THE MUSCLE PRACTICAL CLASS

OBJECTIVES:

To study some of the contractile properties of muscle (human thenar muscles), which include:

a) Single Muscle Twitch
b) Summation
c) Tetanus
d) The recruitment of motor units

EQUIPMENT:

- PC running windows operating system
- BIOPAC Software: BIOPAC STUDENT LAB PRO
- BIOPAC Data Acquisition Unit (MP30)
- BIOPAC Stimulator
- Biopac Force Transducer
- Biopac Tension Adjustor
- S-Hook
- Electrode Gel
- Lab Stand
- Paper Clip or Thread

METHOD:

Contractions from thenar muscles are elicited by electrically stimulating the median nerve which supplies them. The resultant impulses are conducted along the nerve fibers to their terminals. At these sites the neurotransmitter acetylcholine is released into synaptic clefts across which it diffuses to bind to the postsynaptic membrane and as a result of that, an end-plate potential is produced. This leads to a muscle action potential and subsequently to a muscle contraction. Both the electrical (action potentials) and the mechanical (tension change) events are displayed on the screen.

The following are the steps to be performed:

1) Have the subject rest his arm, palm up, on a flat surface and smear some electrode gel on the lower forearm.
2) Place the stimulating probe lengthwise along the wrist.
3) Confirm that "Pulse Rate" is set to 1 Hz in the stimulator window and then click on the "ON" switch.

4) Slowly increase the level setting on the Biopac stimulator unit until an involuntary twitch is noted on the thumb.

   a. A response usually occurs between 20 and 40 volts.

   b. If you don't see any twitching, set the level on the stimulator at 40 volts and slowly move the stimulating probe around the forearm while maintaining a lengthwise orientation.

5) After locating a point on the forearm that generates a distinct twitch from the thumb, find a comfortable voltage setting for the subject.

6) Click the "OFF" switch in the stimulator window without adjusting the level setting on the biopac stimulator unit.

7) Attach the thumb to the force transducer as follows:

   a. Reform a paperclip into a "C" shape and use the "S-Hook" to attach it to the 200g hook on the transducer.

   b. Rest the thumb around the free end of the paperclip. The force transducer will record the twitch response during the stimulation process.

8) Keep the stimulating probe in the same place on the forearm where the twitch was detected.

9) Press the "start" button on the data window.

10) Click the "ON" switch in the stimulator window.

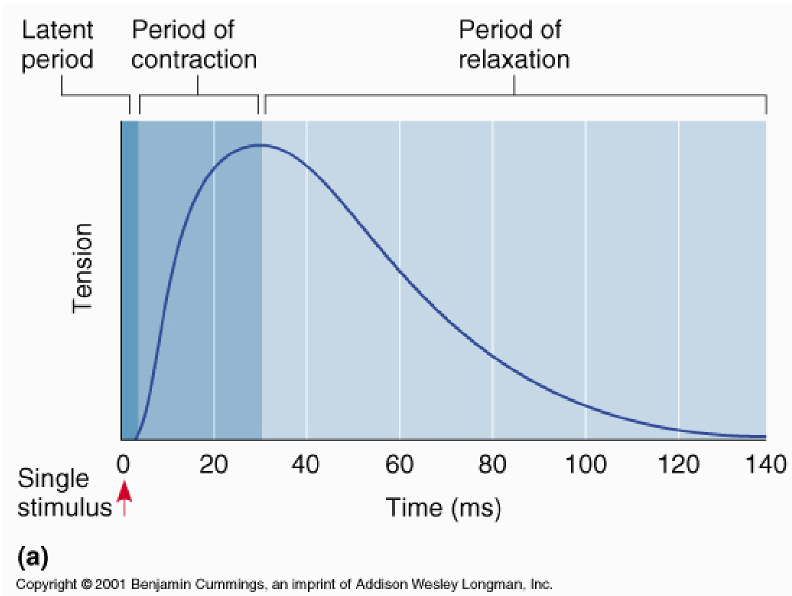
11) Increase the stimulation frequency in the Stimulator window in 1 Hz increments until the force data plateaus.

12) Click the "OFF" switch in the stimulator window.

Experimental Procedures:

1. SINGLE MUSCLE TWITCH

Arrange the stimulator to deliver single stimulus which should be greater than threshold stimulus and record the response, which is called single muscle twitch.



DEFINITION:

The response of the muscle when a single threshold stimulus is applied is called Single Muscle Twitch. Its duration is about 300 msec.

It has three Phases:

1) LATENT PERIOD

It is period of time between the stimulus and the contraction of muscle during which muscle tension is beginning (when excitation-contraction coupling is taking place). It lasts about 2.5 – 4 milliseconds. The latent period corresponds to the time for Ca^{++} release into muscle cytoplasm and the subsequent activation of the contractile machinery of the muscle.

2) PERIOD OF CONTRACTION

Cross bridges are actively formed and the muscle fibers shorten.

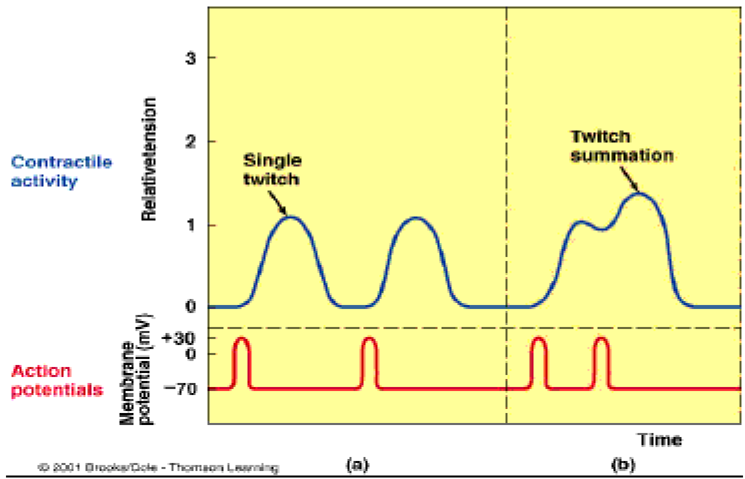
3) PERIOD OF RELAXATION

Ca^{++} re-enters the sarcoplasmic reticulum and muscle tension goes to zero.

It takes about 100 milliseconds for a single muscle twitch contraction to reach its height, and another 200 milliseconds for the relaxation to be complete. The entire response is complete in about 300 milliseconds.

2. SUMMATION

Arrange the stimulator to deliver 2 stimuli. If **2 stimuli** are delivered in rapid succession so that the second stimulus will be applied before the first muscle twitch is over, then the second stimulus will build upon the previous contraction and add to that response. This is called **twitch summation.** The **second twitch** will be **greater** than the first, because of availability of more Ca^{++} in the muscle cytoplasm from the first stimulus.

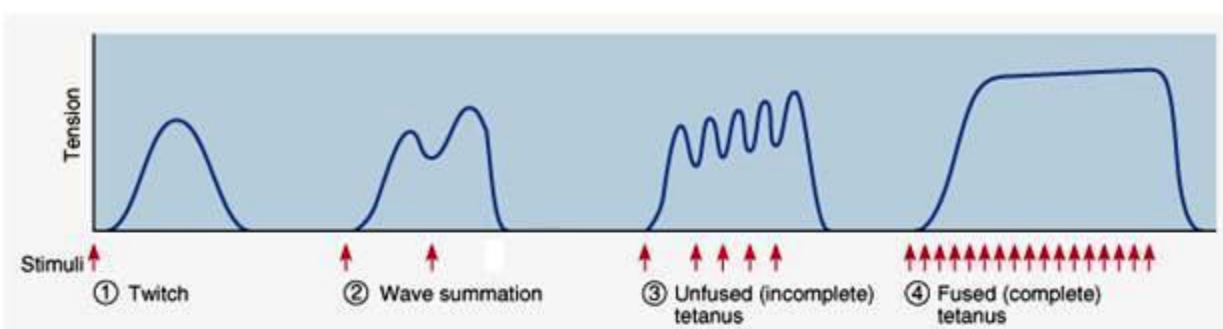


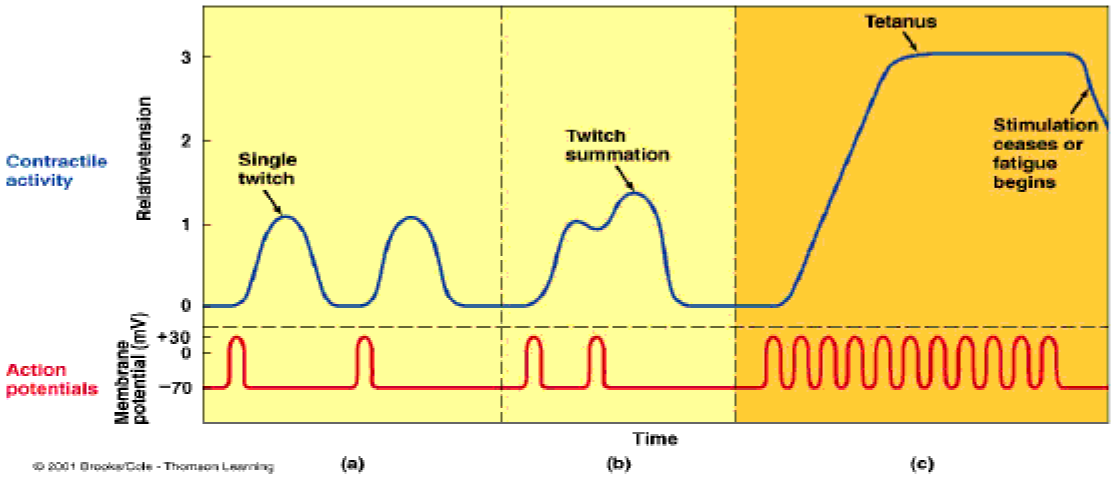
3. TETANUS

Set the stimulator to provide stimulation at gradually increasing frequency till the thenar muscles undergo sustained contraction or tetanus. Tetanus is a smooth sustained muscle contraction resulting from high-frequency stimulation.

As you go on increasing the frequency of stimulus, first more rapidly delivered stimuli (5-10 per second) result in **incomplete tetanus**. i.e. a stronger contraction but not smooth because of various relaxation periods in between. The increased strength of contraction is due to the increased amount of Ca^{++} in the cytoplasm.

If stimuli are given quickly enough (20 per second), **complete tetanus** will result. As you continue to increase the frequency of stimuli, eventually no relaxation will be allowed and the muscle contraction will increase smoothly up to a point of maximum strength where single twitches are not observed.

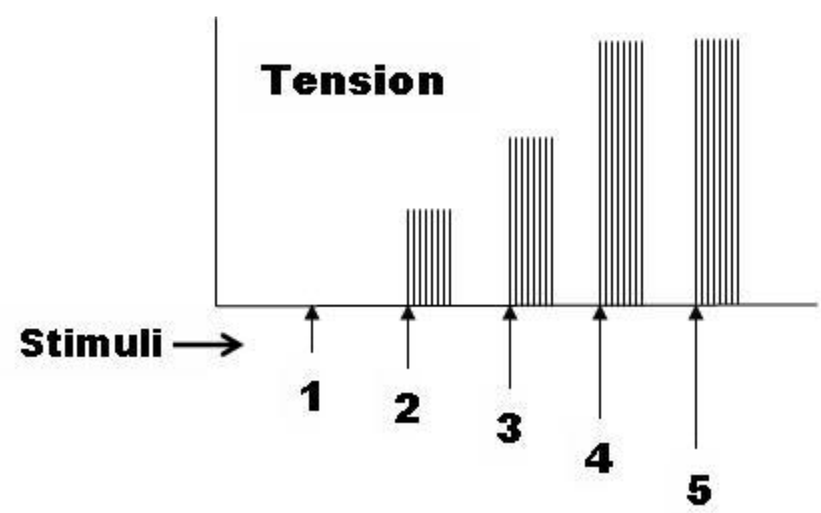




4. MOTOR UNIT RECRUITMENT

A motor neuron and the muscle fibers supplied by it form a **motor unit**. A motor unit may be small consisting of very few muscle fibers and may be large if it consists of hundreds of muscle fibers. A muscle is supplied by many motor units. So if few motor units are stimulated, the resultant muscle contraction will be weak. But if the stimulus intensity is increased, more motor units will be recruited (stimulated) and muscle contraction will be stronger. This phenomenon is called "**motor unit recruitment**".

Set the stimulator to "repeat" and stimulate once every 30 seconds. Increase the stimulus intensity in steps of 0.5 volts. Start at zero volts and continue till a voltage is reached which produces a maximum twitch response. After achieving maximum contraction, increase the stimulus intensity further and find still the same response will be obtained.



1 = A Sub-threshold Stimulus: It is a minimal stimulus which is not sufficient to produce a single muscle twitch.

2 = A Threshold Stimulus: It is an adequate stimulus which is just enough to produce a single muscle twitch.

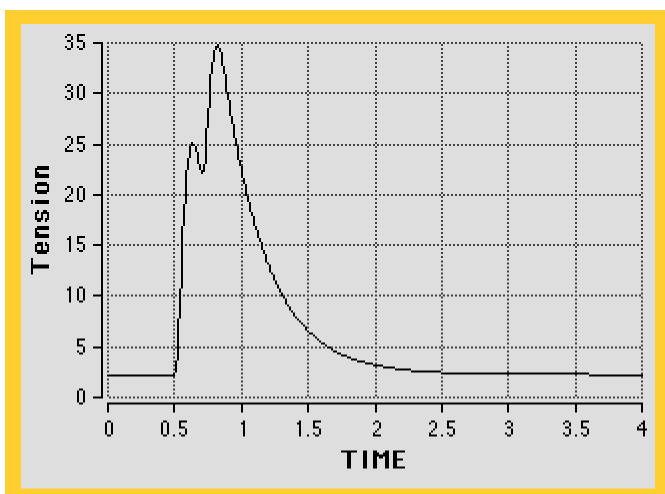
3 = A Sub-maximal Stimulus: It is a stimulus which produces a stronger contraction, but not the strongest.

4 = A Maximal Stimulus: It is a stimulus which can produce maximum contraction.

5 = A Supramaximal Stimulus: It is a stimulus which is more than maximal stimulus in magnitude, but still produces the same contraction as that from the maximal stimulus, because all motor units are already recruited (stimulated).

SUMMARY

- Single threshold stimulus usually releases enough acetylcholine in the neuromuscular junctions of the motor unit to produce action potentials in the muscle membranes. This will cause the muscle to contract after a short delay. This is called Single Muscle Twitch.
- Order of events: ACh release -> muscle action potential -> Ca^{++} release -> contraction. A single muscle twitch gives only 20-30% of the maximum tension possible- the muscle starts to relax before the maximum is reached.
- If a second stimulus is given before a muscle relaxes the muscle will shorten further, building up more tension than a simple twitch. This is called summation, as shown in the following graph:



- In the above graph of summation, the muscle does not completely relax between stimuli and the tension summates to 35% of maximum.
- If many stimuli are given very close together the muscle will go into a smooth continuous contraction called tetanus.

Motor nerves

Not Important : (Read if you want ^_^)

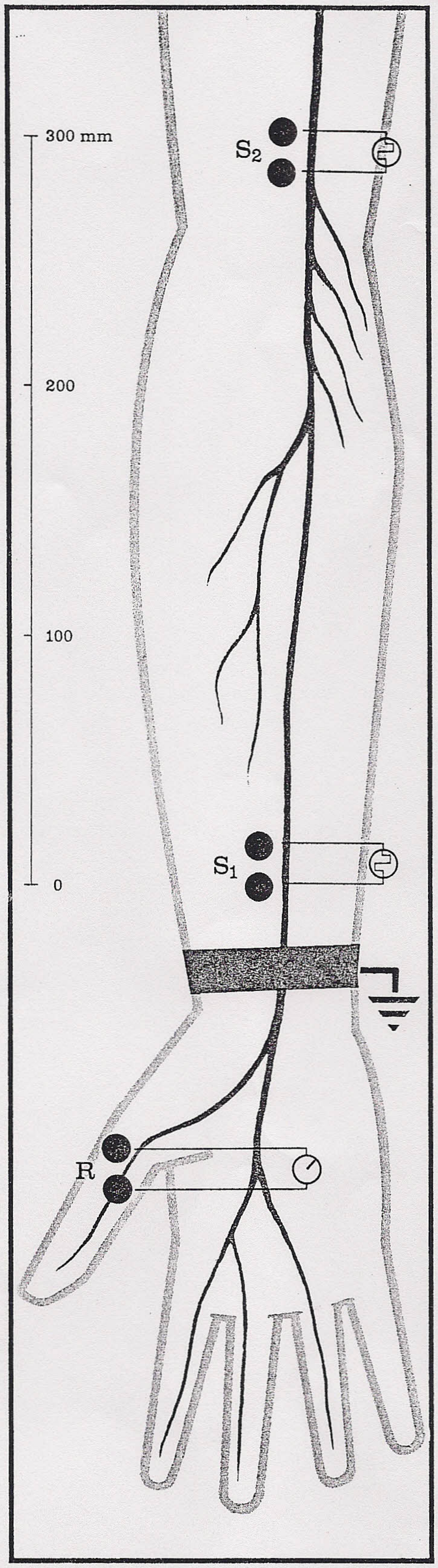
To determine the conduction velocity of a motor nerve, for example in the nervus medianus of the forearm, the nerve is stimulated at two different sites (S_1 and S_2). The response to the stimulus is recorded from a distally placed muscle of the hand (R), together with the stimulus artefact, on an oscillograph. Since the stimulation sites are at different distances from the recording site, the latency between the start of stimulation, which is identified by the stimulus artefact, and the muscle response differs in length. The conduction velocity can thus be determined from the time difference in latency between the two responses and the distance between the stimulation points.

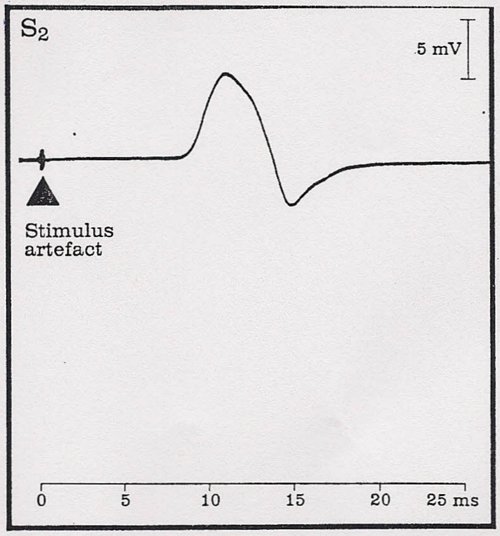
Important

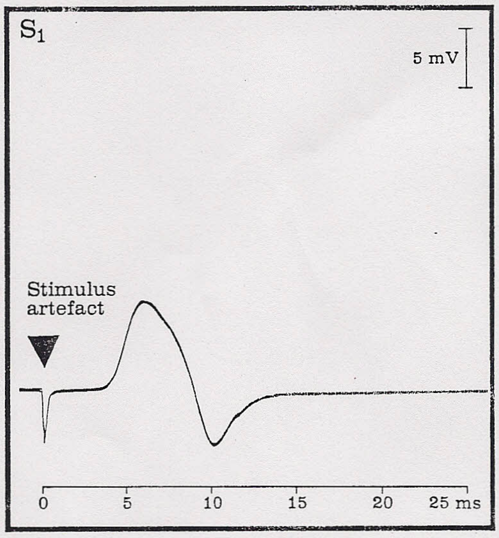
Normal values

In humans, the conduction velocity in the motor and rapidly-conducting sensory nerves is between about 40 and 80 m/sec, depending on the nerve. In the upper extremities, a motor conduction velocity of less than 50 m/sec is considered abnormal, whilst in the lower extremities only values of less than 40 m/sec are abnormal.

All Important







Determination of motor conduction velocity of n. medianus. The recording electrodes (R) are attached to the ball of the thumb. The stimulation electrodes are placed over the nerve, just above the wrist (S_1) and in the bend of the elbow (S_2). An earth electrode is placed between the stimulation and the recording site at the wrist. Stimulation response is in each case shown as muscle action potential on the oscillograph.

Latency time on stimulation in the bend of the elbow: 8.5 ms

Latency time on stimulation above the wrist: 3.5 ms

Difference: 5.0 ms

Distance between the stimulation sites: 284 mm

Conduction velocity:

$$v = \frac{s}{t} = \frac{284\ \text{mm}}{5\ \text{ms}} = 56.8\ \text{mm/ms} = 56.8\ \text{m/s}$$

velocity in sensory and motor nerves