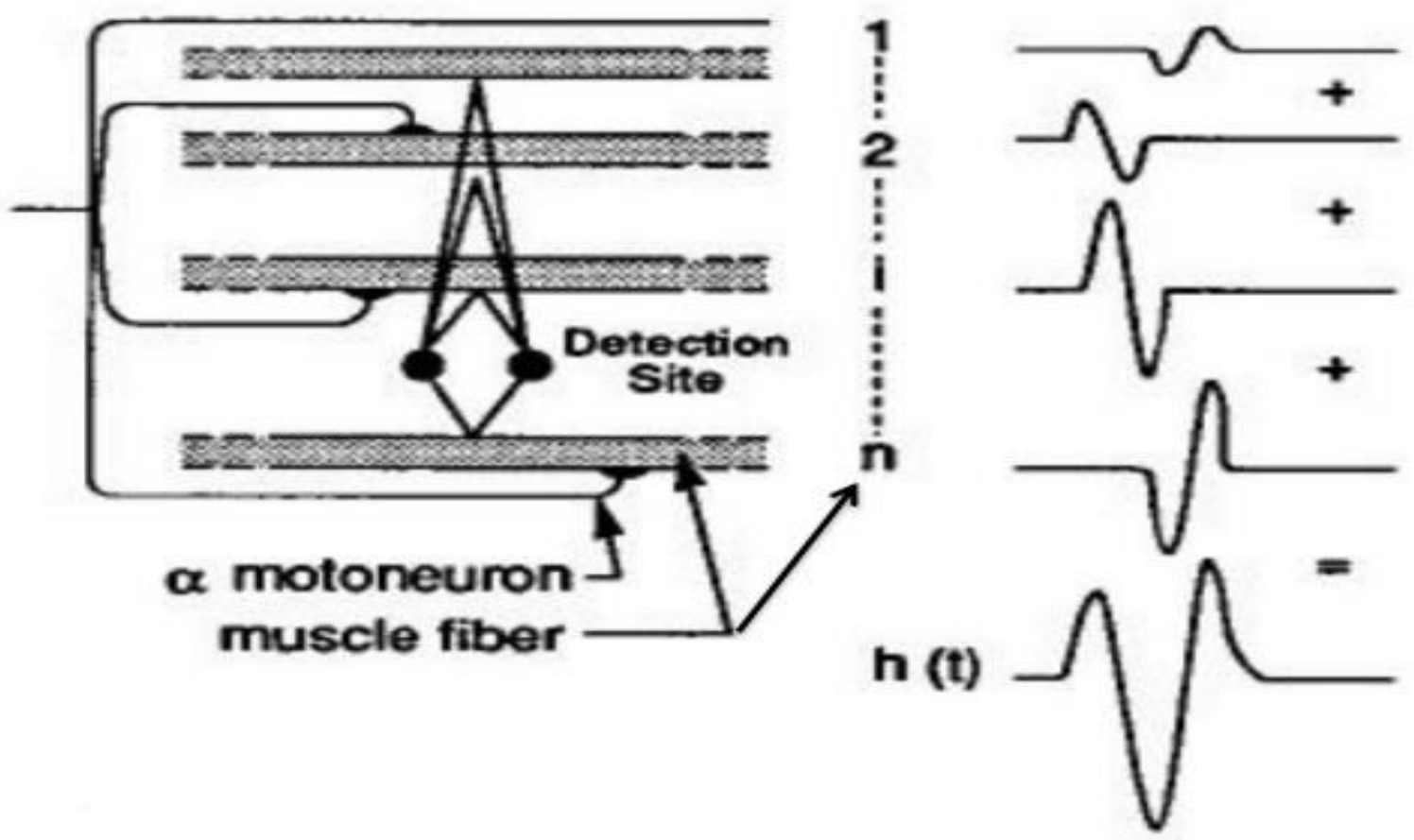
Physiological Basis

Hypothetical EMG from a single Muscle cell

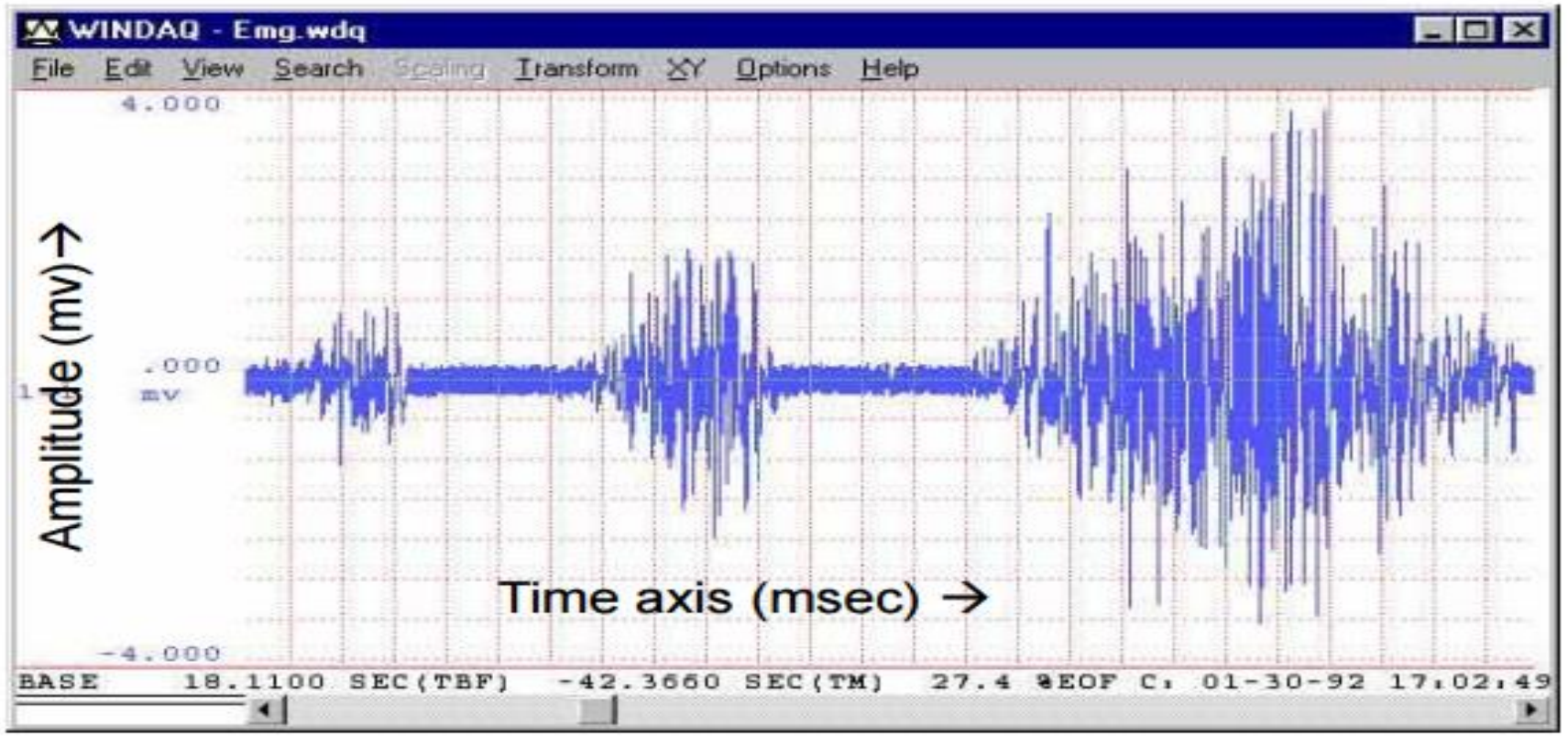


Physiological Basis

Hypothetical EMG from a Motor Unit



Typical EMG recording



Average amplitude over a time interval = 0

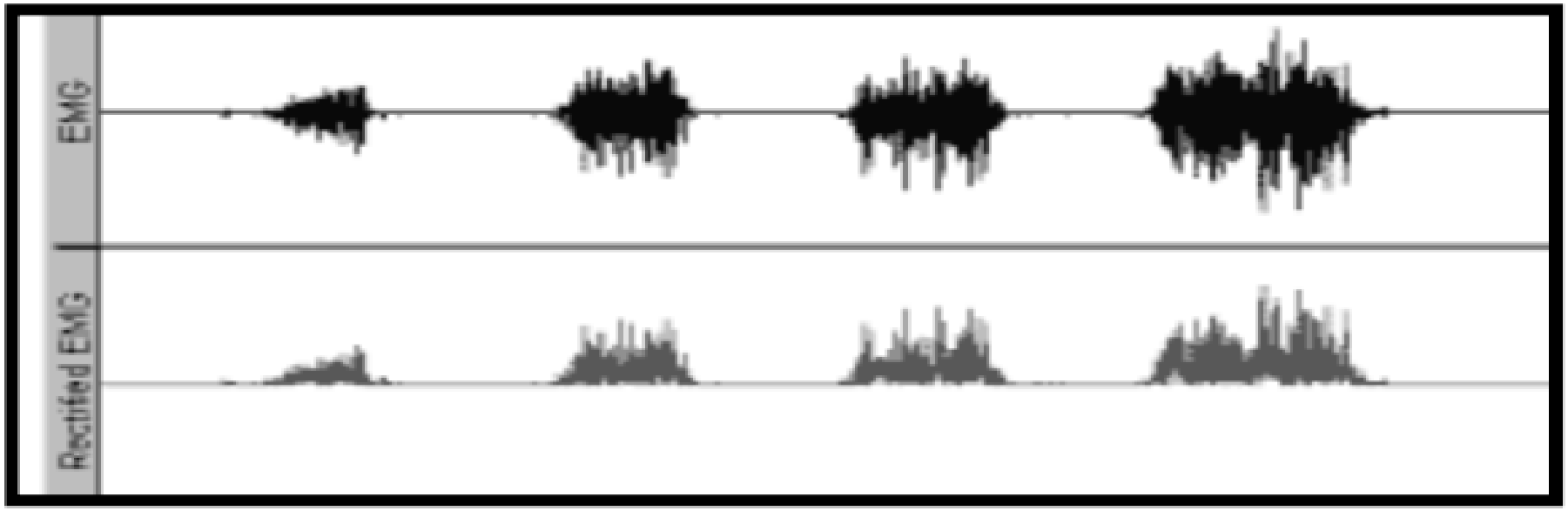
Analyzing the EMG Signal

- Amplitude & Frequency

- More MU →more amplitude, more spikes and more turns in signal
- Change in firing rate → change in frequency content of EMG
- Change in muscle fiber type → change in AP velocity, change in EMG frequency.
- EMG is spatial and temporal summation of APs

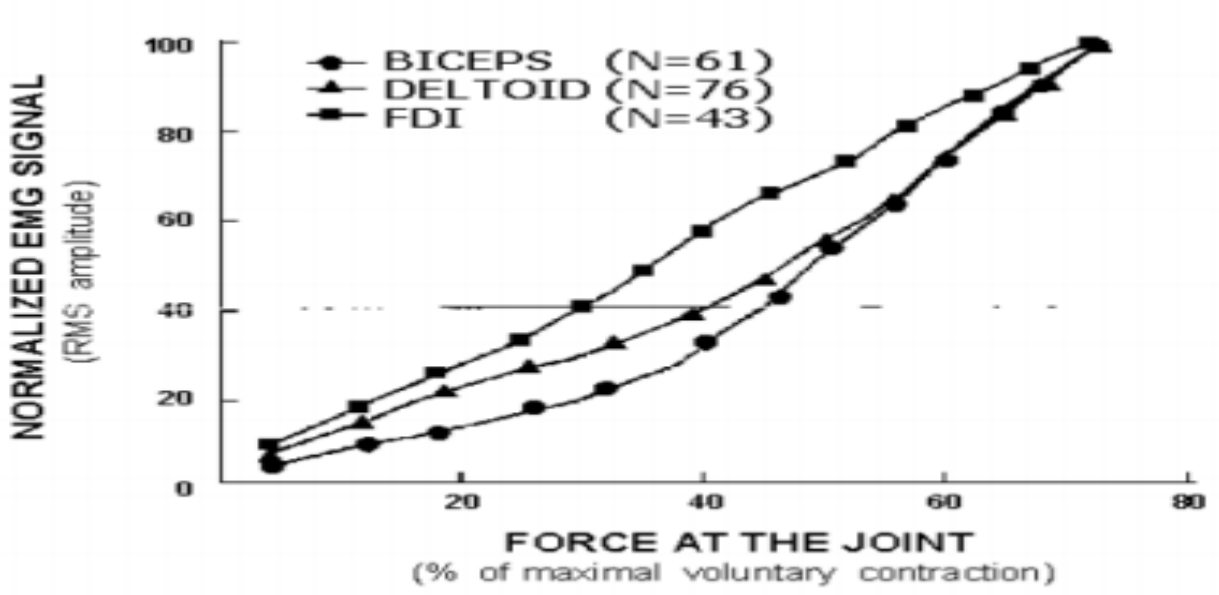
Average Rectified Amplitude

- Rectified = all negative values converted to positive values (absolute value)
- Then the average rectified amplitude provides a measure of signal strength



EMG Amplitude vs Muscle Contraction Intensity

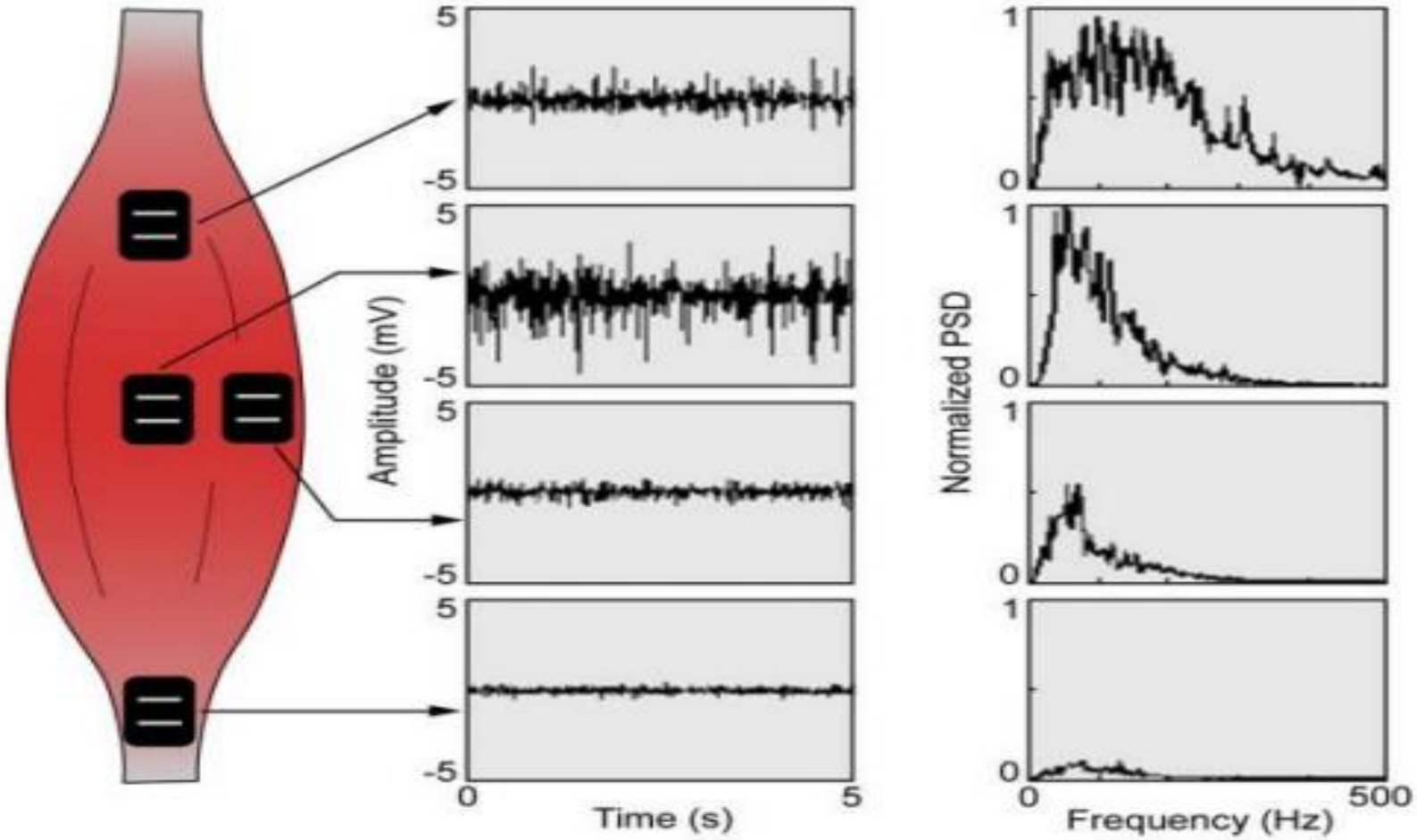
Amplitude increases with increased contraction intensity, BUT it is not a linear relationship



Factors Influencing Signal Measured

- Geometrical & Anatomical Factors
  - Electrode size
  - Electrode shape
  - Electrode separation distance with respect to muscle tendon junctions
  - Thickness of skin and subcutaneous fat
  - Misalignment between electrodes and fiber alignment
- Physiological Factors
  - Blood flow and temperature
  - Type and level of contraction
  - Muscle fiber conduction velocity
  - Number of motor units (MU)
  - Degree of MU synchronization

Effect of electrode position on EMG



Normalization

- Def: calibration against a known reference
- This allows researchers ability to compare different activities for the same muscle, different muscles, activities on different days, different subjects for same or different tasks, etc.
- Choices of normalization
  - Maximum voluntary contraction (MVC)
    - » Functional activty
    - » Isometric activty
  - Unresisted normal activity
  - Submaximum contraction
- Limitations
  - Variability of force generation due to motivation/physiological reasons

What can be learned from an EMG?

- Time course of muscle contraction
- Contraction force
- Coordination of several muscles in a movement sequence
    - These parameters are DERIVED from the amplitude, frequency, and change of these over time of the EMG signal

- Field of Ergonomics: from the EMG conclusions about muscle strain and the occurrence of muscular fatigue can be derived as well