Characteristics of Whole Muscle Contraction

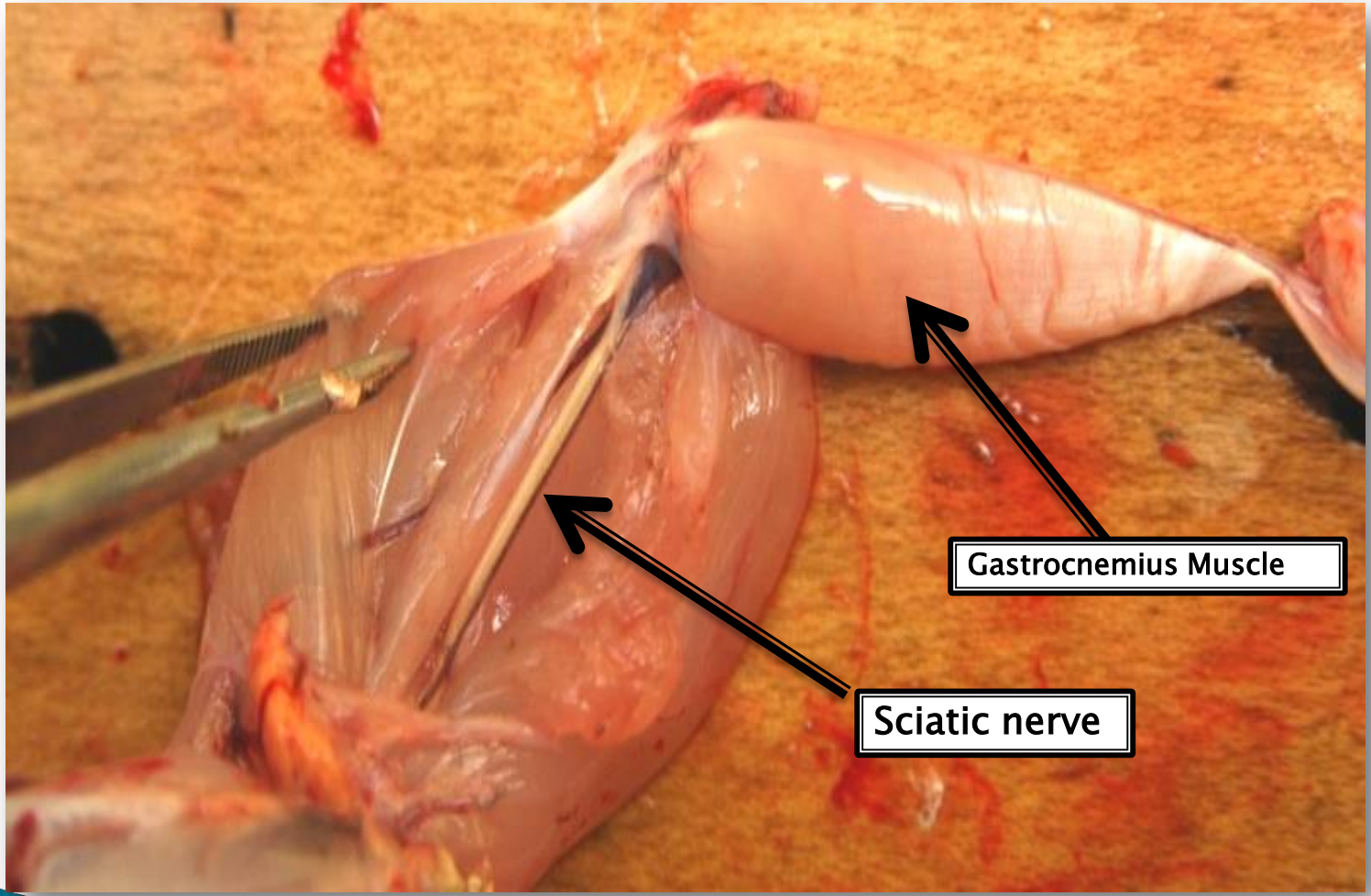
Dr. Tamara Alqudah

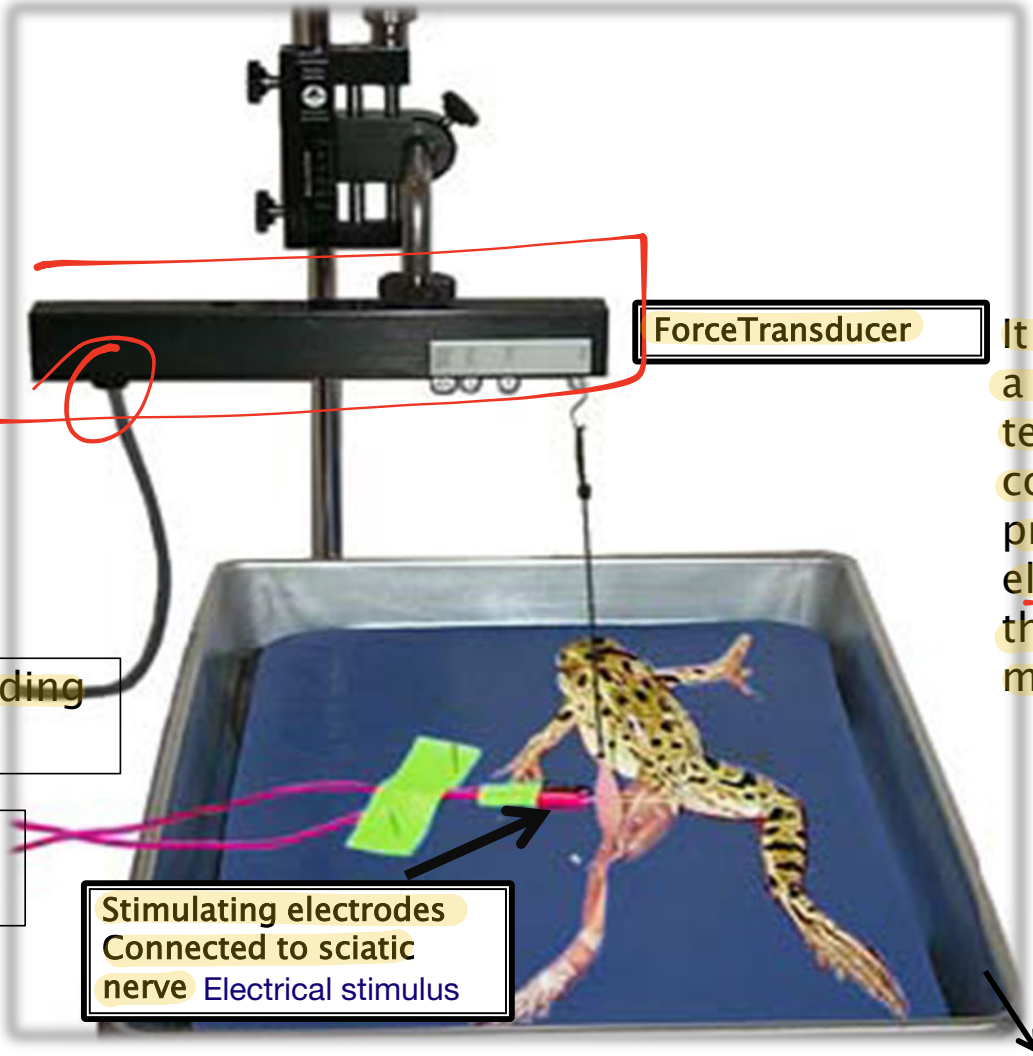
Aim of the experiment

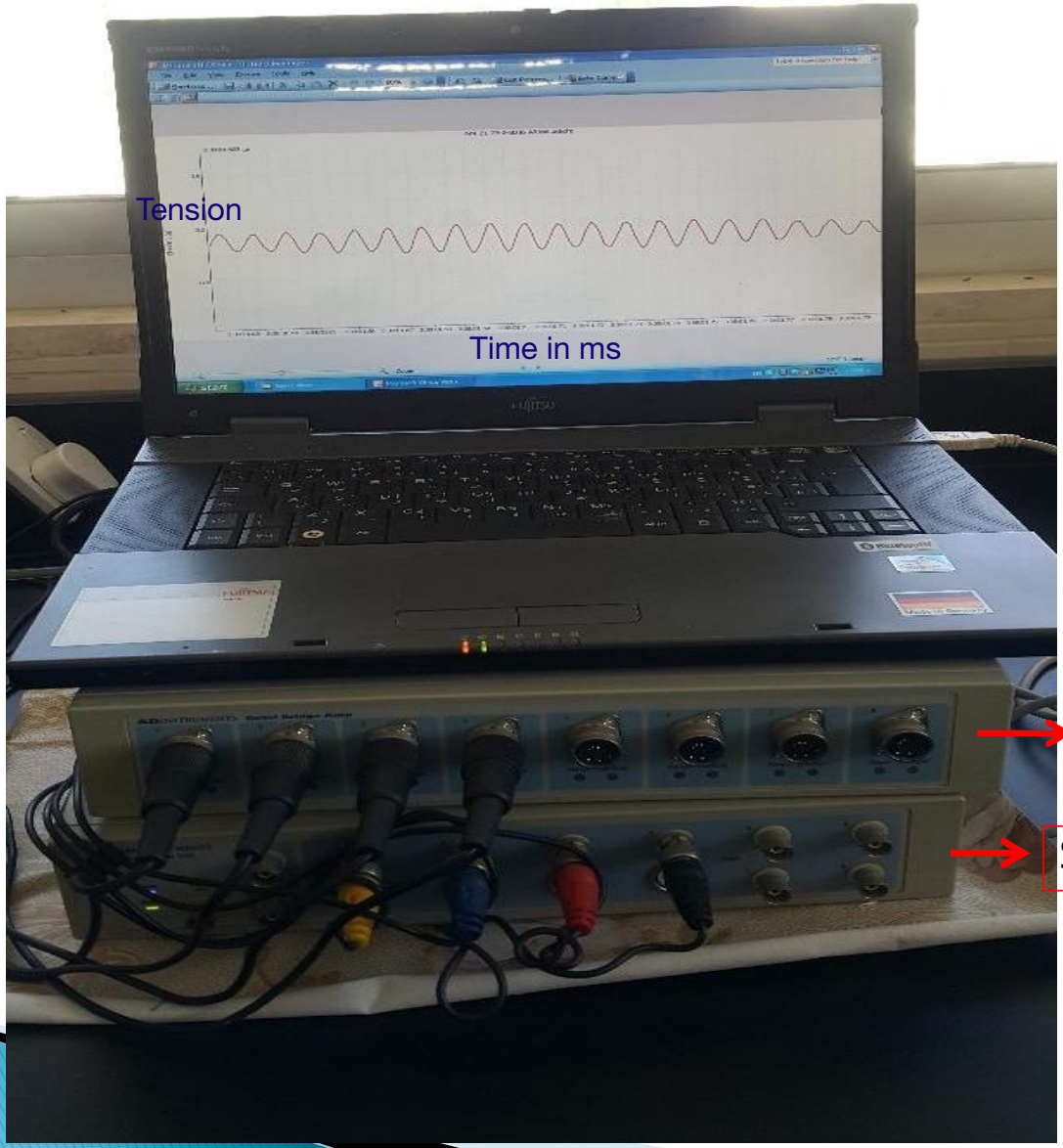
- Learn about the characteristics of whole skeletal muscle contraction by studying the contractile behavior of the frog's gastrocnemius muscle.

- The characteristics you will learn in this experiment:

✓ Simple muscle twitch
✓ Frequency summation
✓ Tetanization
✓ Fatigue
✓ Treppe phenomenon


Gastrocnemius Muscle
Sciatic nerve


ForceTransducer
It converts a force such as tension, compression or pressure into an electrical signal that can be measured
To the recording system
To the stimulator
Attached to sciatic nerve
Stimulating electrodes Connected to sciatic nerve
Electrical stimulus
Organ bath
Extracellular like fluid to maintain viability of the tissues (25 C')



Signal from force transducer

Recording system

Stimulator

How is it conducted

- We use the gastrocnemius muscle of the frog
  - ✓ Better tolerance to handling and changes in temperature as compared to mammalian muscles

- We must keep the muscle and the sciatic nerve which innervates it intact.
- The tissue is kept in an organ bath in a warm (25°C) solution.
- The solution is called amphibian Ringer's solution. It contains salts in concentrations similar to those found in the frog's extracellular fluid and will maintain the viability of the tissue for a long time.

- The knee joint of the frog is fixed to the organ bath thereby fixing the gastrocnemius muscle at one end

- The other end of the muscle is separated from the bone and connected by a thread to a force transducer.
- Stimulating electrodes are connected to the sciatic nerve
- We stimulate the sciatic nerve using a device called electrical stimulator, this stimulation will result in contraction of the gastrocnemius muscle.

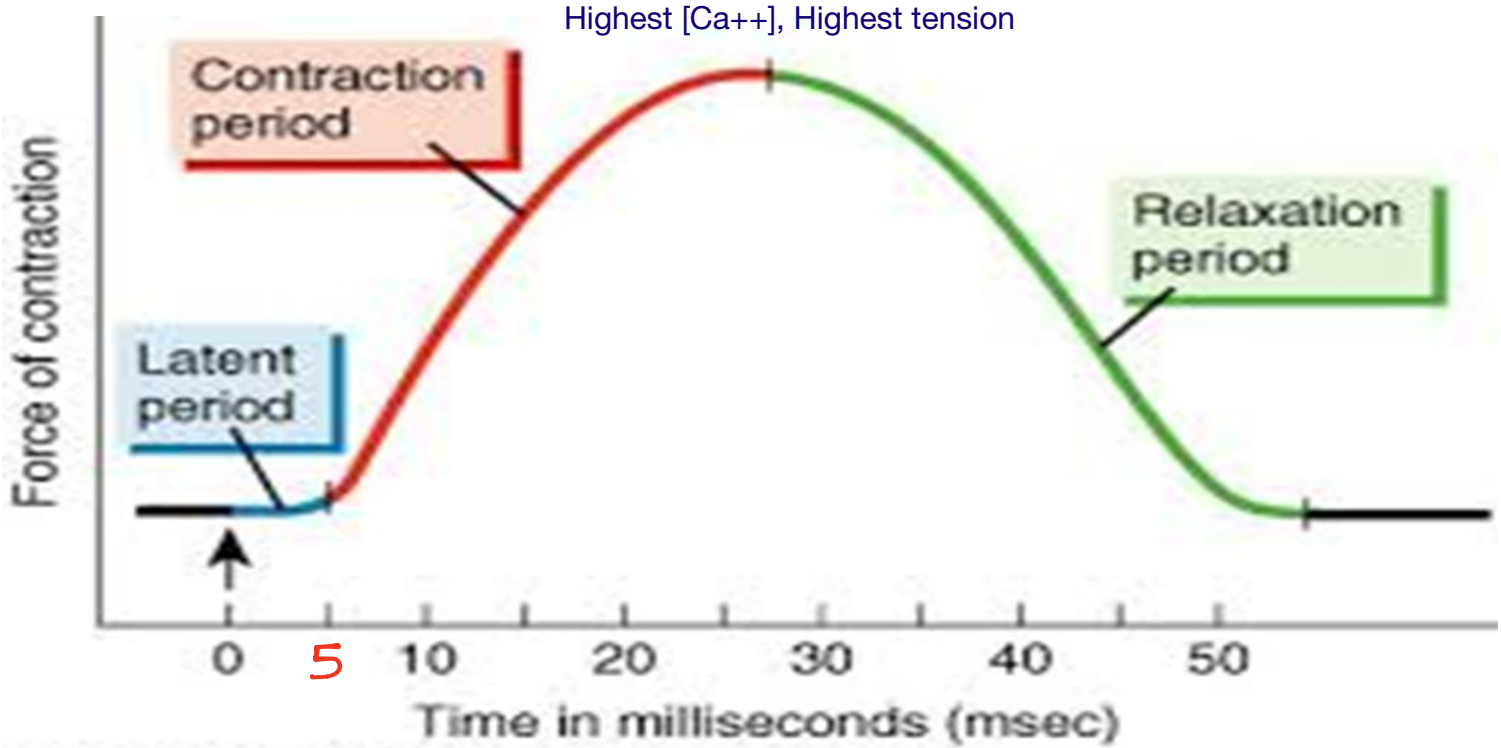
- Using the electrical stimulator ,we can change the **magnitude (voltage)** and **frequency** of stimulation.

- When the muscle contracts it will shorten and pull the thread which is connected to the transducer.
- The transducer converts this mechanical energy to electrical energy

- The data is then conveyed to a certain software capable of generating a simple graph of tension versus time.

Simple muscle twitch

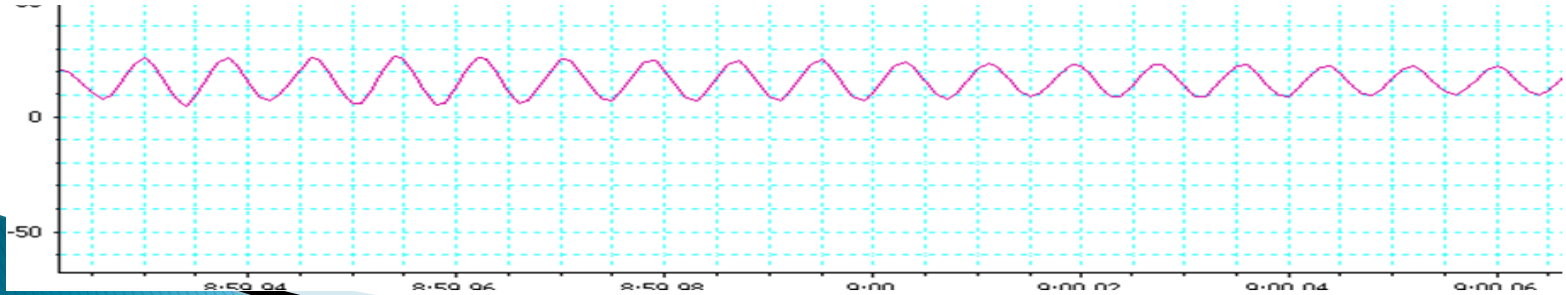
Highest [Ca++], Highest tension



Give a stimulus above the threshold at low frequency

- Any single stimulus impulse above a certain threshold will produce a contraction, or single twitch.
- A **threshold stimulation** is the smallest amount of stimulation that will result in a contraction.

- Muscle twitch, is a brief muscle contraction followed by relaxation that occurs in response to a single stimulus.



Components of muscle twitch

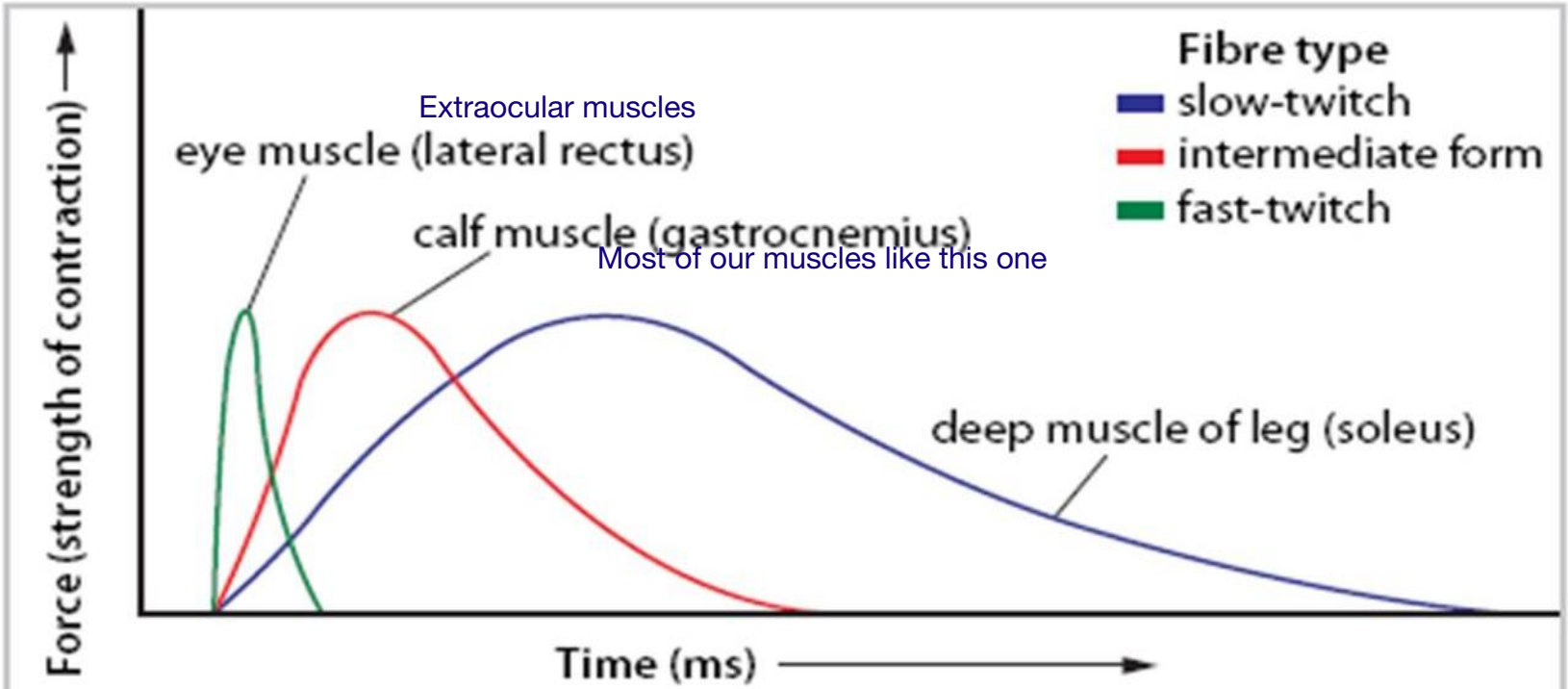
Latent period And until the tension starts to increase

- The time between giving a stimulus to the nerve and the subsequent contraction of the muscle
- Caused by the time taken for the action potential to propagate through the nerve, the time for transmission at the neuromuscular junction, then the subsequent steps in excitation–contraction coupling

Contraction period: when the tension starts to increase till maximum tension is achieved.

Relaxation period: when tension starts to decrease till it returns to baseline.

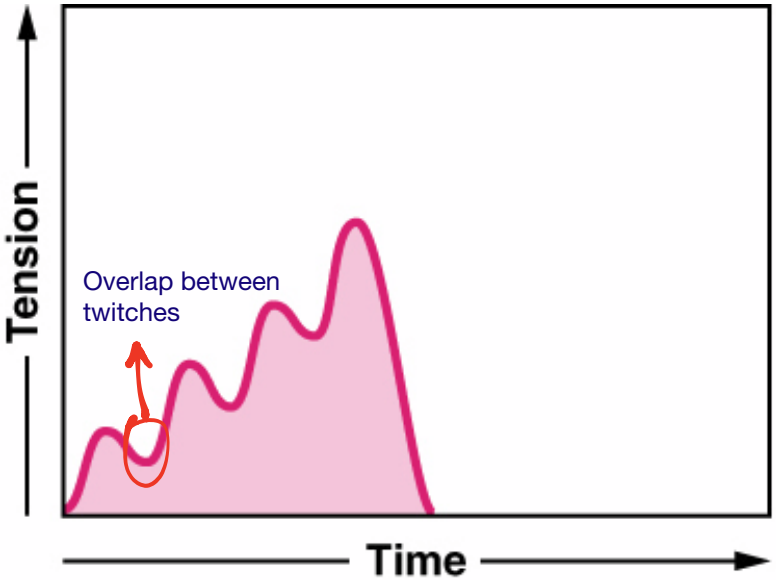
Muscle twitch in different muscle types



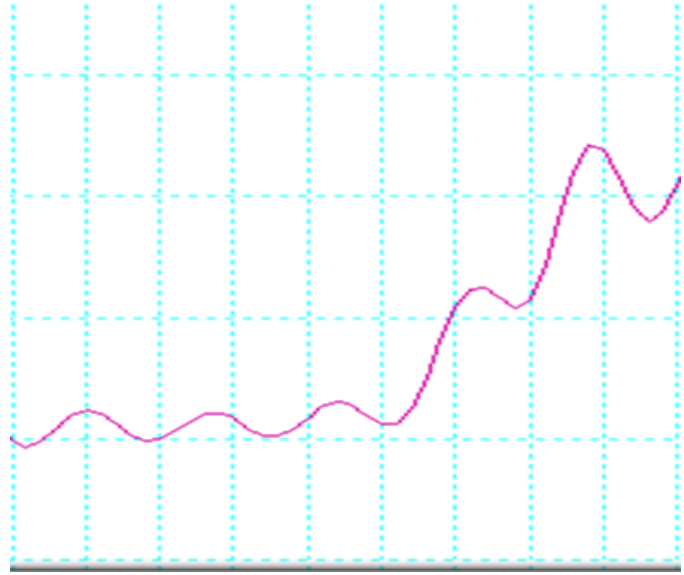
Fast twitch muscle(e.g. ocular) have twitches that reach maximum tension within 3-5 ms.
Slow twitch muscles(e.g. postural) have twitches that reach maximum tension in 40 ms.
Muscles that control most of our bodies movements have intermediate twitch lengths of 10-20 ms

Deep back muscles

Frequency Summation



(a) Wave summation



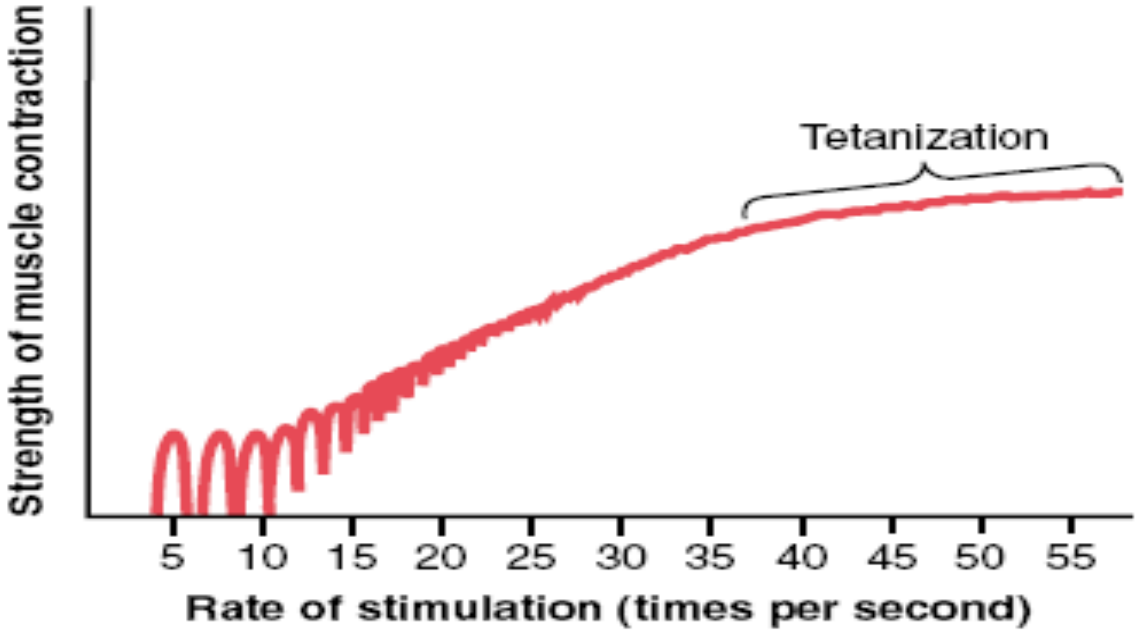
If we fix the voltage and increase the frequency of stimulation

To increase the tension

- Summation is adding together of individual twitch contractions to increase the intensity of overall muscle contraction. Achieved by increasing the frequency of stimulation

- The increase in tension observed in summation happens because a muscle fibre is unable to fully relax between twitches, each new contraction is partially added to the previous contraction resulting in higher tension(stronger contraction)
- The concentration of Calcium in the cytosol becomes higher with each successive contraction

Tetanization



If we fix the voltage and continue to increase the frequency of stimulation

- Tetanization occurs when the frequency of stimulation reaches a critical level, at this point the maximum tension a muscle can generate is reached.

- Any additional increase in frequency beyond that point has no further effect on increasing the muscle's tension.

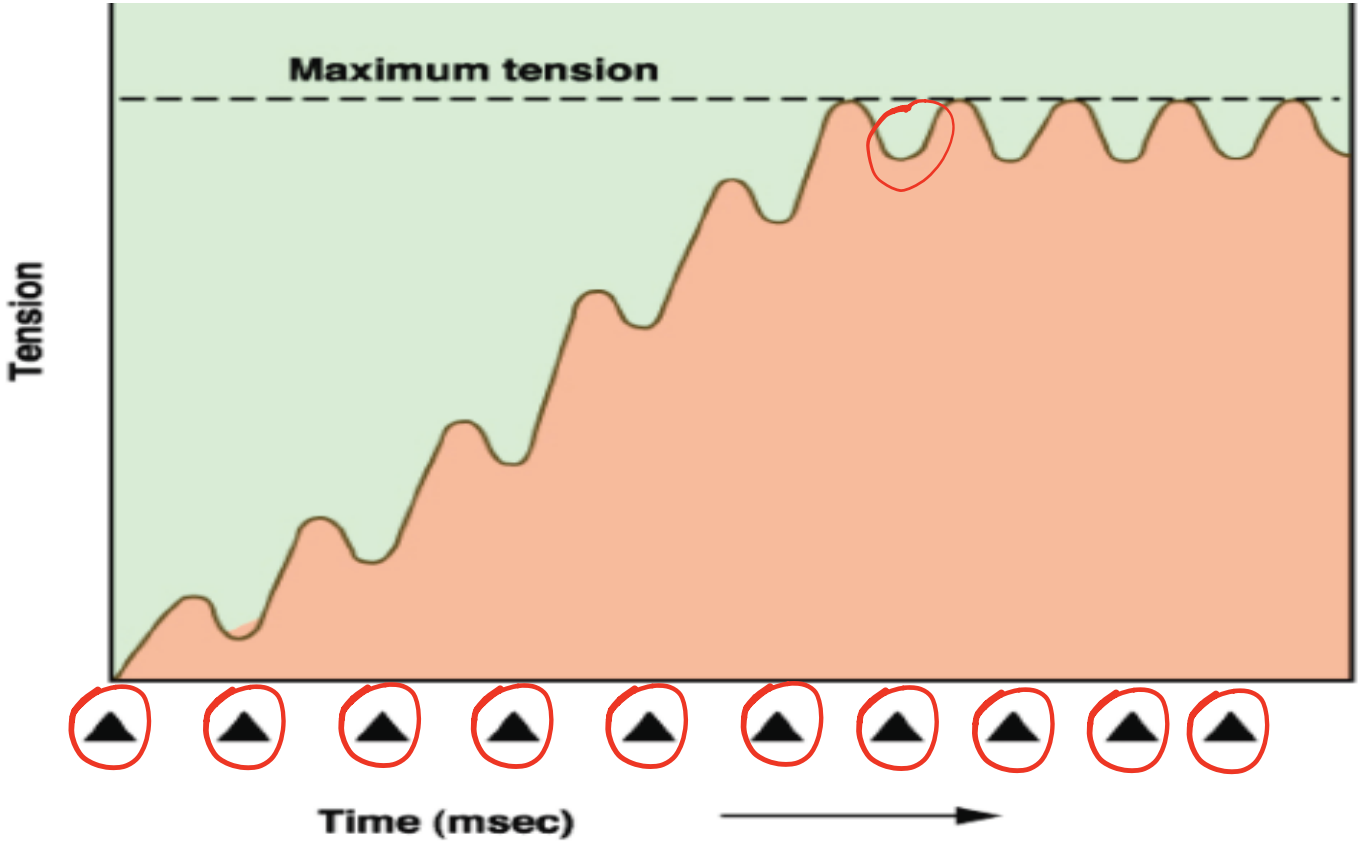
All actin-myosin bridges are formed

- This occurs because enough calcium ions are maintained in the muscle sarcoplasm, even between action potentials, so that full contractile state is sustained. Tetanization is a good thing

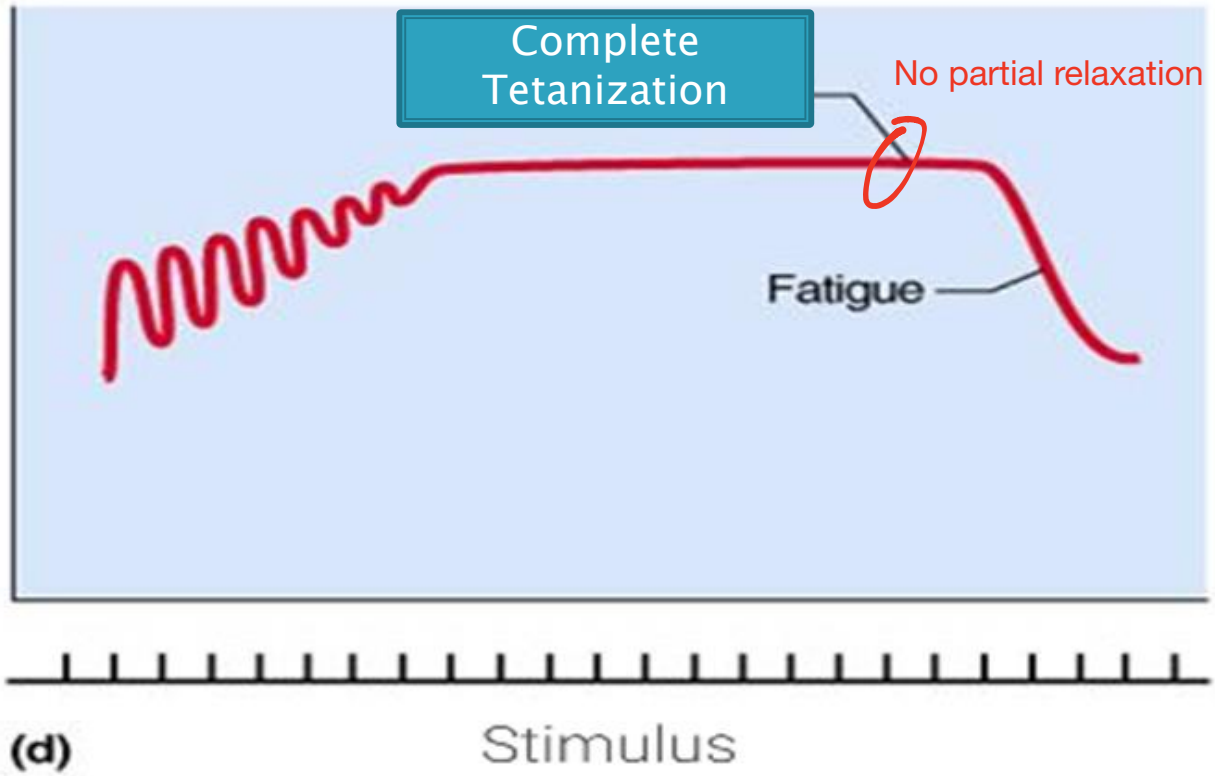
- Incomplete Tetanization occurs when the muscle reaches the maximum tension but is able to partially relax between stimulus impulses.

- Complete Tetanization occurs when the muscle reaches maximum tension and there is no relaxation at all between stimulus impulses. Occurs at higher frequency of stimulation when successive contractions eventually become so rapid that they fuse together and the whole muscle contraction appears to be completely smooth and continuous.

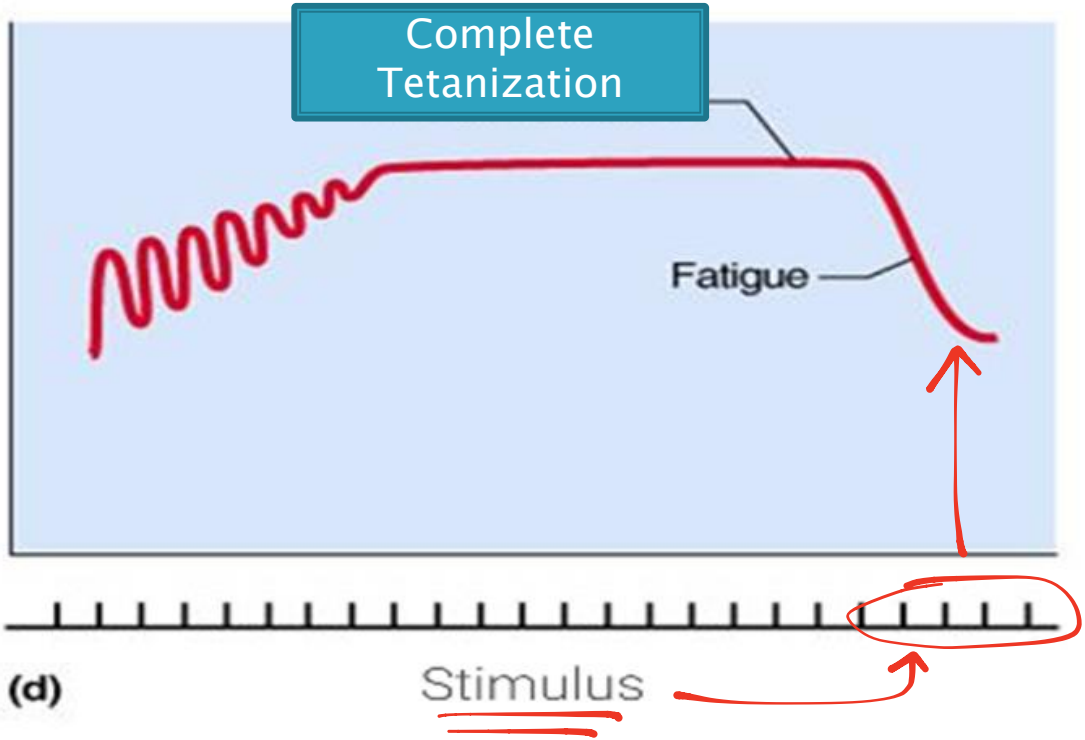
Incomplete Tetanization



Complete Tetanization



Fatigue

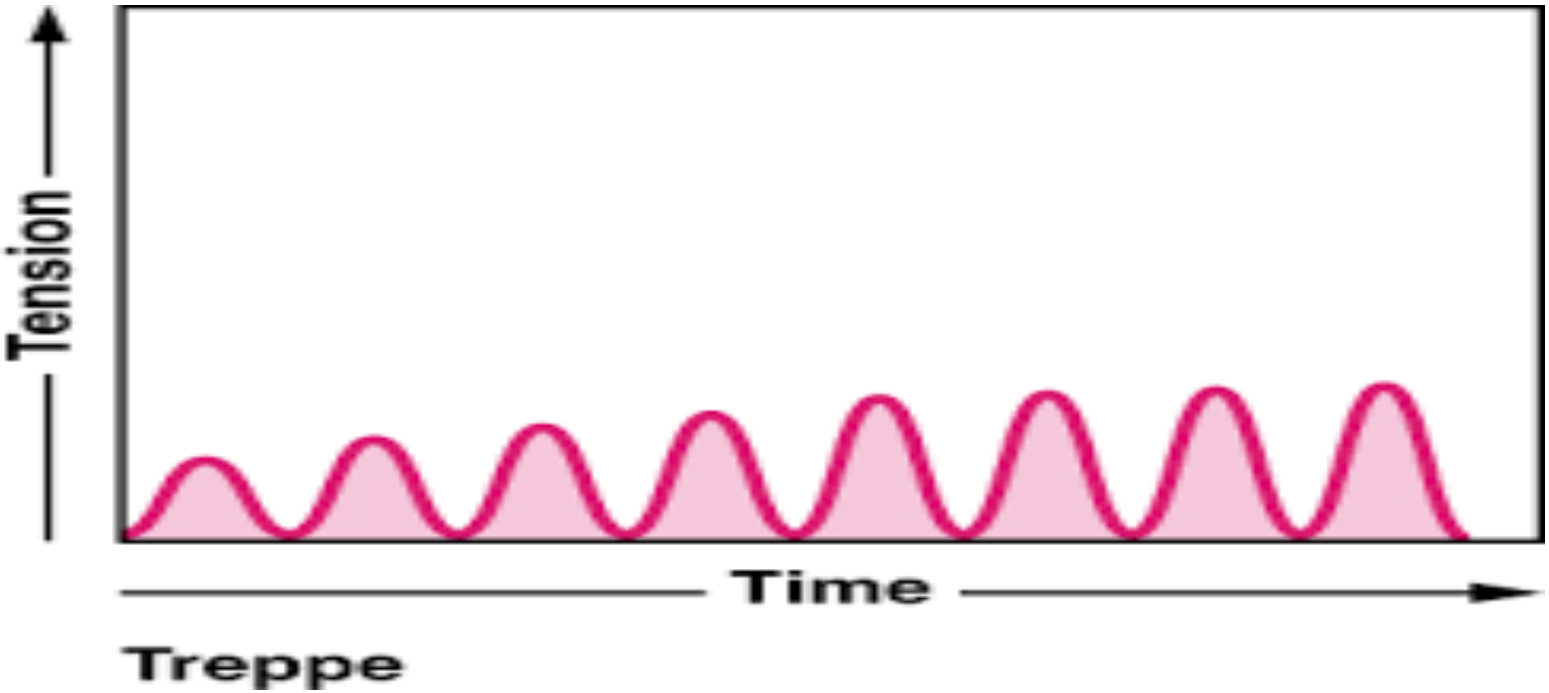


If we continue to give stimulation at a very high frequency for a long time

- Fatigue is a decline in the ability of the muscle to respond to stimulation, occurs after prolonged and strong contraction.
- On the graph it is depicted as a drop in tension **<u>despite continued stimulation</u>**
- Why does fatigue happen?

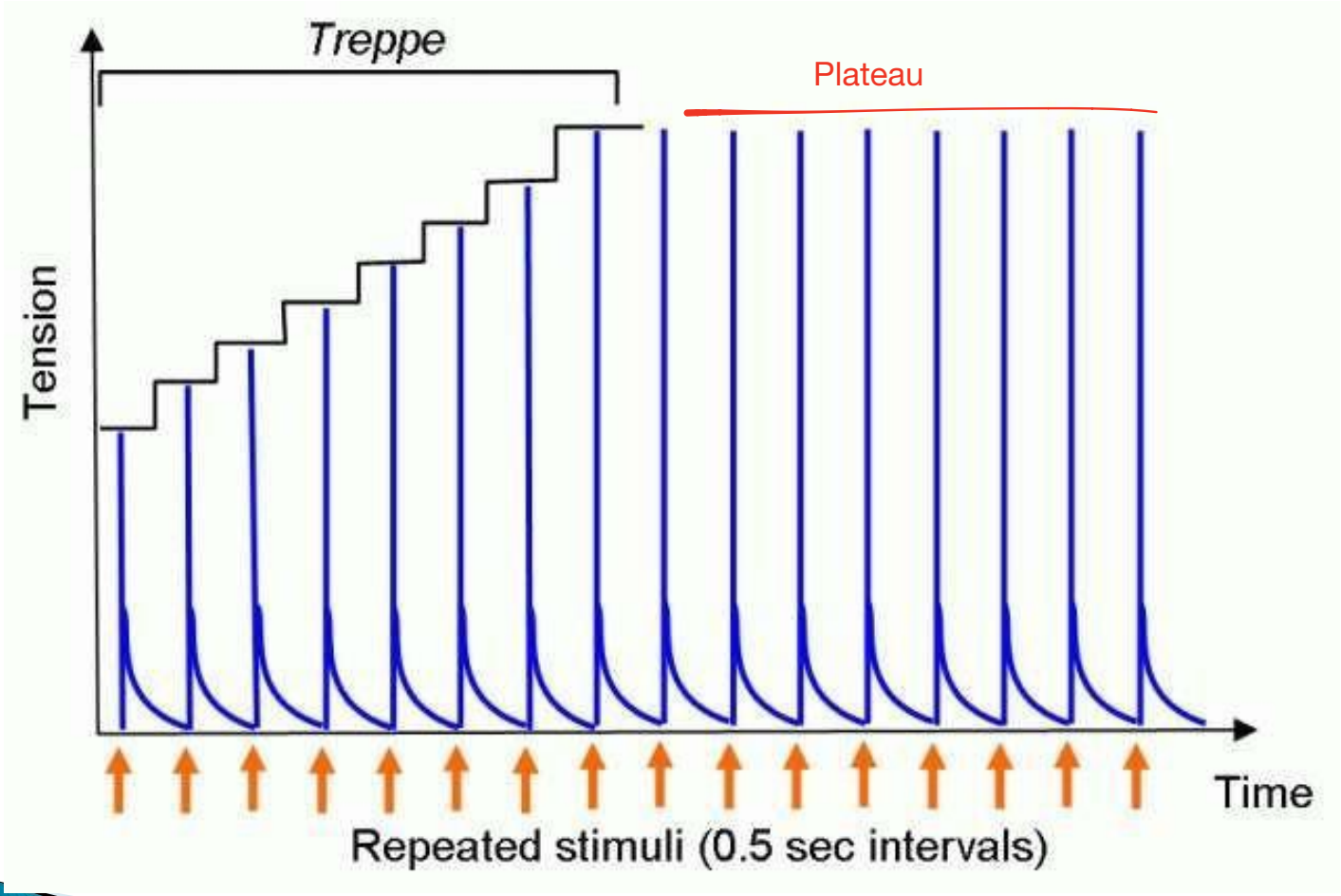
1. Inability of the contractile and metabolic processes of the muscle fibers to continue supplying the same work output.
2. Transmission at the neuromuscular junction can diminish after intense prolonged muscle activity
3. Interruption of blood flow which leads to loss of nutrient supply, especially loss of oxygen.

Treppe(Staircase)Effect



Giving the same stimulus in terms of voltage and frequency

But different response


Treppe
Plateau
Tension
Time
Repeated stimuli (0.5 sec intervals)

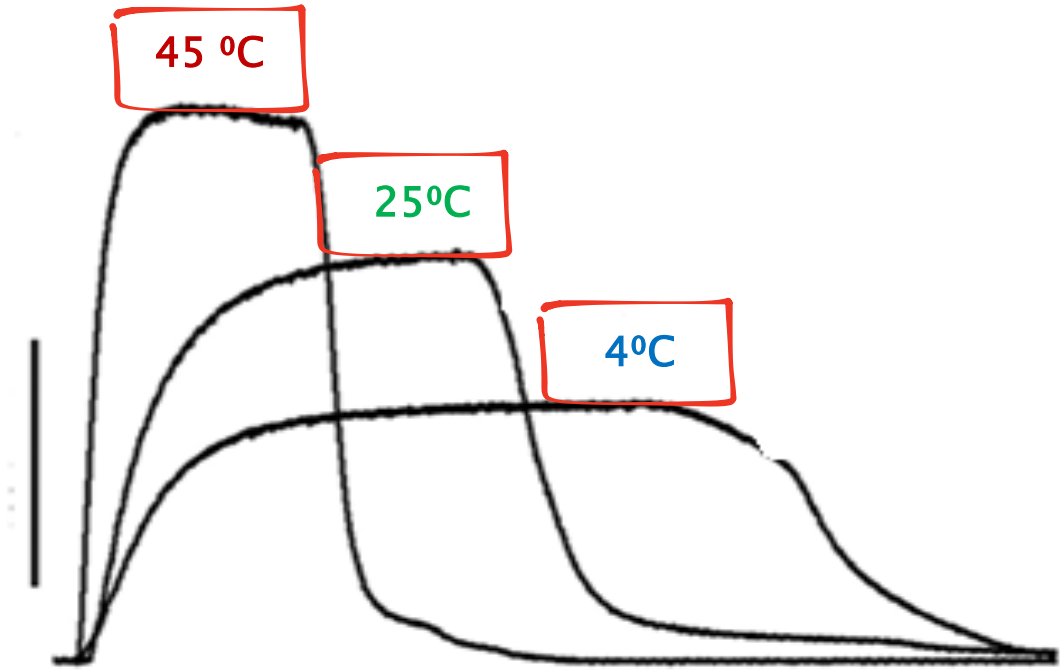
- Treppe effect happens when a muscle begins to contract after a long period of rest, its strength of contraction will gradually increase with every successive stimulus till a plateau is reached.

- It is believed to be caused by:

1. The rise in muscle temperature.
2. The enhanced blood flow
3. The increased concentration of calcium ions in the cytosol

- This is the basis of '**Warming Up**' .

Effect of Temperature on muscle twitch



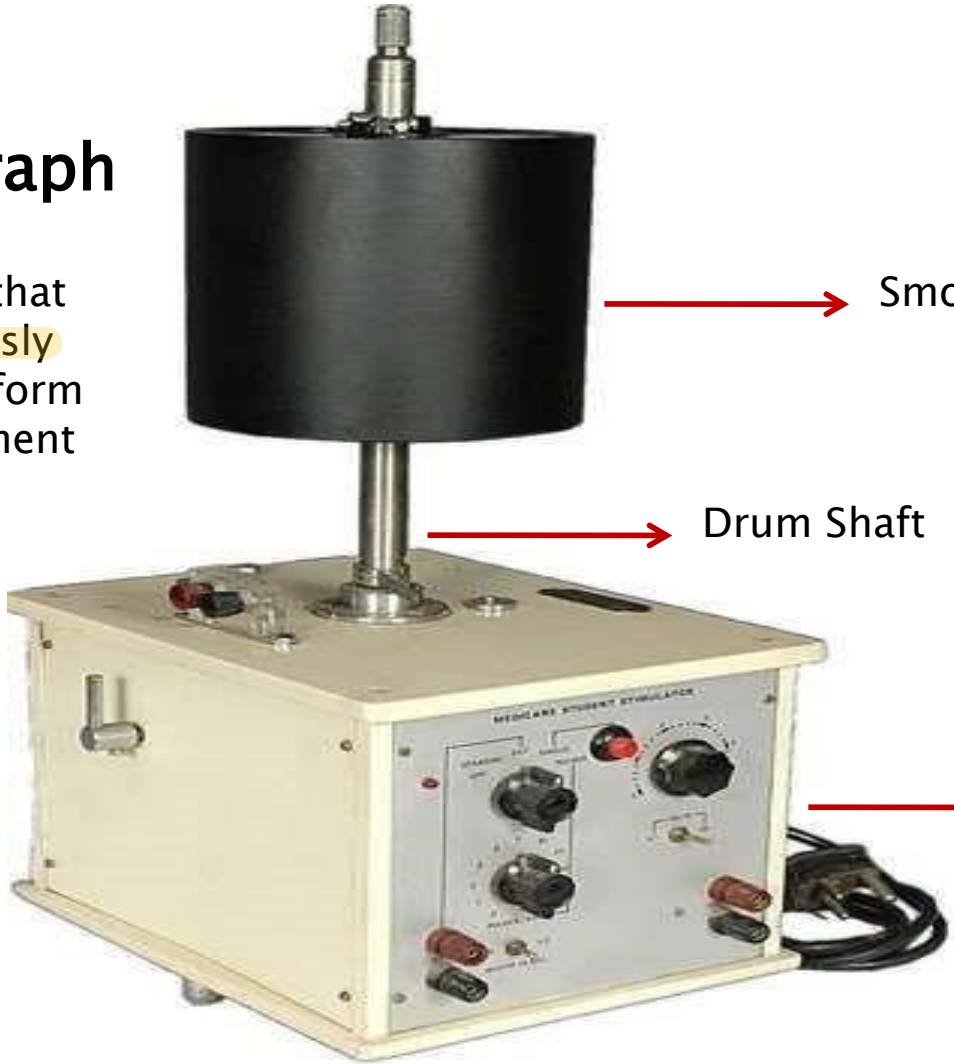
We change the temperature of the ringer solution in the organ bath for this part of the expirement

Know that temperature affects contraction

	Low Temp	Room Temp	High Temp
1- Latent period	Longest	Between	Shortest
2- Contraction period /duration	Longest	Between	Shortest
3- Amplitude Tension	Shortest	Between	Longest

Kymograph

The device that was previously used to perform this experiment



Thank you

- My e-mail
  tamara.alqudah@ju.edu.jo
  My office
  Faculty of medicine, 3rd floor, opposite the elevator