

# The physiological background of EMG



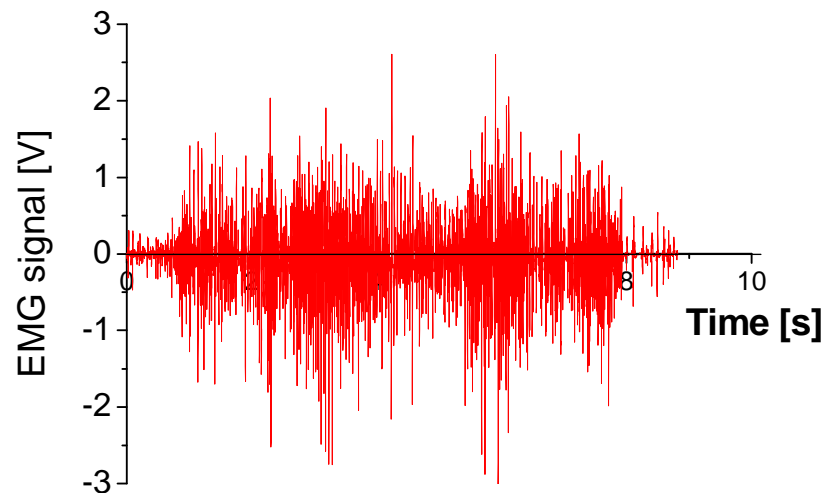
Lida Mademli

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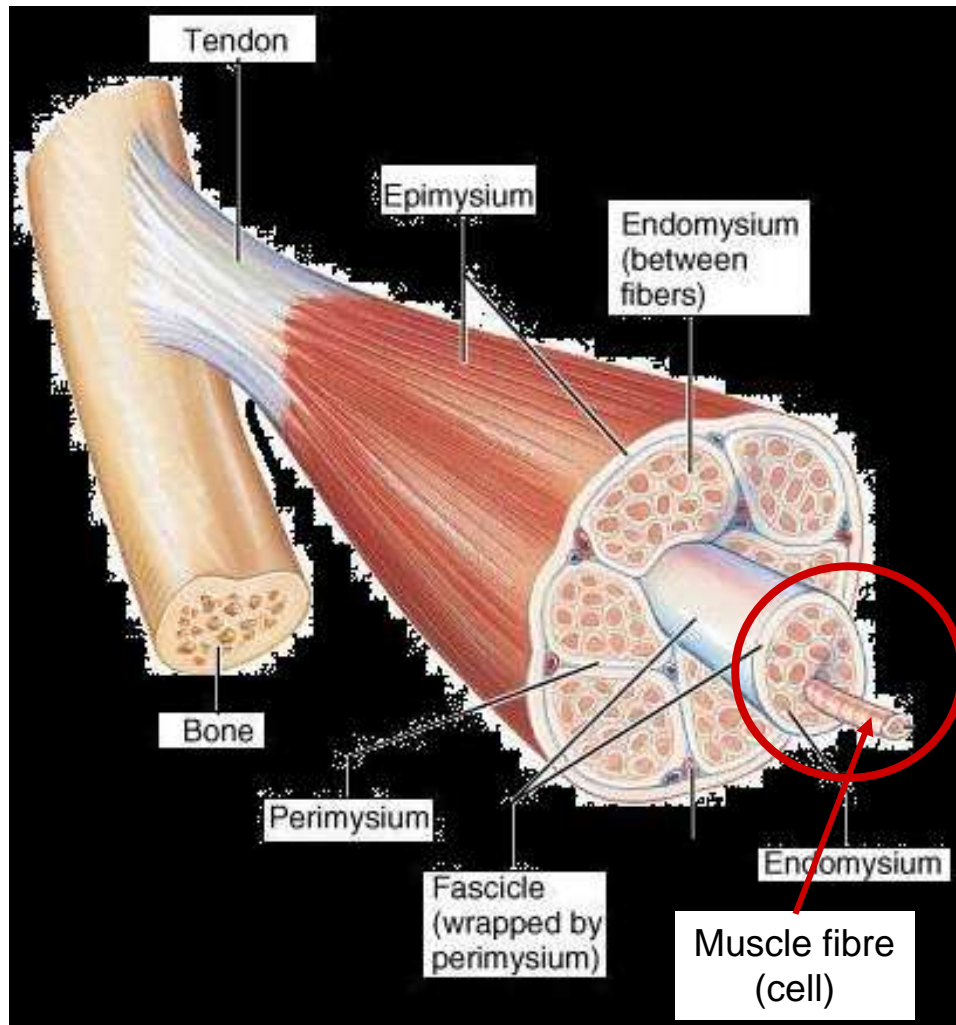
Centre of Research & Technology - Hellas  
Informatics & Telematics Institute

### **Electromyography:**

The discipline that deals with the detection, analysis, and use of the electrical signal that emanates from contracting muscles.



# Skeletal Muscle Organization



Muscle consist of:

- Muscle fascicles (bundles of muscle fibres)
- Muscle fascicles are wrapped by perimysium
- Muscle fascicles consist of
  - Muscle fibres (muscle cell)
  - Muscle fibres are wrapped by endomysium

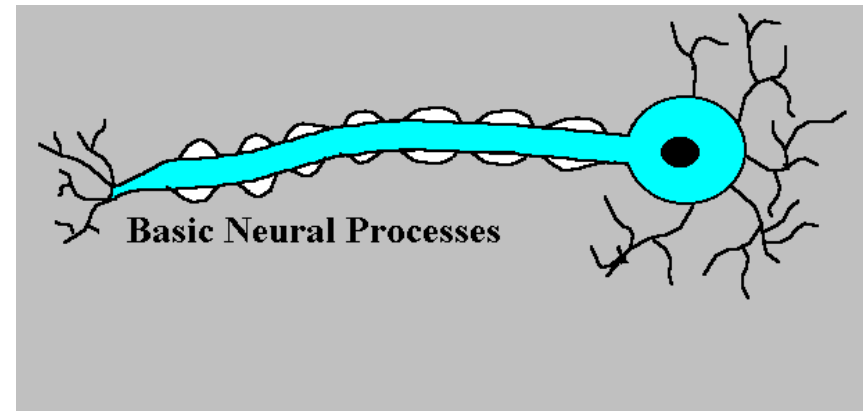
**The Muscle Fibre is what contracts**

# Skeletal Muscle Contraction: The Sliding Filament Theory



# How the electrical stimulus travels down the motoneuron to innervate (activate) the muscle fibre.

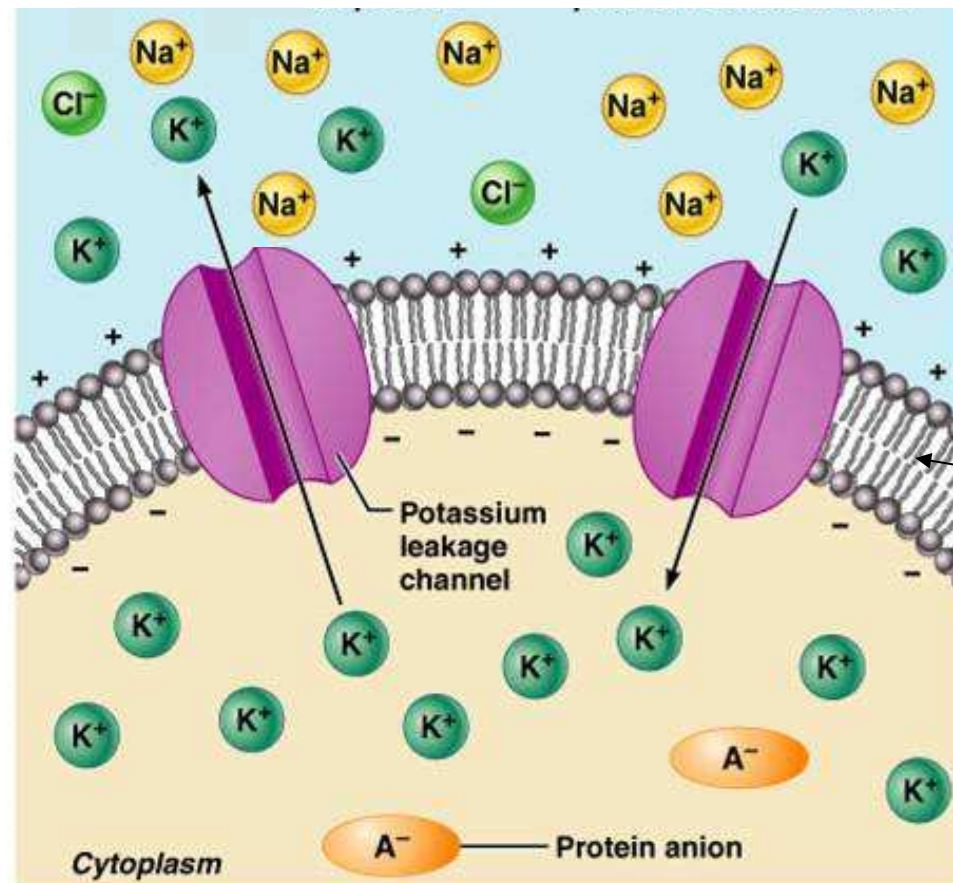
- The change in polarity travels down the neuron (**action potential**)
- Neurotransmitter (acetylcholine) is released from terminal end



**Resting potential of muscle = ~ -90mV** *(Purves et al 2001)*

In the absence of an impulse, the inside is electrically negative and the outside is positive

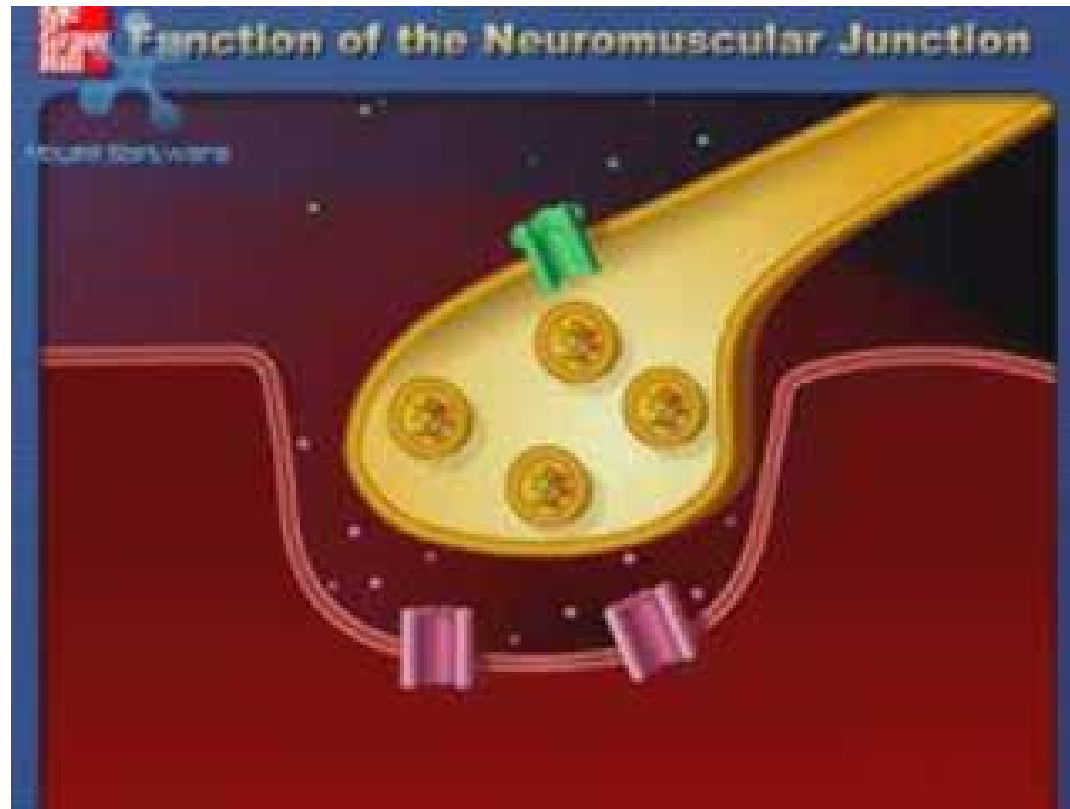
Extracellular space



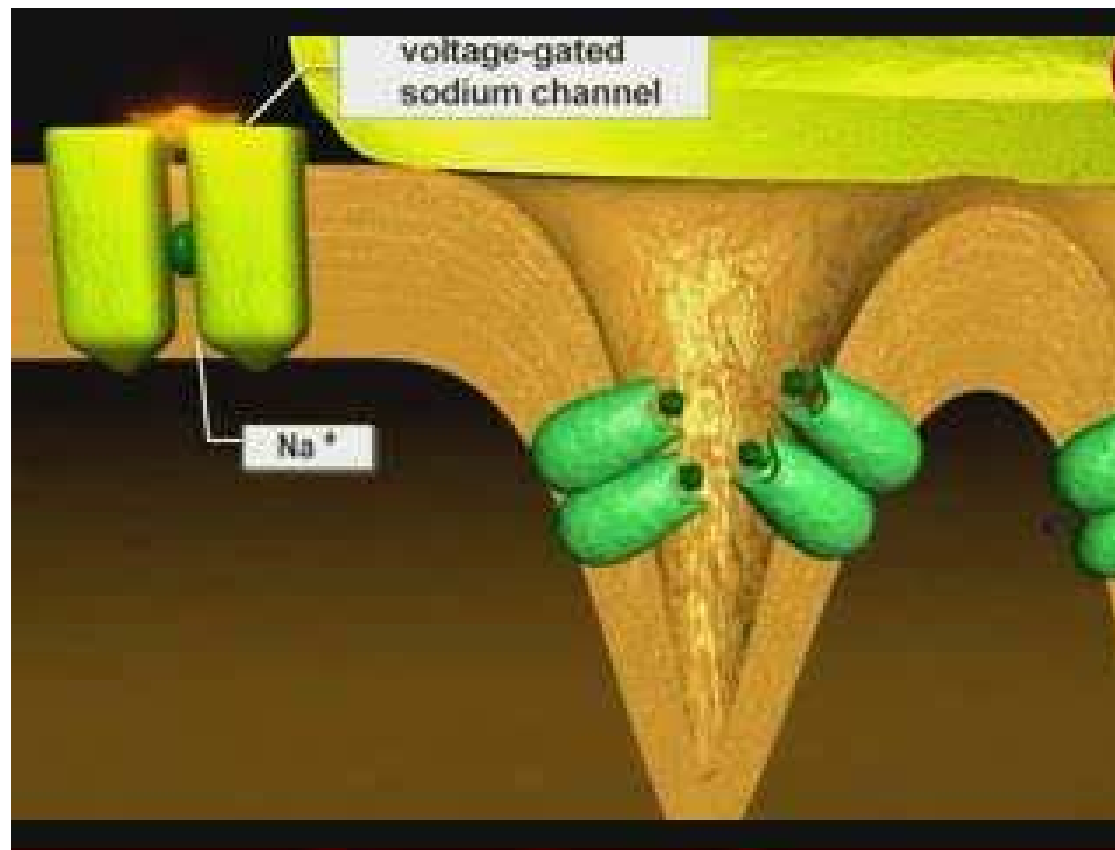
Muscle fibre membrane

Intracellular space

# Skeletal Muscle excitation and contraction

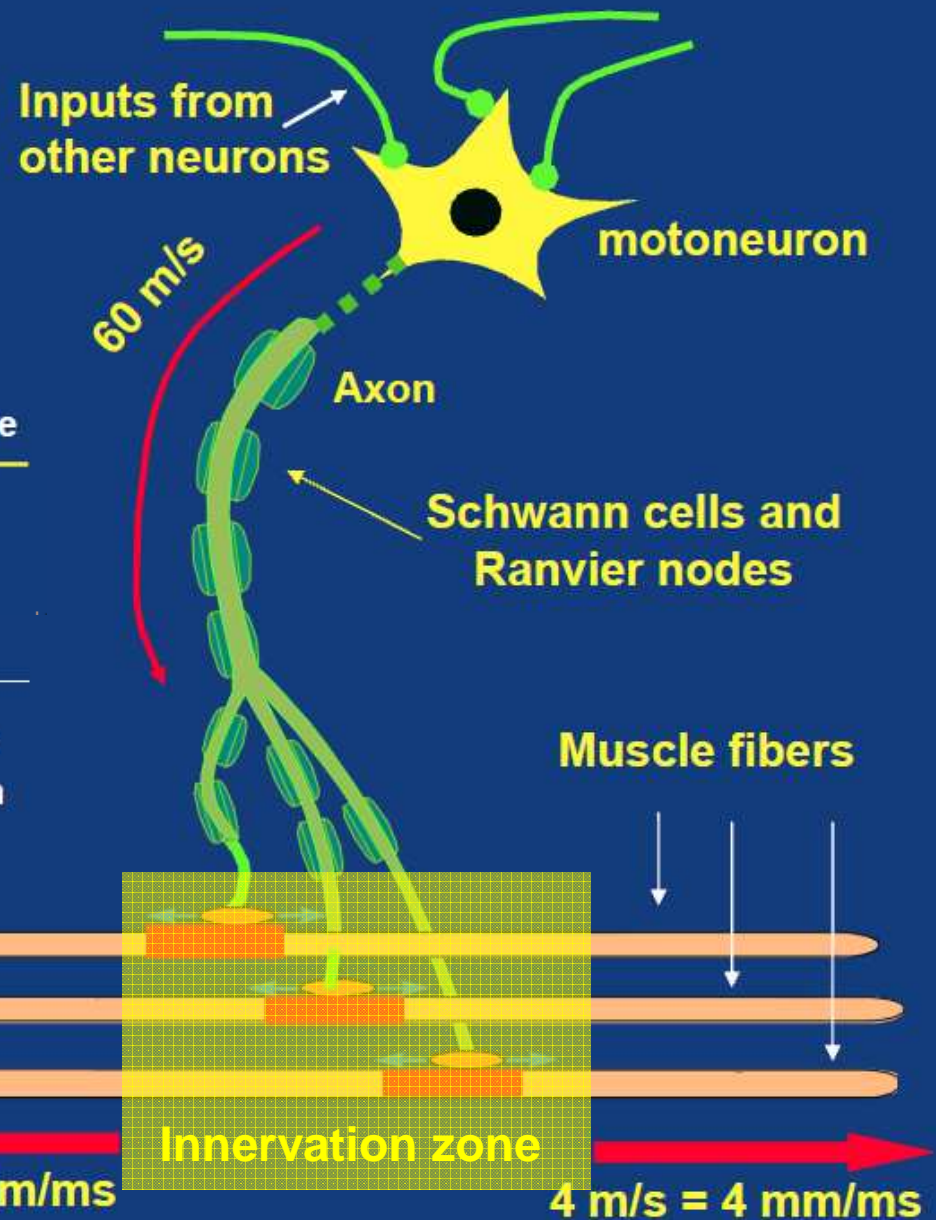
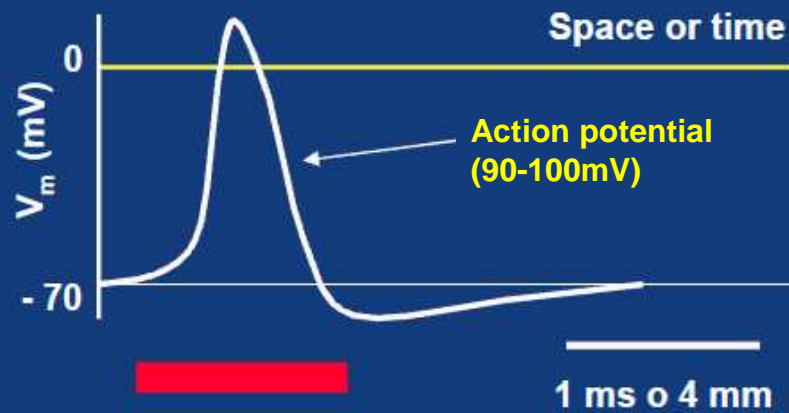


# Skeletal Muscle excitation and contraction



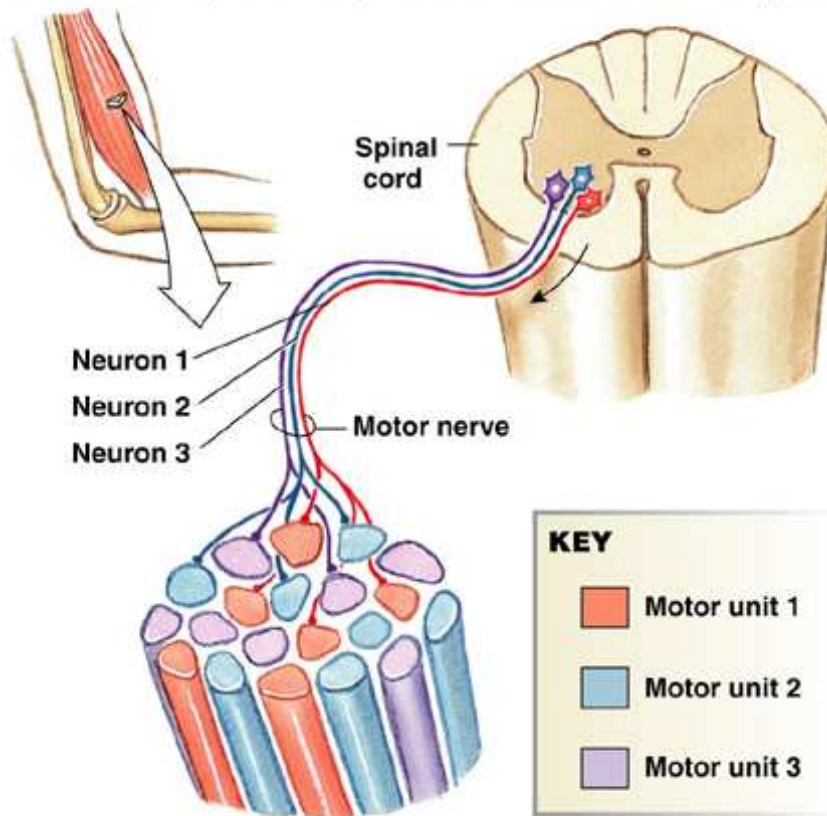


# The Motor Unit (MU) (electrical activity)



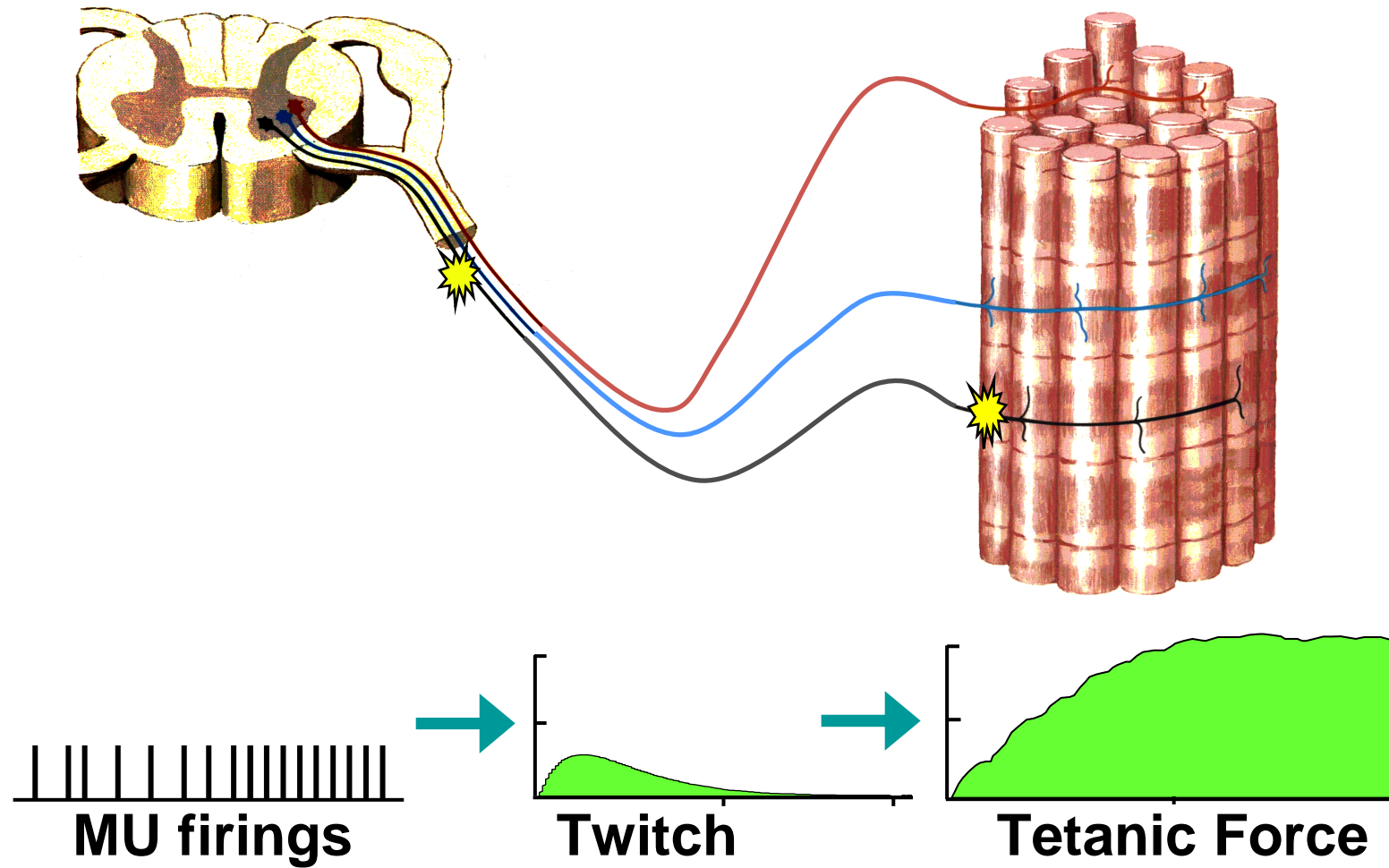
One muscle: 10-1000 MU    One MU: 10-2000 fibers of the same type (I or II)

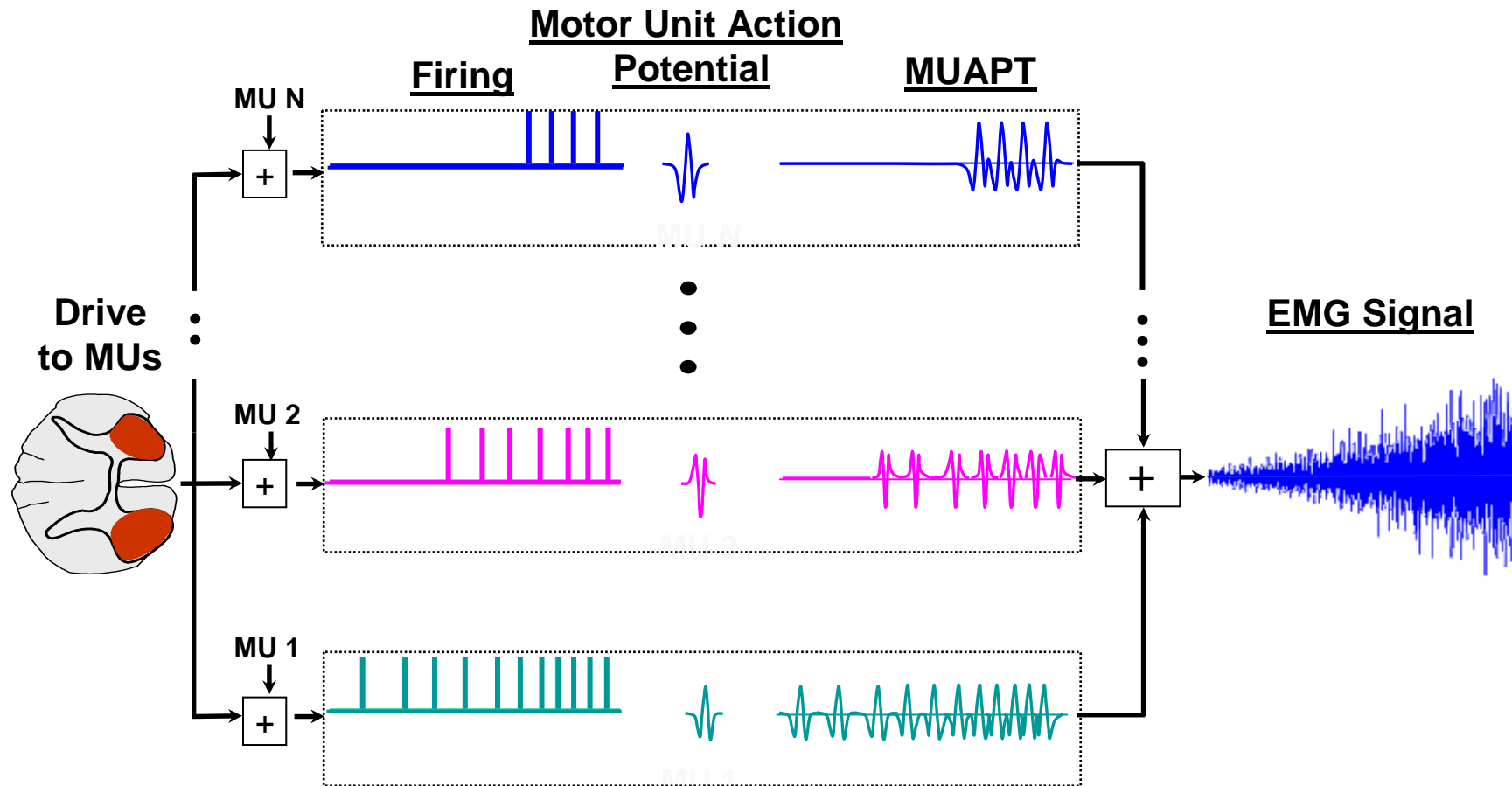
# The Motor Unit



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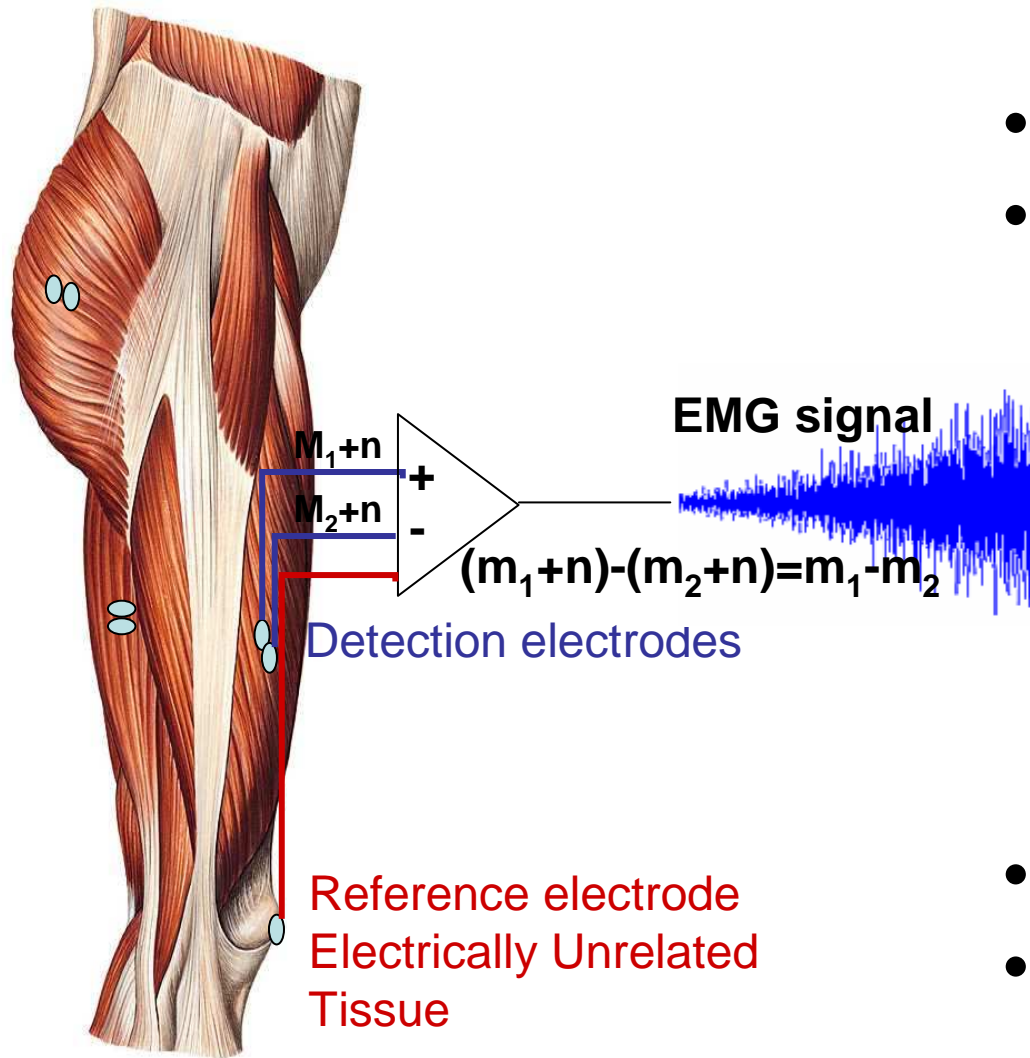
- One muscle may have many motor units of different fibre types (slow or fast twitch)
- One motor unit can have from 5 to few thousands muscle fibres.
- The motor unit is the brain's smallest functional unit of force development control.





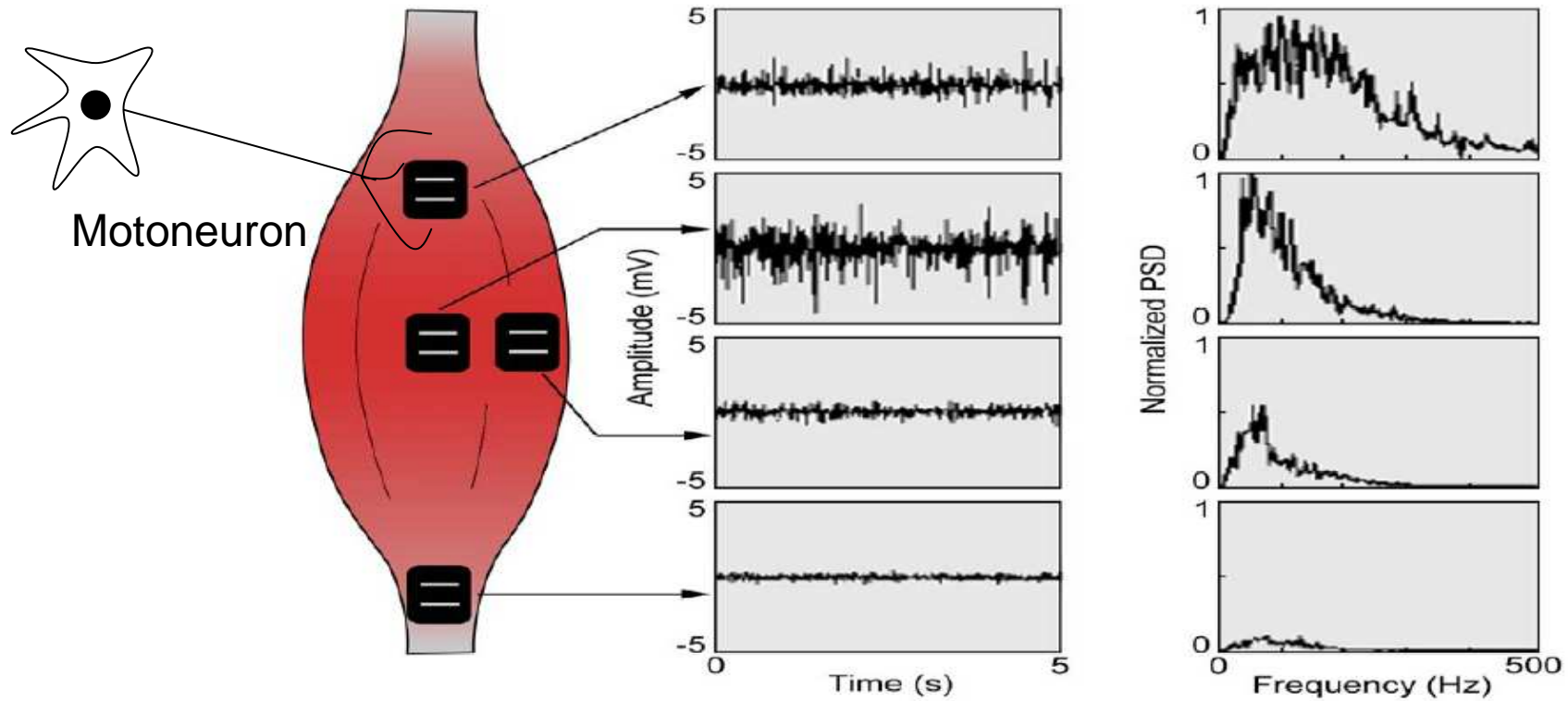
(De Luca CJ and Erim Z. Common drive of motor units in regulation of muscle force. Trends in Neuroscience, 17: 299-305, 1994. )

# EMG-signal capture



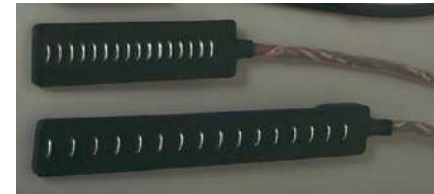
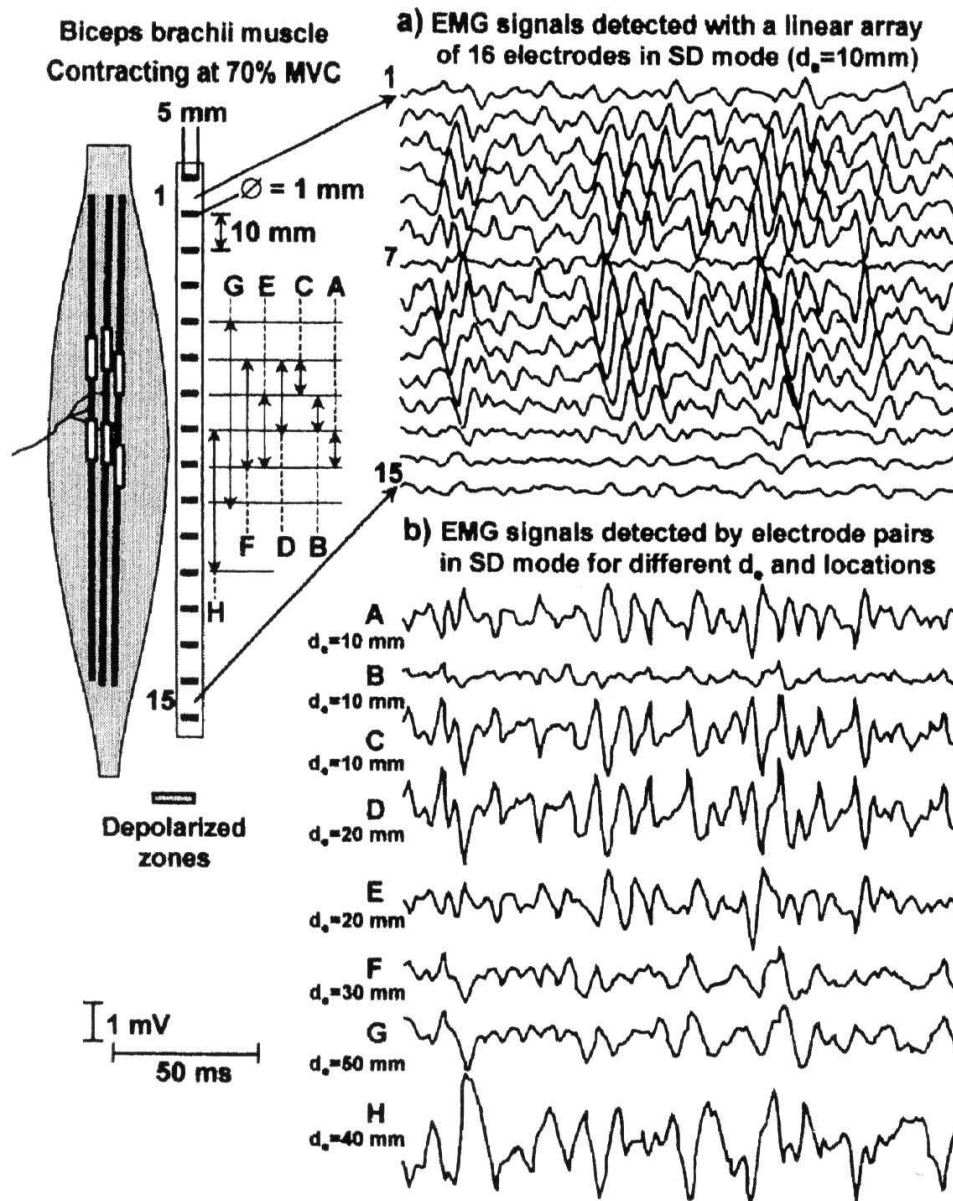
- Differential amplifier
- Input from two different points of the muscle
  - Close (usually 1-2cm)
  - Electrode alignment with the direction of muscle fibres → Increased probability of detecting same signal
- Subtracts the two inputs
- Amplifies the difference

# Surface Electrode Placement



# Physiology of the EMG

# EMG electrodes



- Above the innervation zone, electrode 7 small amplitude
- Above the myotendinous junction, more tendon tissue, electrodes 14 and 15 small amplitudes.



## Array vs bipolar Electrodes

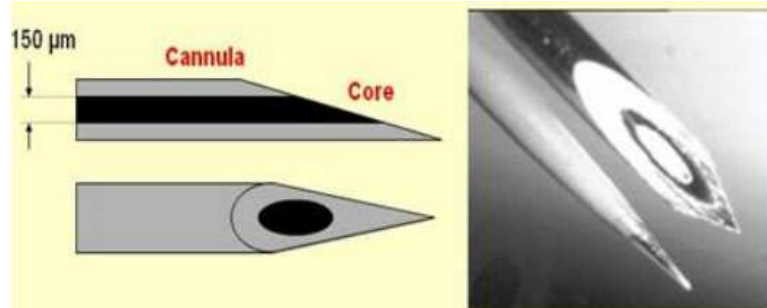
- Linear array
  - identification of single MU action potentials (MUAPs),
  - location of innervation and tendon zones,
  - estimation of CV of the individual MUAPs and of their firing patterns
- Bipolar electrodes
  - Easier positioning
  - When correctly positioned, record the required information for clinical tests, and fatigue manifestation, etc.



# Types of EMG electrodes

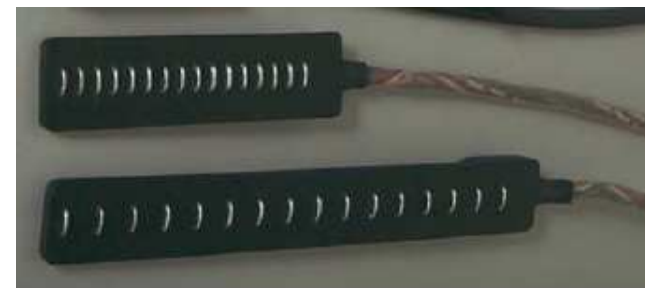
## Inserted

- Fine-wire (Intra-muscular)
- Needle



## Surface

- Bipolar (wired or wireless)
- Array (wired)



## Surface Electrodes

- Advantages
  - Quick, easy to apply
  - No medical supervision, required certification
  - Minimal discomfort
  - Easy to reposition
- Disadvantages
  - Generally used only for superficial muscles
  - Cross-talk concerns
  - No standard electrode placement
  - May affect movement patterns of subject

## Fine-wire Electrodes

- Advantages
  - Extremely sensitive
  - Record the activity of a single motor unit
  - Access to deep musculature
  - Little cross-talk concern
- Disadvantages
  - Extremely sensitive
  - Requires medical personnel, certification
  - Repositioning nearly impossible
  - Detection area may not be representative of entire muscle

- The quality of the detected sEMG signal determines the usefulness of the information extracted from the sEMG signal.
- It is of high importance to maximise the quality of the acquired signal.
- The quality of the acquired signal depends on:
  - Sensor location (upon the middle of muscle belly)
  - Sensor characteristics
  - Electrode-skin interface (good skin preparation)
  - Cross-talk from other muscles
  - Noise contamination

- **Physiological Noise:** EKG, EOG, respiratory signals, etc.
  - Reduced by proper positioning of the sensors (location and orientation)
- **Ambient Noise:** Power line radiation (50, 60 Hz)
  - Removed by differential amplification
- **Baseline Noise:** Electro-chemical noise (skin-electrode interface)
  - Reduced by effective skin preparation
- **Movement Artifact noise:** Movement of electrode with respect to the skin (the most obstreperous noise)
  - Reduced by effective skin preparation, proper fixation of the sensor to the skin and filtering

## Characteristics of EMG Signal

- Amplitude range: 0–10 mV (+5 to -5) prior to amplification
- EMG frequency: Range of 10 - 500 Hz
- Dominant energy: 50 – 150 Hz
- Peak in the neighborhood of 80-100Hz

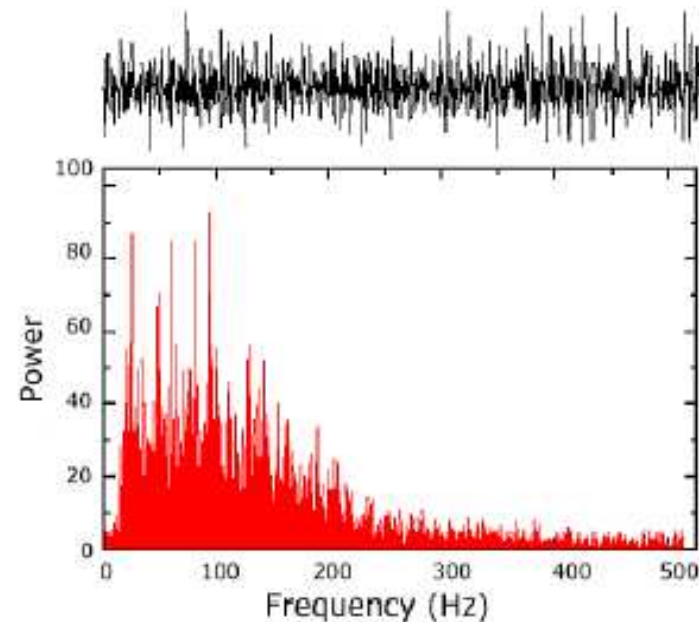


Figure 1: Frequency spectrum of the EMG signal detected from the Tibialis Anterior muscle during a constant force isometric contraction at 50% of voluntary maximum.

- Frequency range of muscle - slow twitch motor units
- Fast twitch motor units
- 75-125 Hz
- 125 - 250 Hz

## Most usual EMG parameters in biomechanics or physiology

Time domain:

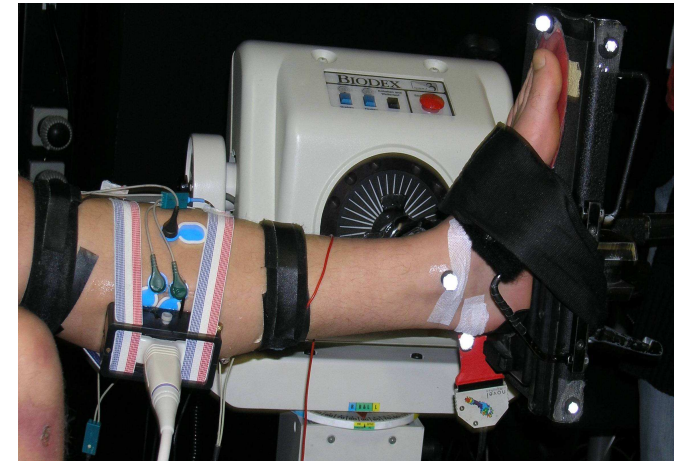
- RMS
- Average of the rectified EMG

Frequency domain:

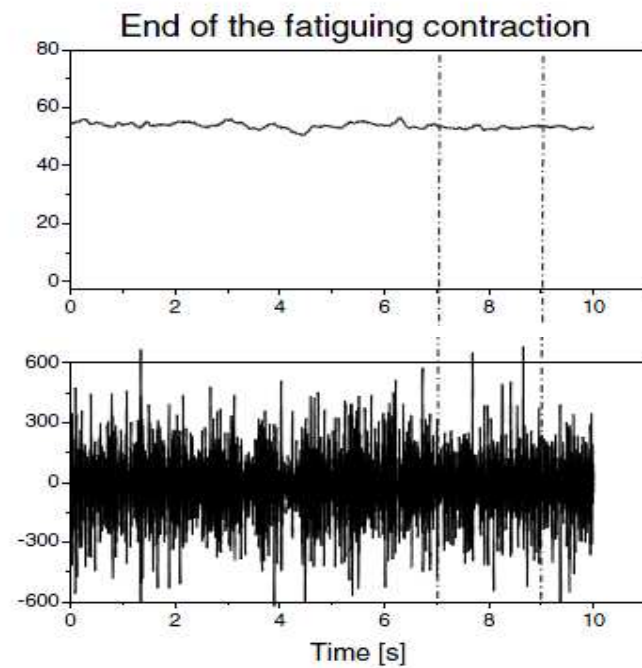
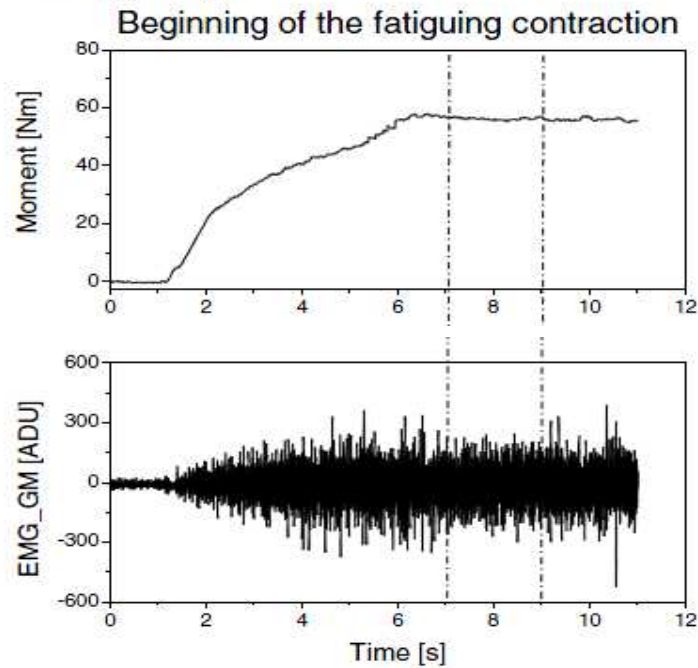
- FFT Analysis (spectral analysis)
  - Power Density
  - Mean power frequency
  - Median power frequency



- During fatigue:  
The EMG signal was analysed for a 2s plateau of the moment.

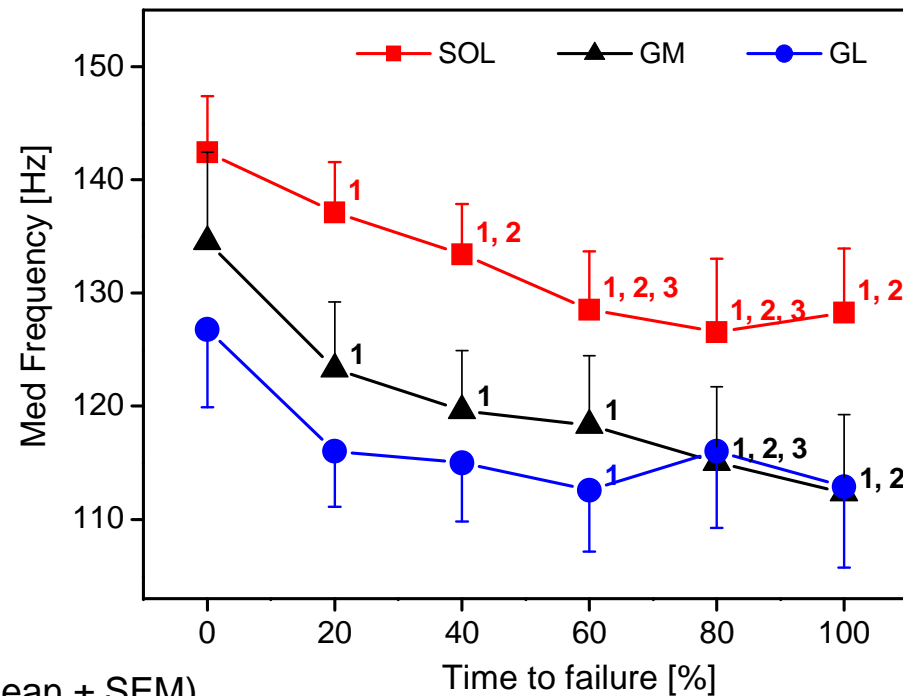
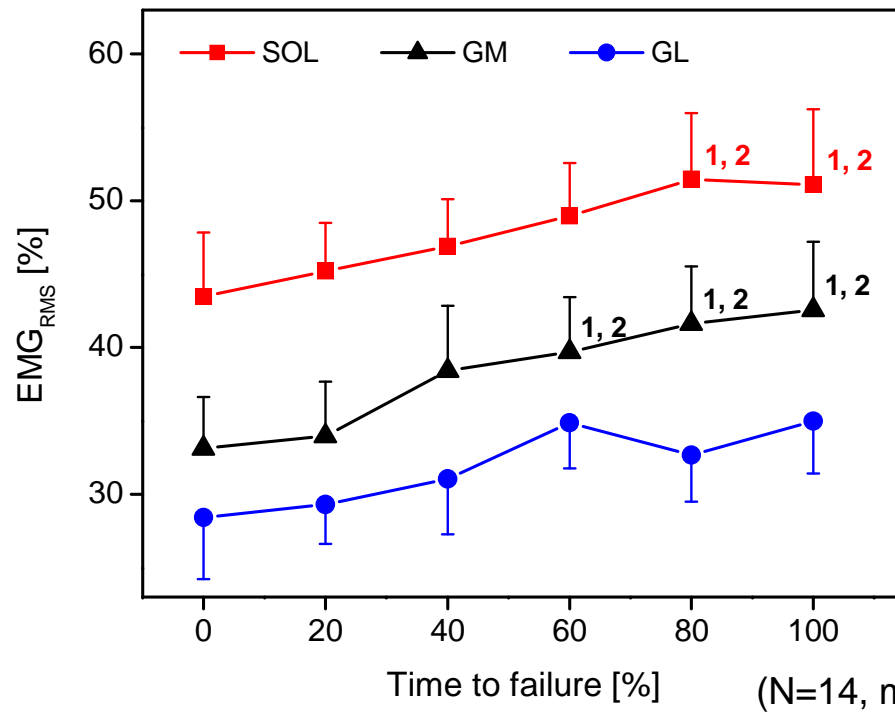


Young subject



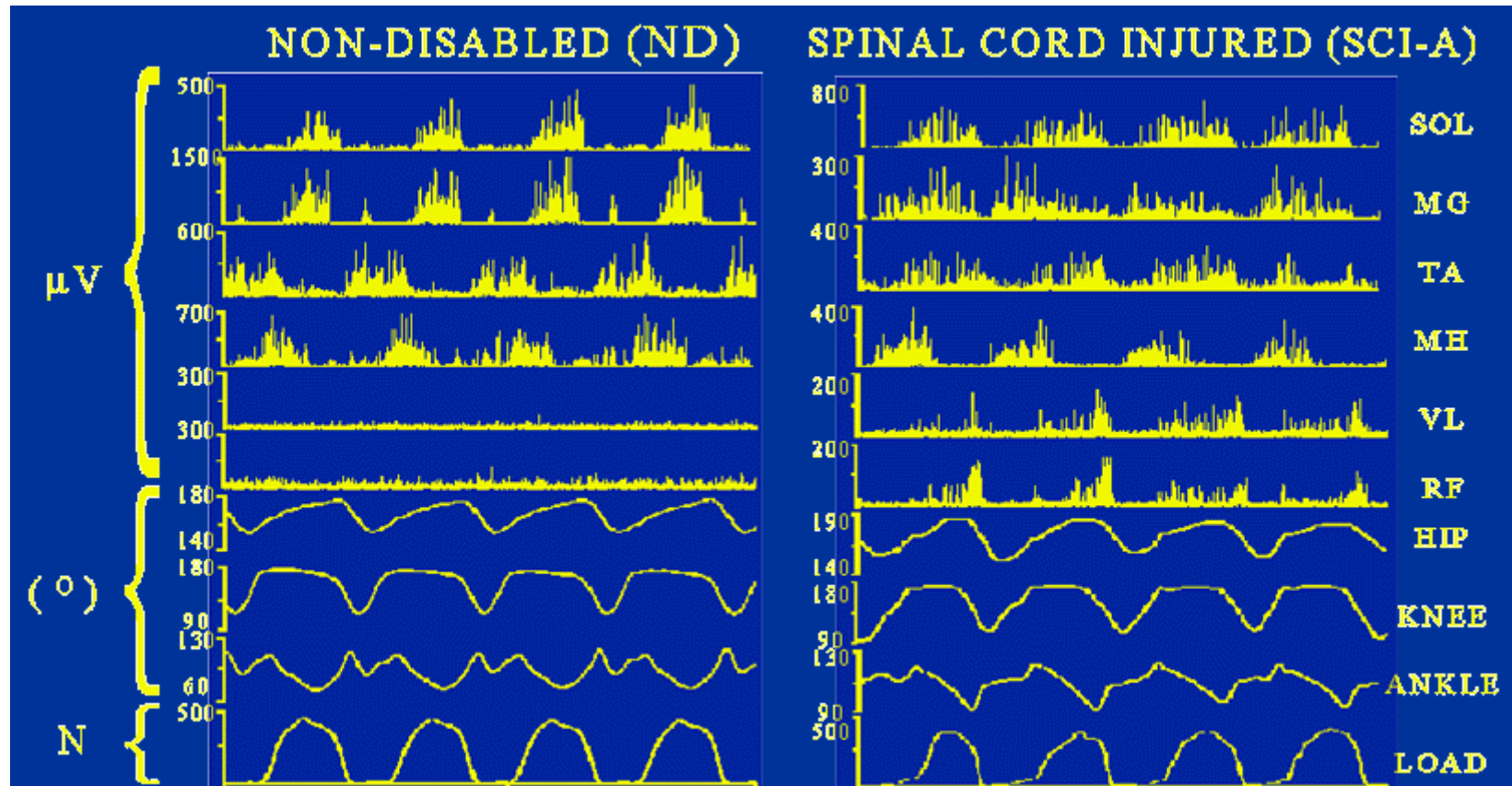
During the sustained fatiguing contraction:

- Time to failure:  $407 \pm 129$  sec



- Sig. increase in the RMS EMG for GM and Sol
- Sig. decrease in median frequency of GM, GL, and Sol

# EMG during normal and abnormal gait



## **Proper Use of sEMG – Intraindividual**

**Monitor variation in performance of a muscle in a subject:**

- during separate tasks
  - Sensor not removed
- during different occasions
  - Sensors not removed
  - Sensor removed, but replaced in same location
- **Compare the relative contribution of individual muscles during a task**
- **Determine when the muscle contraction begins and ends (on/off from raw rectified signal)**
- **Pattern identification (tasks)**

## Proper Use of sEMG – Interindividual

Different subject will have muscles with:

- Different physiological cross-sectional area
- Different lengths/geometry
- Different ratios of slow to fast-twitch fibres
- Different recruitment patterns
- Different firing frequencies

⇒ **Before comparing the EMG signal across subjects a normalisation of the signal is needed**

## **Proper Use of sEMG – Interindividual**

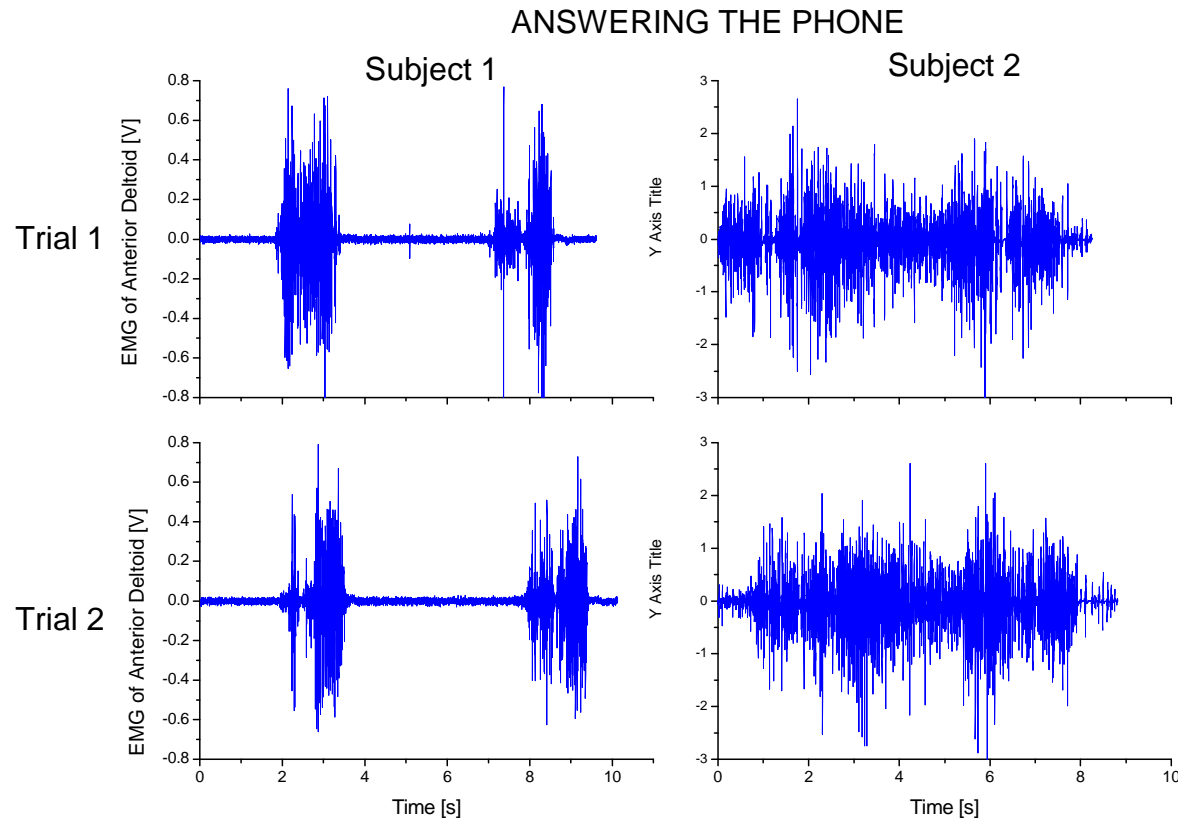
Usual normalisation: To the signal captured during an isometric maximal voluntary contraction.

We can:

- Compare the contribution of a specific muscle across subjects during static or dynamic contractions
- Compare the relative contribution of various muscles across subjects during static or dynamic contractions.
- Determine when the muscle contraction begins and ends (from raw rectified signal)

# Potential Use of sEMG

It is possible that the EMG signal during a specific movement will demonstrate interindividual differences. This can be used in user authentication systems (ACTIBIO).



## Potential Use of sEMG

The muscle activity recorded using sEMG can be useful as an input signal to the system which can control devices such as keyboard, mouse or computer.

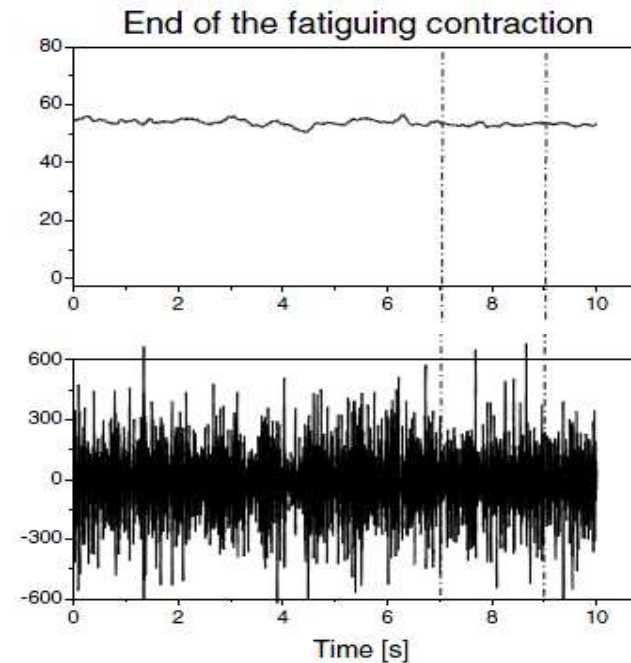
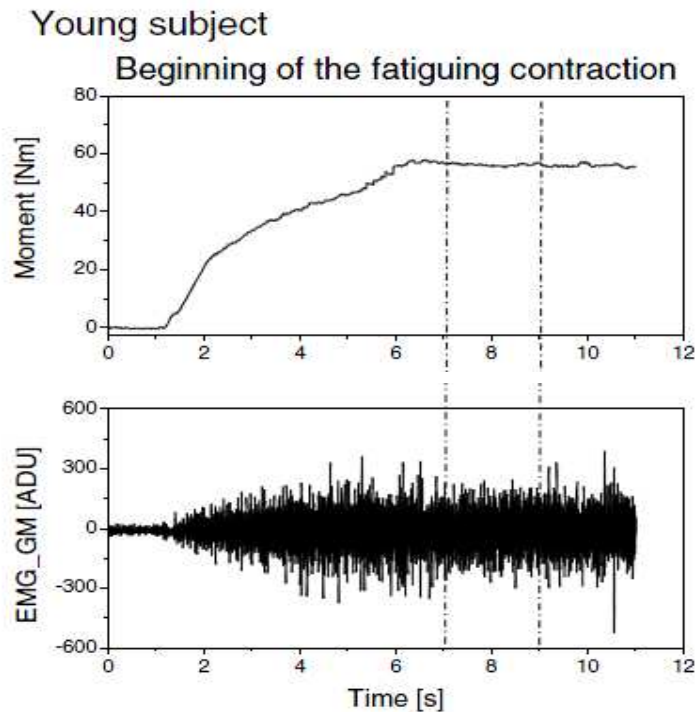
*(Arjunan et al. 2007)*



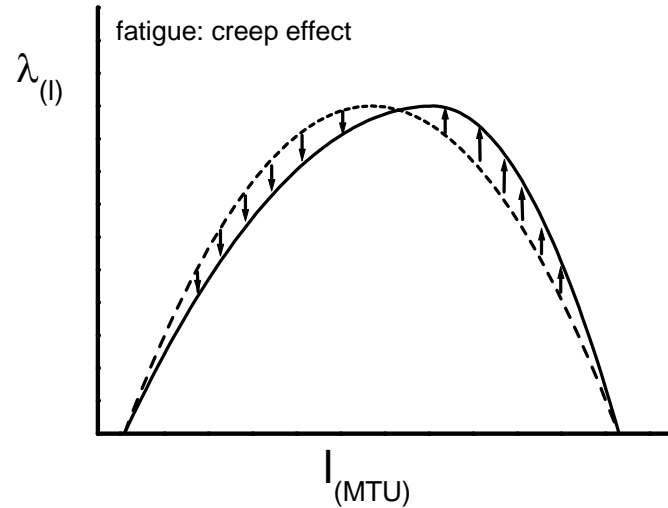
# Use of sEMG

“The strength of sEMG is a good measure of the strength of contraction of muscle”. *(Arjunan et al. 2007)*

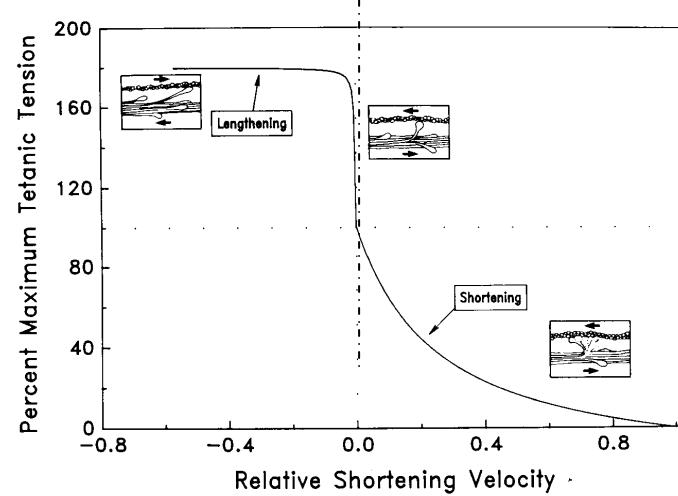
**Not always true: For example**



## Force-length relationship

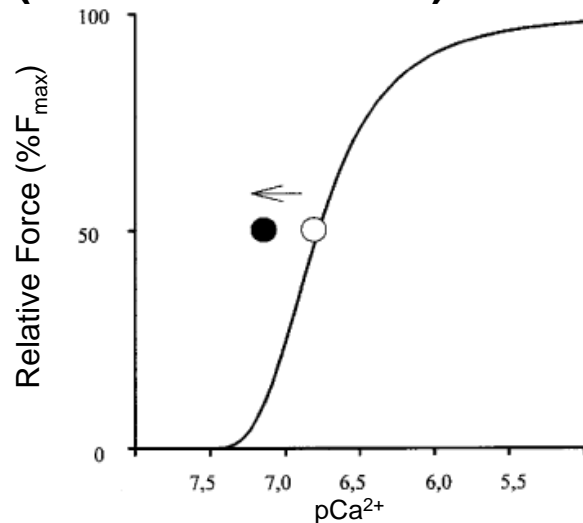


## Force-velocity relationship



(Figure taken from Lieber, 1992)

## Force-Ca<sup>2+</sup> concentration relationship (Muscle activation)



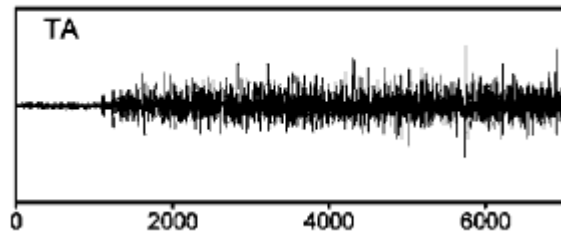
(Figure taken from Rassier, 2000)

## Muscle force depends mainly on:

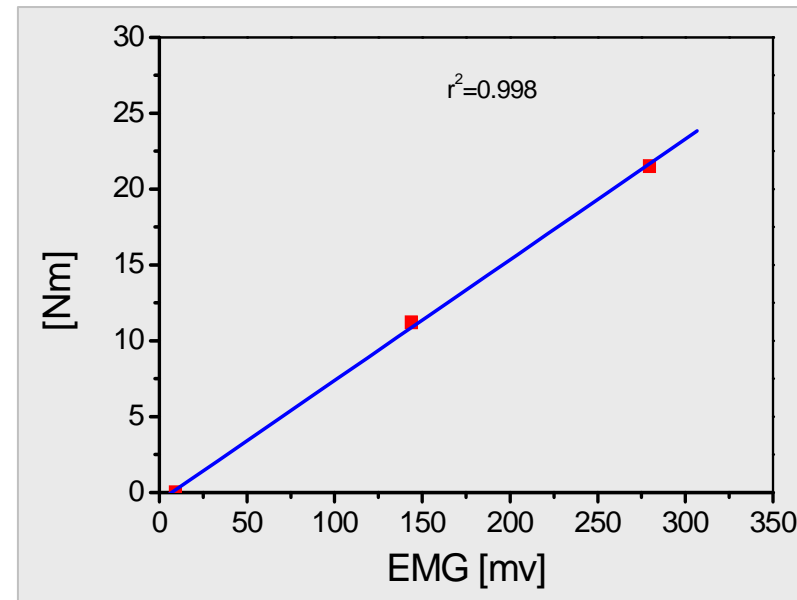
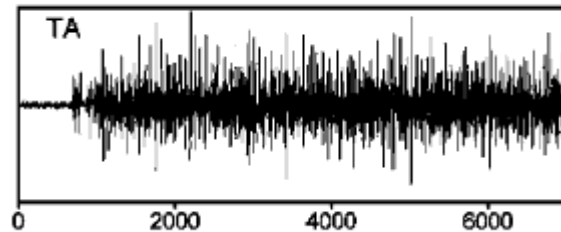
1. The muscle length
2. The contraction velocity
3. The muscle activation (= free Ca<sup>2+</sup> in the muscle fibre)

Linear relationship between EMG and force

Moment: 12.5 Nm



Moment: 24.5 Nm



(Mademli et al., 2004)

**2: “*Electromyography is too easy to use  
and  
consequently too easy to abuse*”**

**De Luca CJ, The Use of Surface Electromyography in Biomechanics,  
J. Applied Biomechanics, 13: 135-163, 1997**

**THANK YOU FOR YOUR ATTENTION**



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