

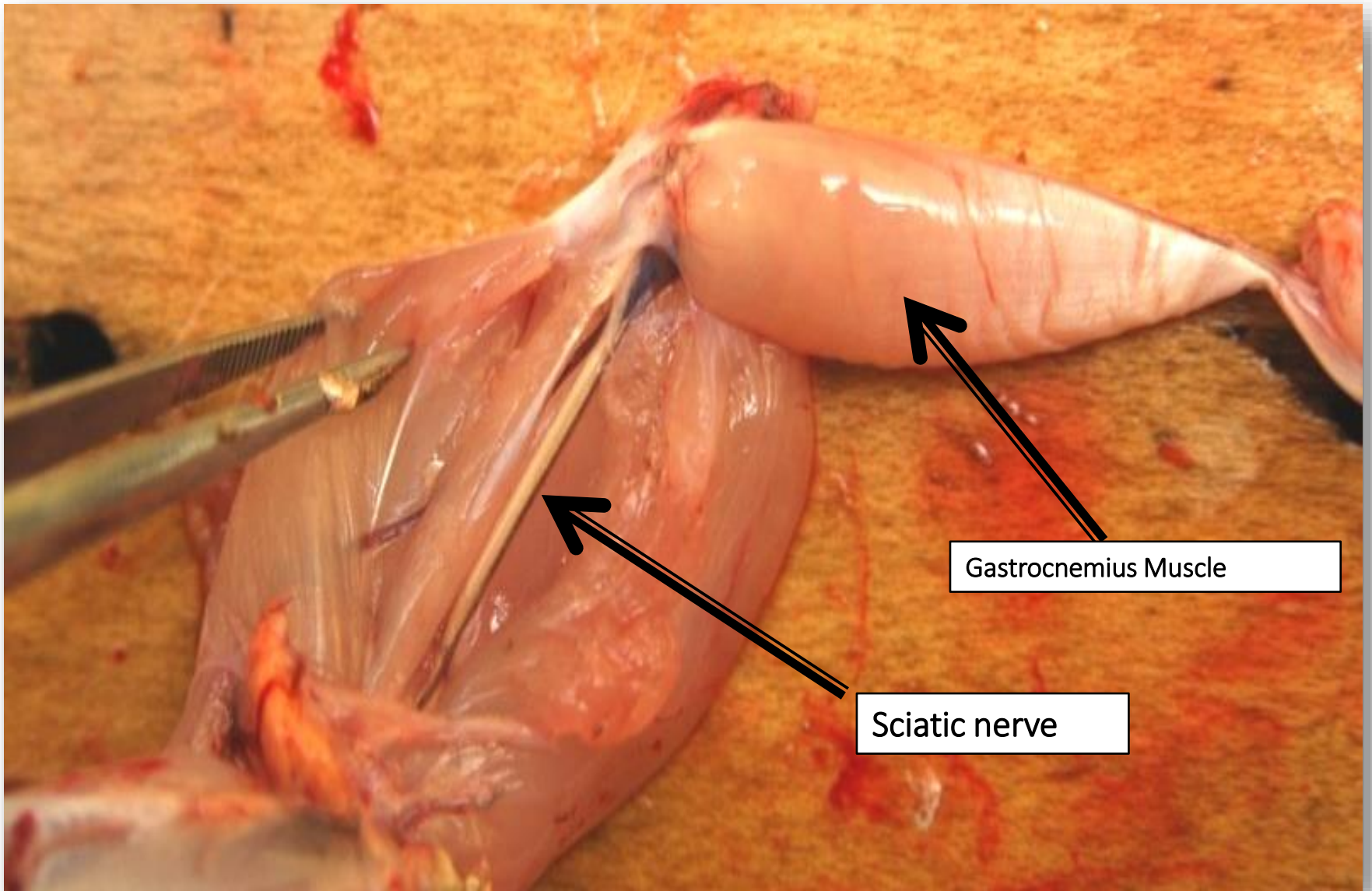
Characteristics of Whole Skeletal Muscle Contraction

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Aim of the experiment

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

- ✓ Simple muscle twitch
- ✓ Summation
- ✓ Tetanization
- ✓ Fatigue
- ✓ Treppe phenomenon
- ✓ Effect temperature on simple muscle twitch



Gastrocnemius Muscle

Sciatic nerve



CEP

STIMULATOR MODEL 8048

MODE



PULSE WIDTH mS



FREQUENCY Hz



VOLTAGE



AMPLITUDE

MULTIPLIER



VOLUME



EXTERNAL TRIGGER



SINGLE PULSE



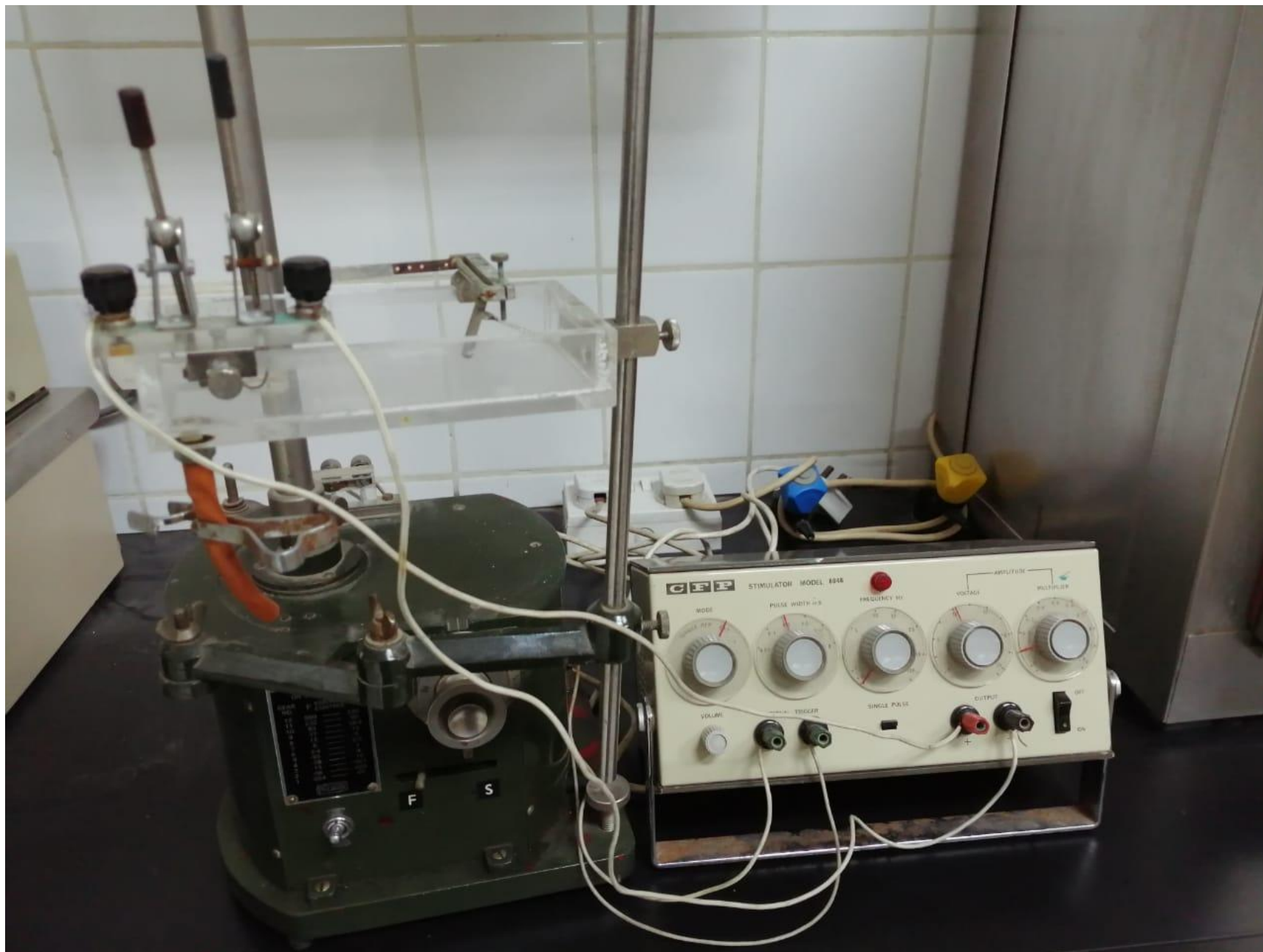
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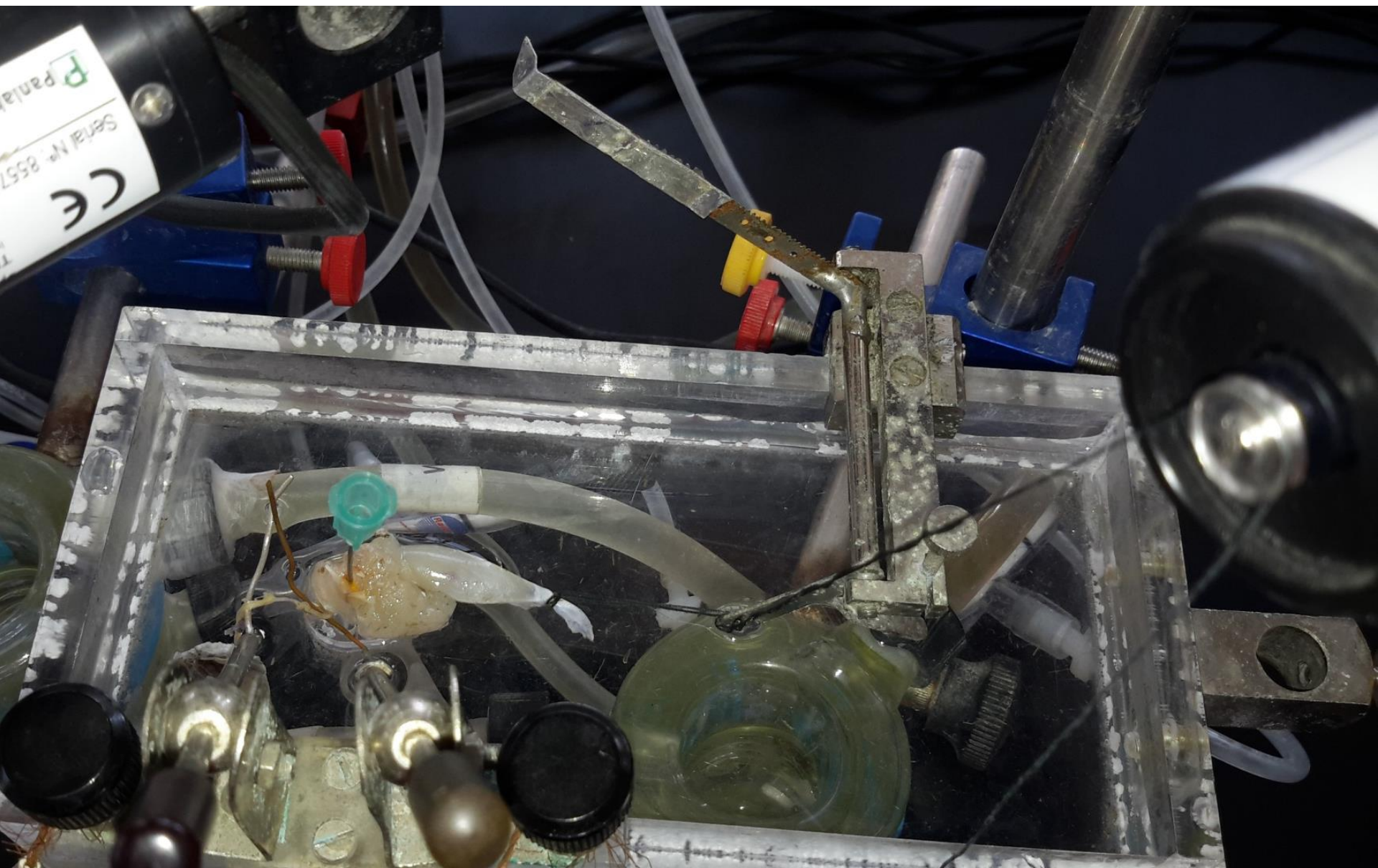


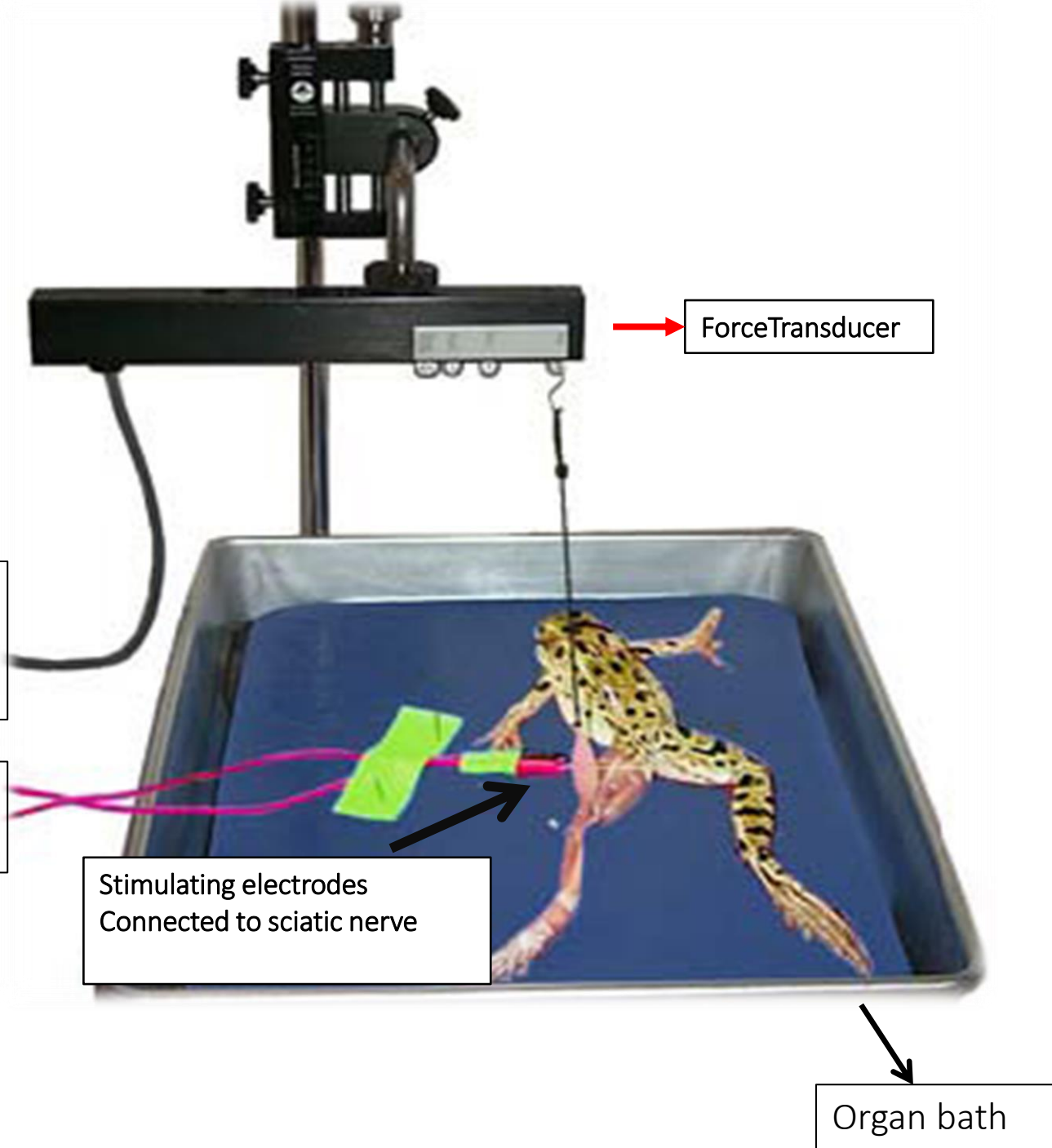
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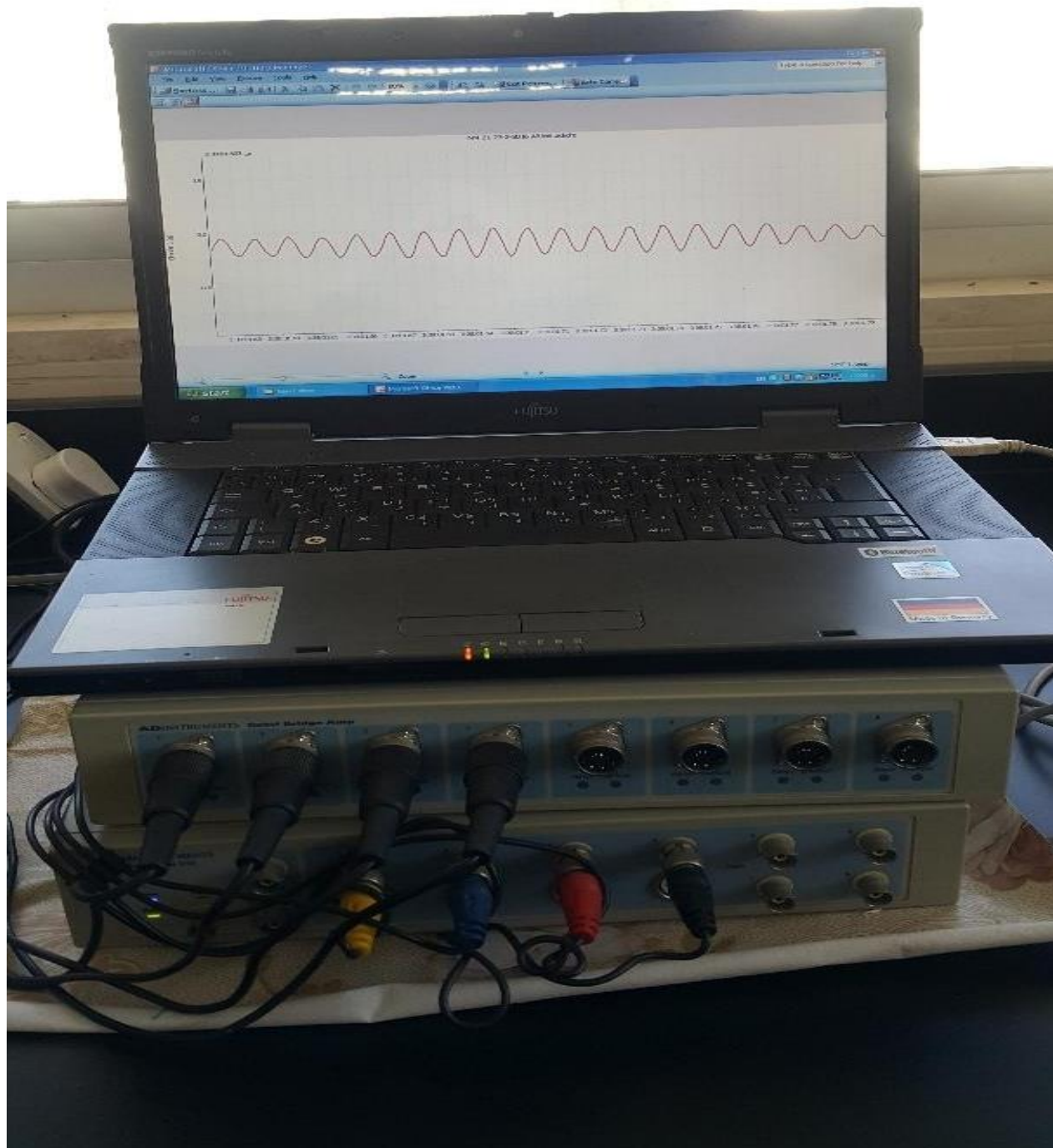


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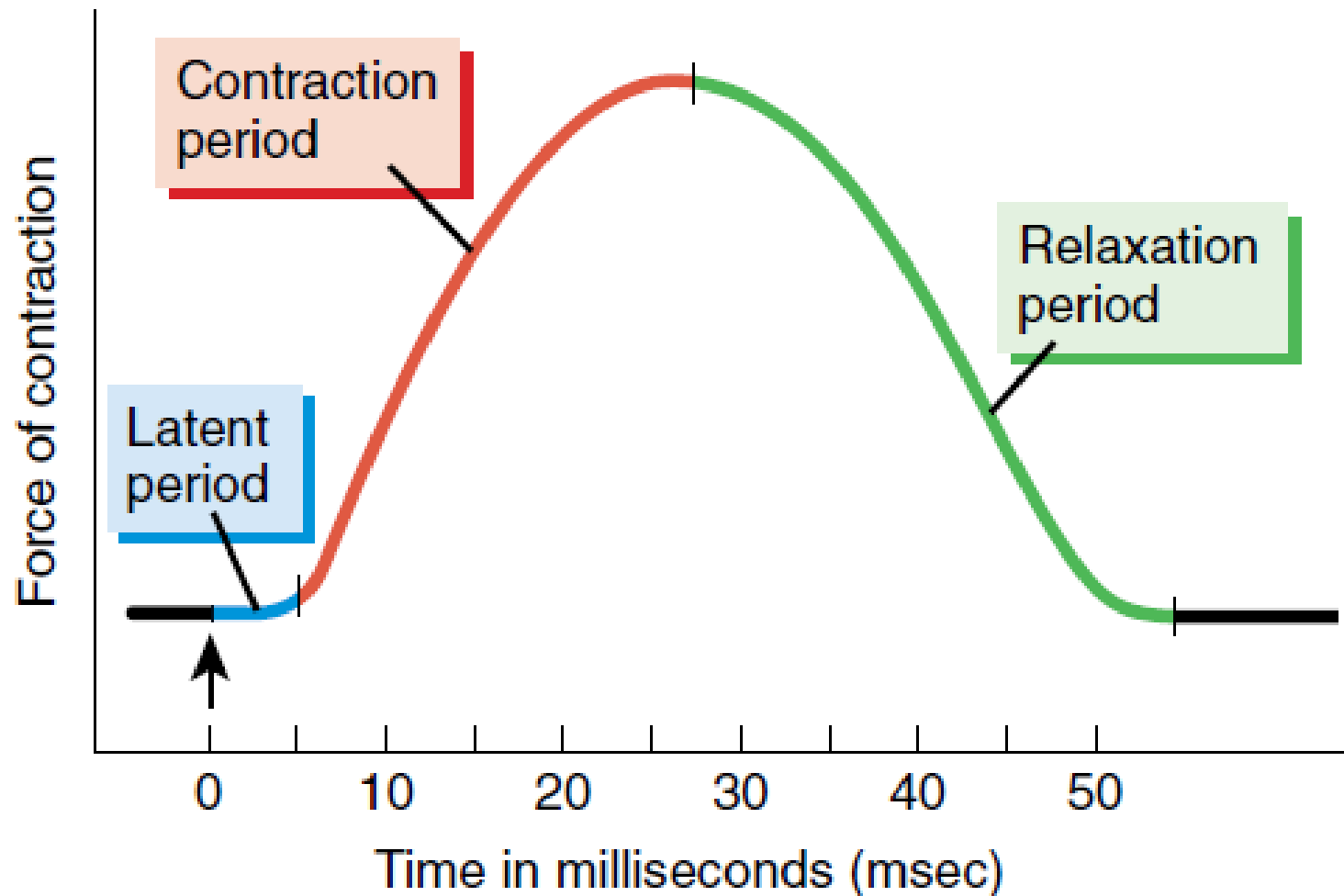


Method

- 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.
- Force transducer converts a **force** such as tension, compression or pressure into an electrical signal that can be measured

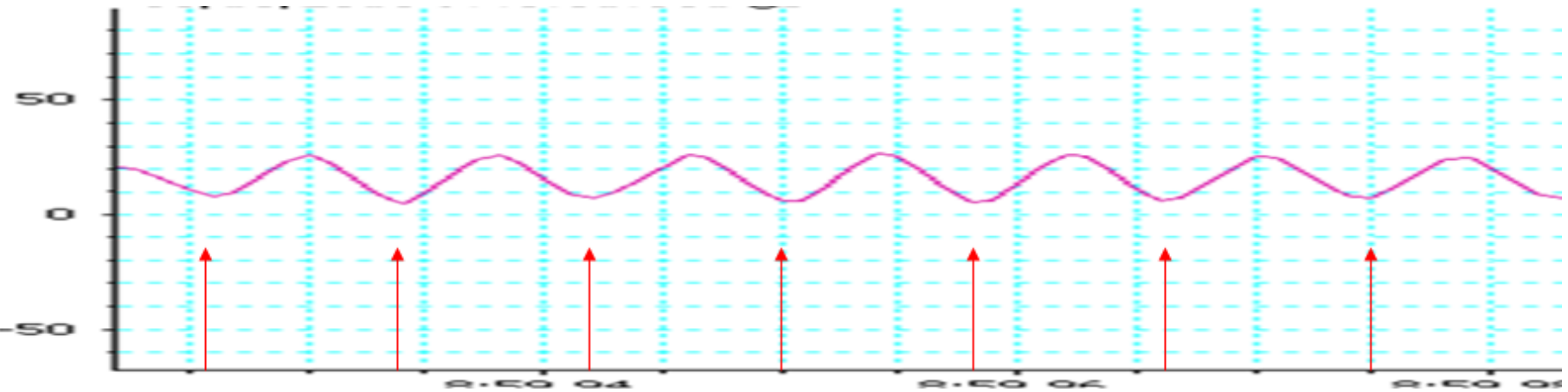
- Stimulating electrodes are connected to the sciatic nerve
- We stimulate the sciatic nerve using a device called electrical stimulator, this stimulation will result in isotonic contraction of the gastrocnemius muscle.
- When the muscle contracts it will shorten and pull the thread which is connected 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.
- Using the electrical stimulator, we can change the magnitude (voltage) and frequency of stimulation.

Simple muscle twitch



Give a stimulus above the threshold

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



Give a stimulus above the threshold at low frequency

Components of muscle twitch

Latent period

- The time between the application of the stimulus and the beginning of contraction.
- During the latent period, the action potential sweeps over the sarcolemma and calcium ions are released from the sarcoplasmic reticulum.

Contraction period:

- When the tension starts to increase till maximum tension is achieved.
- During this time, calcium ions bind to troponin, myosin-binding sites on actin are exposed, and cross-bridges form.

Relaxation period:

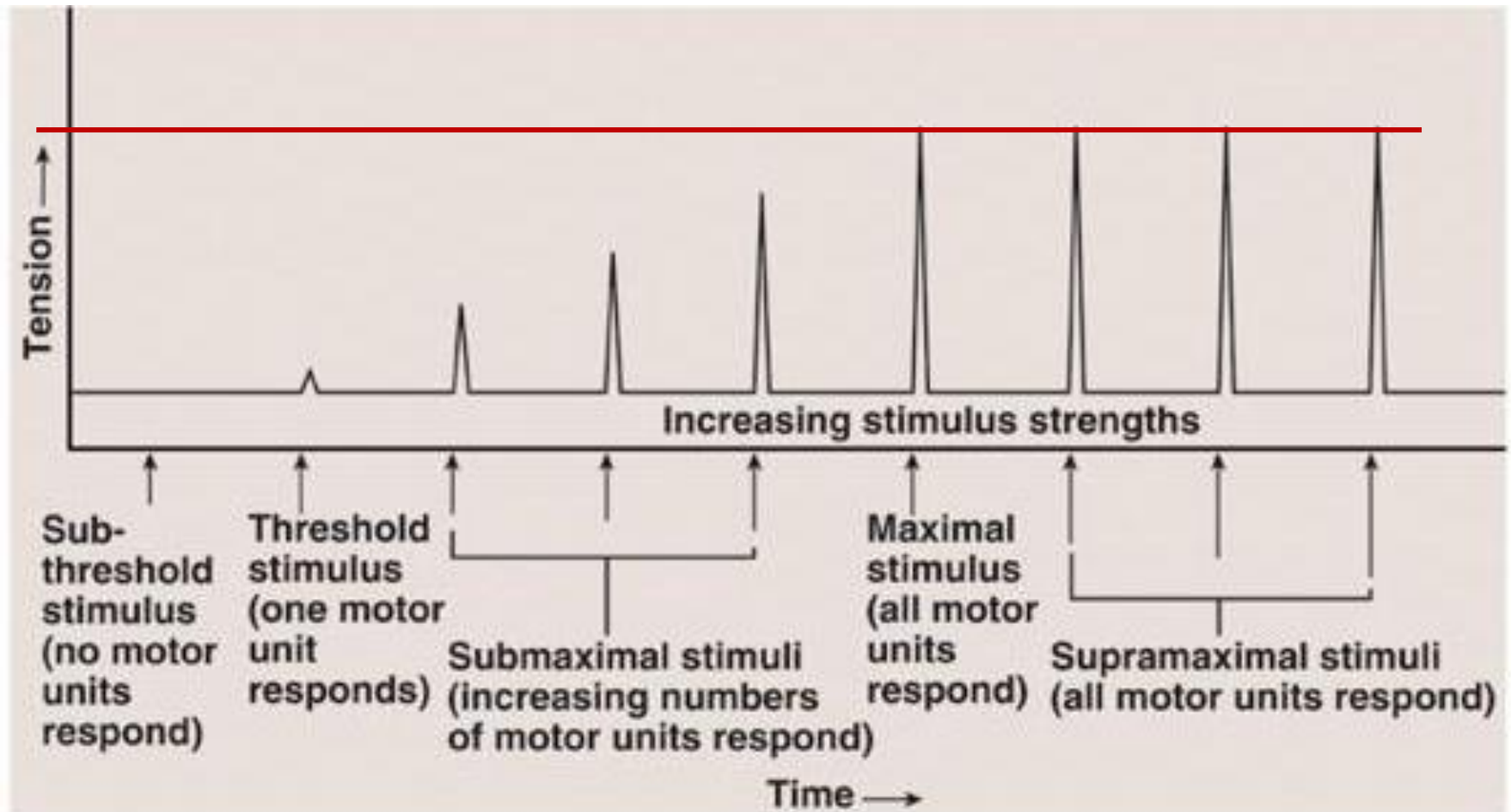
- When the tension starts to decrease till it returns to baseline.
- Calcium ions are actively transported back into the sarcoplasmic reticulum, myosin-binding sites are covered by tropomyosin, myosin heads detach from actin, and tension in the muscle fiber decreases.

Summation

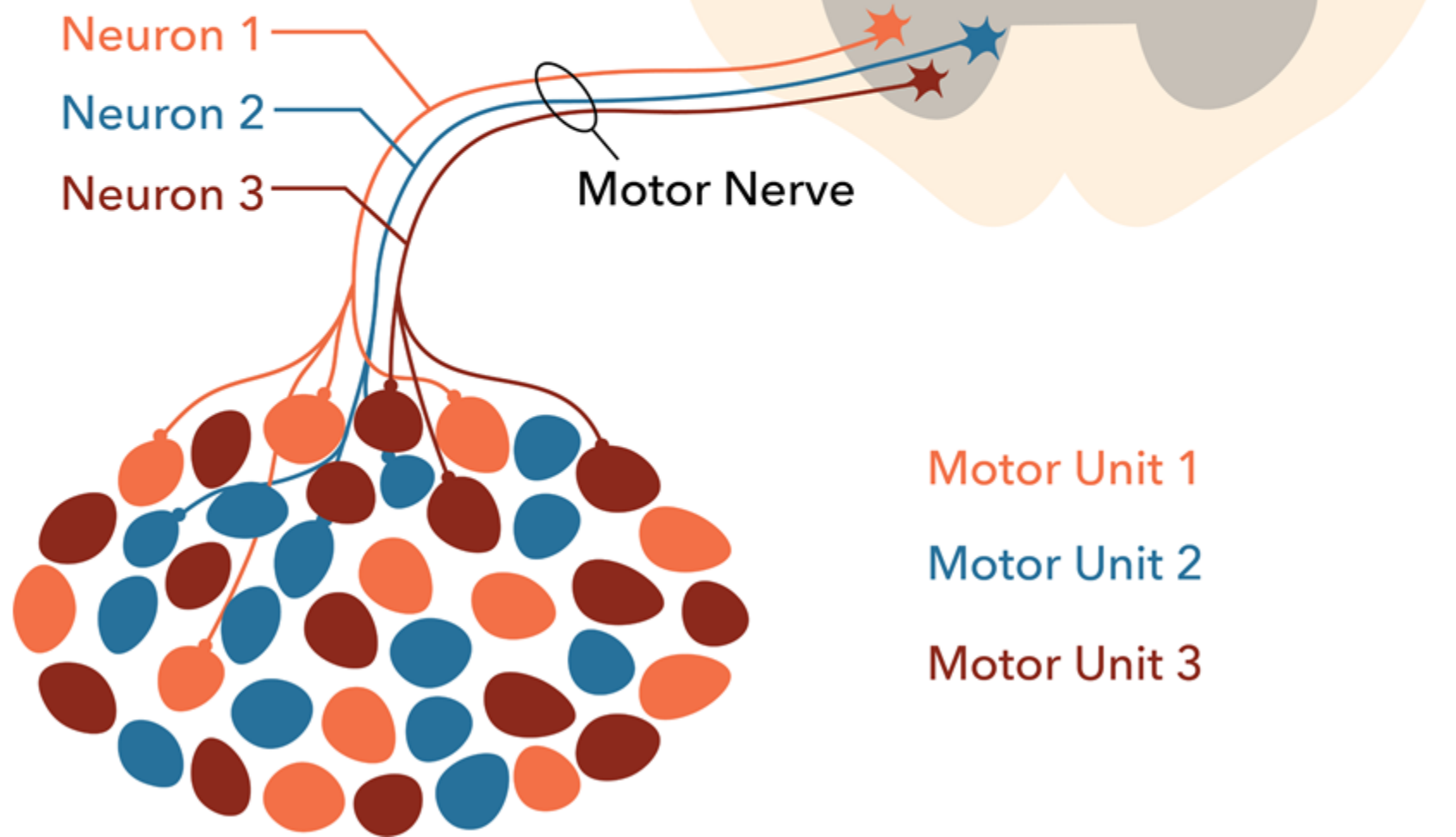
- Summation is used to increase the intensity of overall muscle contraction.
- Summation occurs in two ways:
 1. Multiple fiber summation: by increasing the number of motor units contracting simultaneously. It is achieved by increasing the stimulus strength
 2. Frequency summation: by increasing the frequency of contraction leading to an overlap between successive muscle twitches. It is achieved by increasing the frequency of stimulation
 - ✓ Can lead to tetanization

Multiple fiber summation

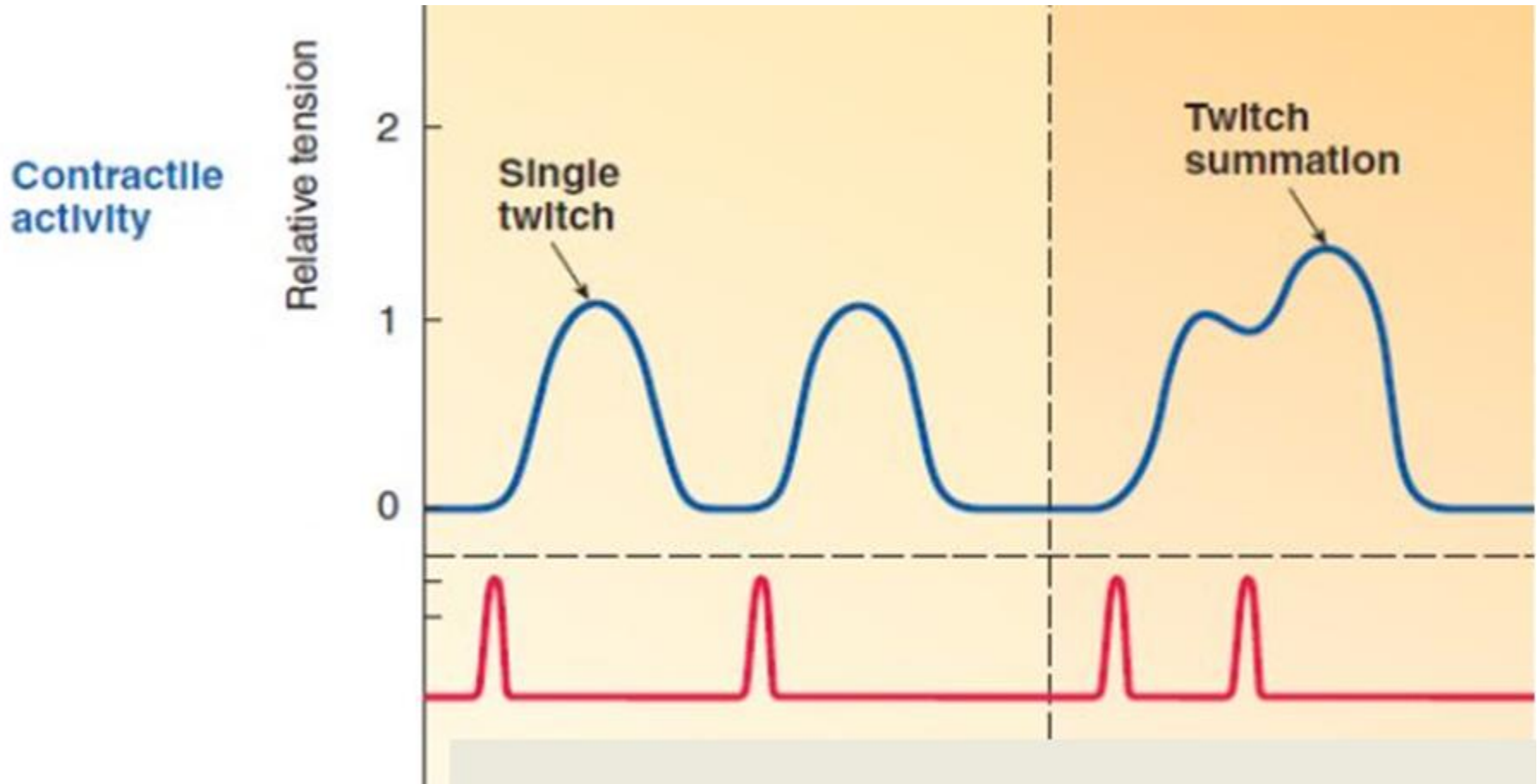
- Increasing the stimulus strength (voltage) will lead to Multiple fiber summation.
- Occurs by increasing the number of motor units contracting simultaneously



Spinal Cord



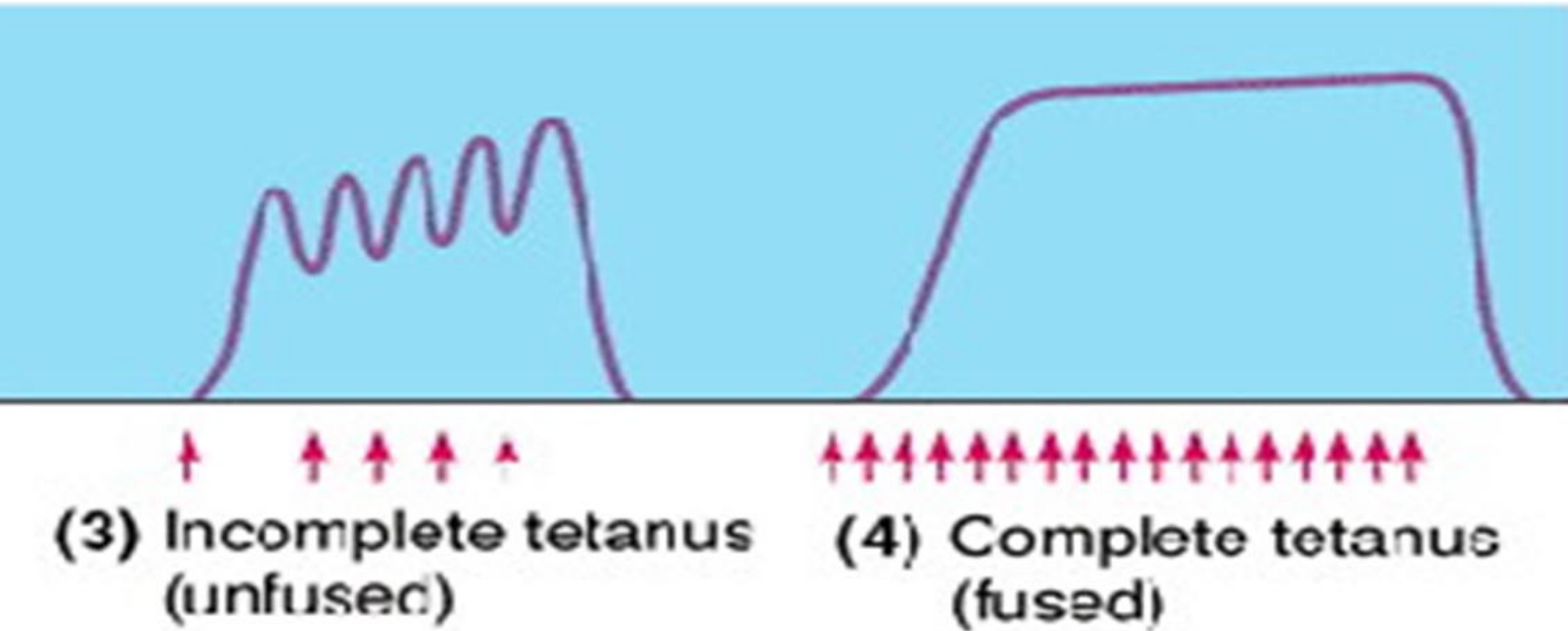
Frequency (Wave) Summation



If we fix the voltage and increase the frequency of stimulation

- The increase in tension observed in frequency summation happens because a muscle fibre is unable to fully relax between twitches, the new contraction is partially added to the previous one 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 greatly increase the frequency of stimulation

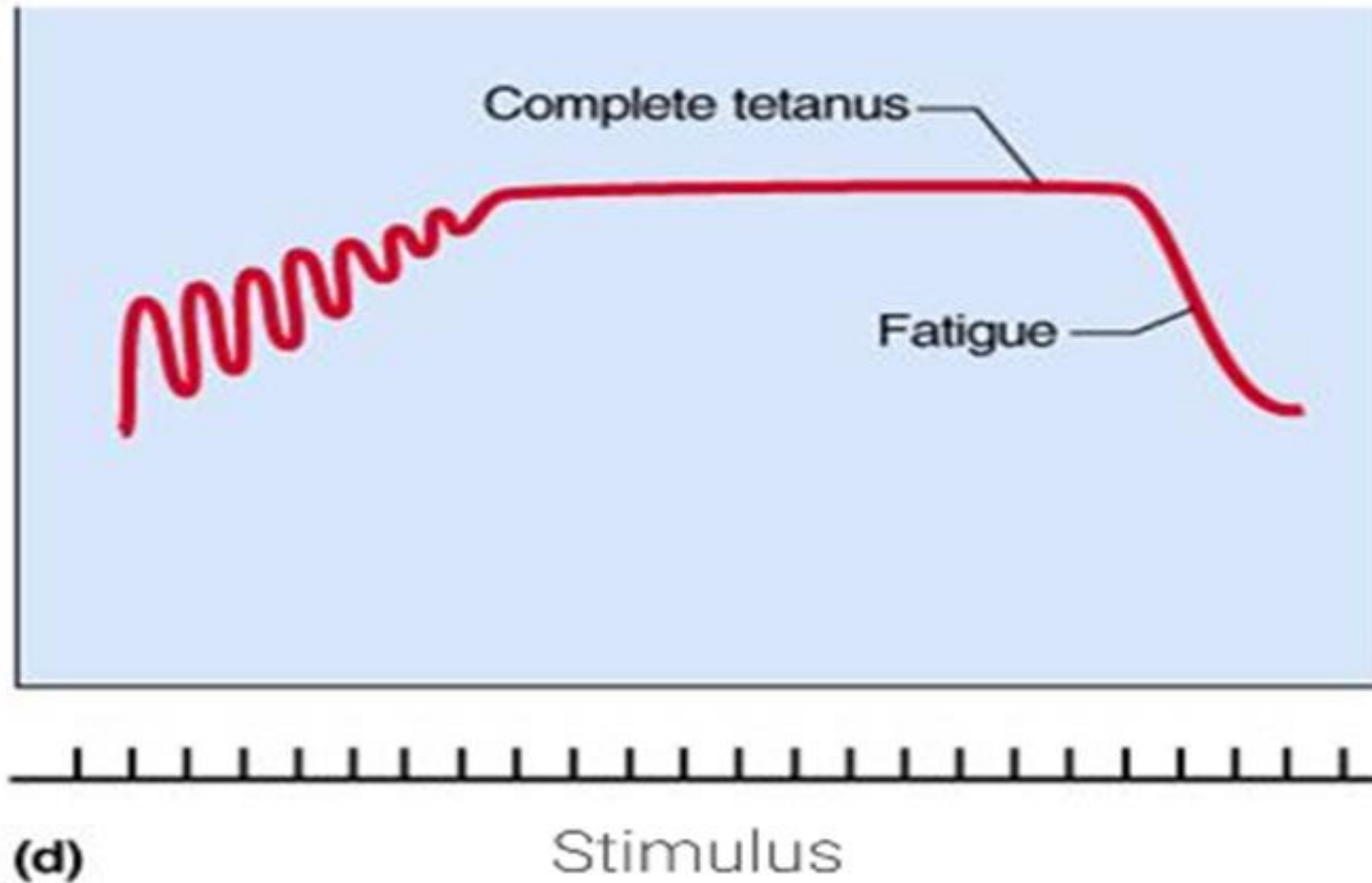
Incomplete tetanization

- Unfused (incomplete) tetanization is a sustained but wavering contraction.
- Occurs When a skeletal muscle fiber is stimulated at a high rate, so it can only partially relax between stimuli.

Complete tetanization

- Fused (complete) tetanization, a sustained contraction in which individual twitches can't be detected.
- Occurs when a skeletal muscle fiber is stimulated at a very high rate, so it does not relax at all between stimuli.
- 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.
- It occurs because enough calcium ions are maintained in the muscle sarcoplasm, even between action potentials, so that full contractile state is sustained.

Fatigue



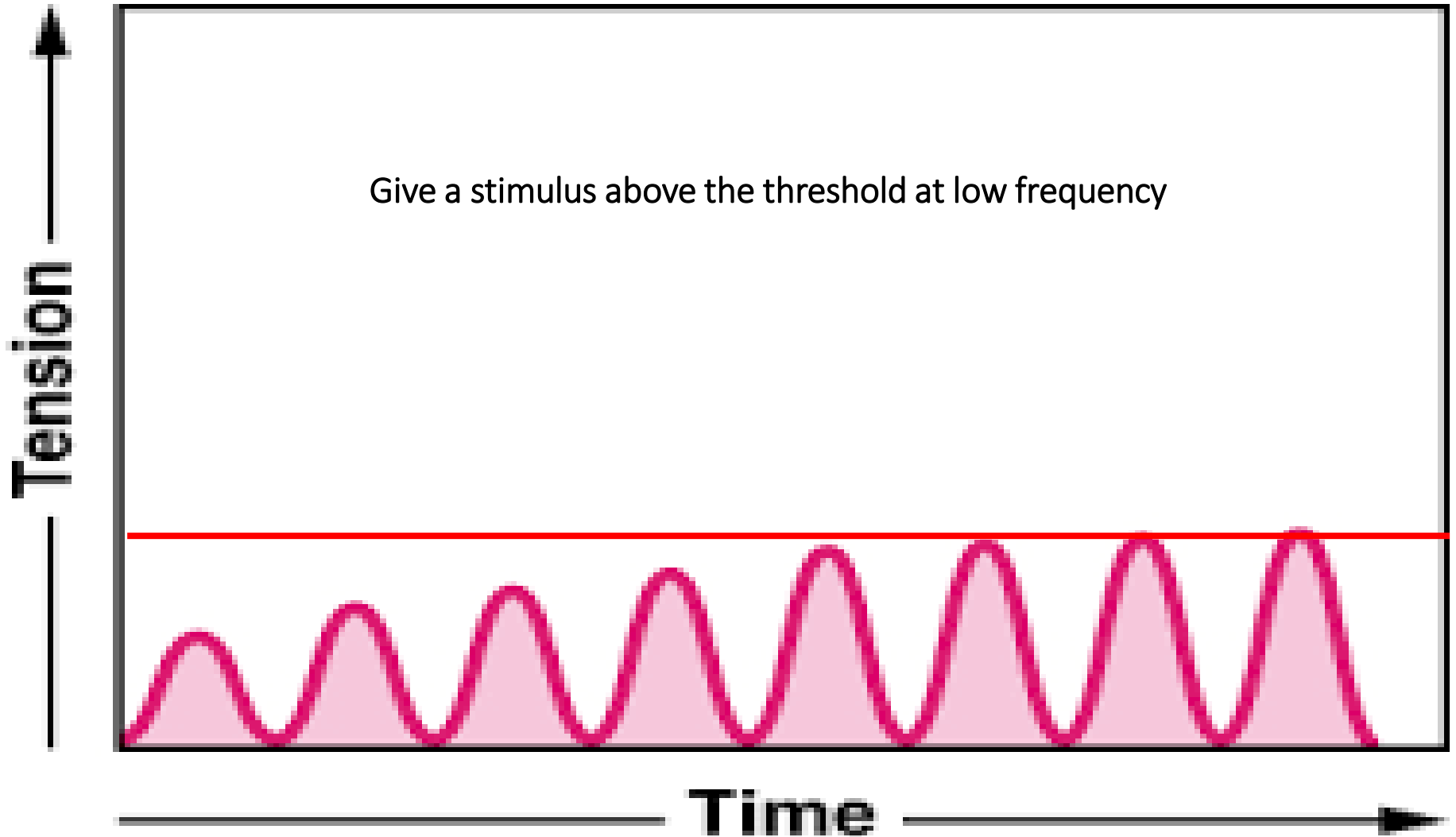
If we continue to give stimulation at a very high frequency for a long time

- 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 **despite continued stimulation**

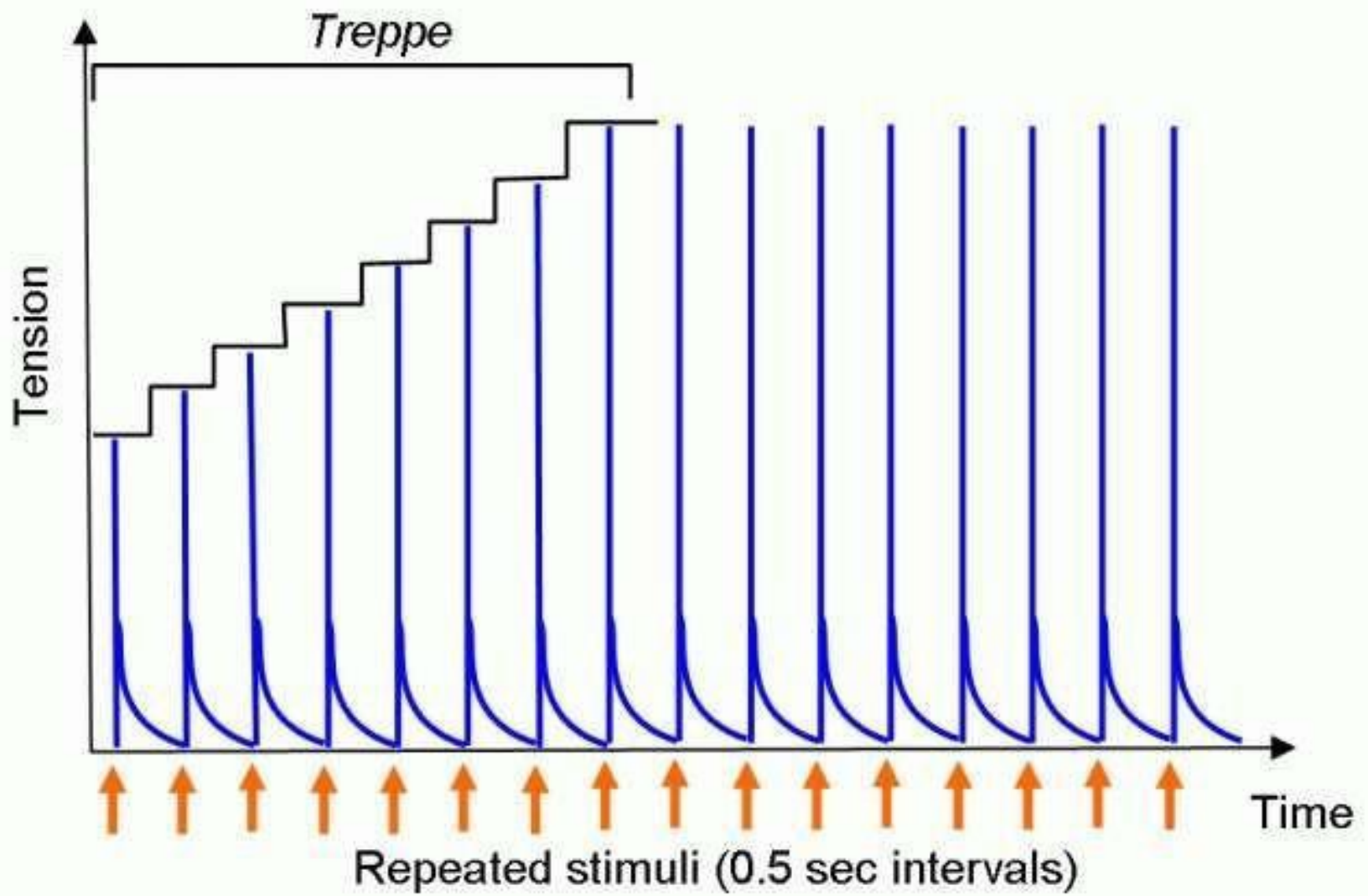
Why does fatigue happen?

1. Decreased transmission at the neuromuscular junction
2. Inadequate release of calcium from the sarcoplasmic reticulum
3. Accumulation of lactic acid and ADP

Treppe (Staircase) Effect

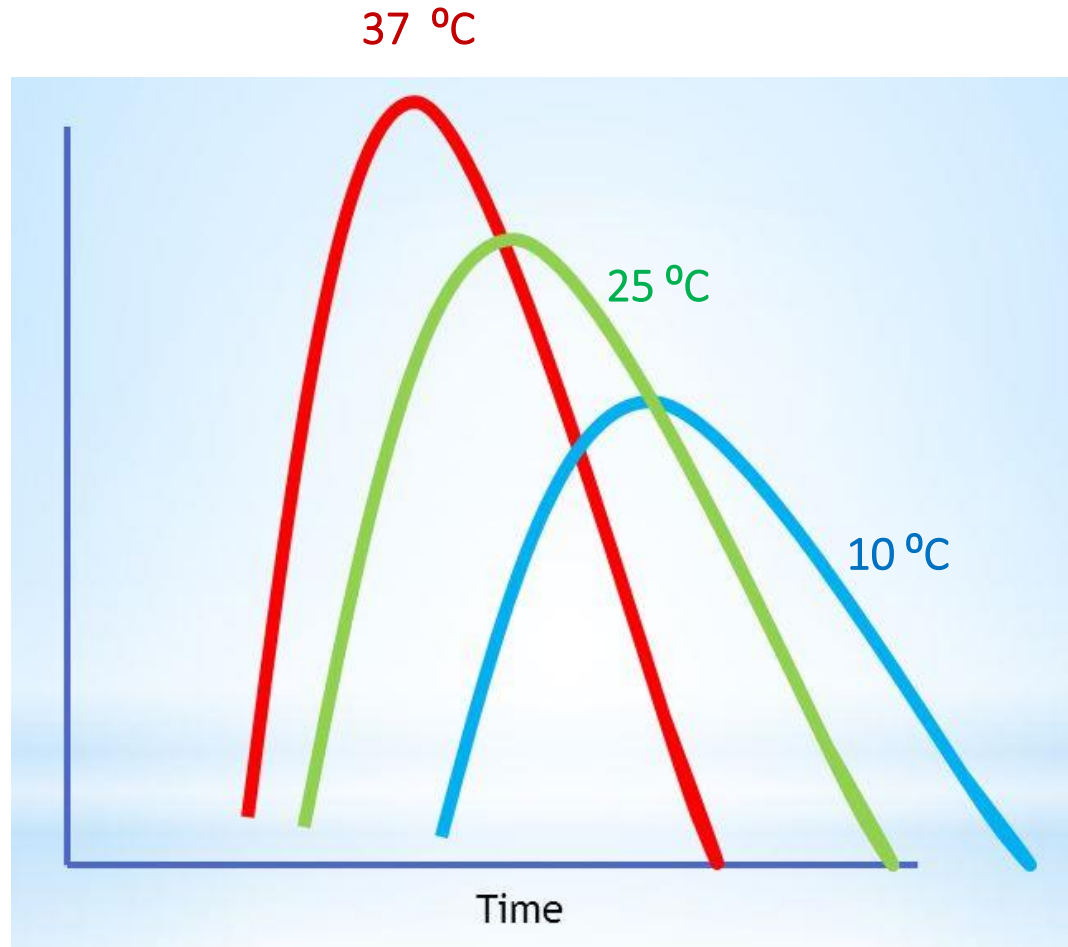


We are giving the same stimulus in terms of voltage and frequency but the response of the muscle improves



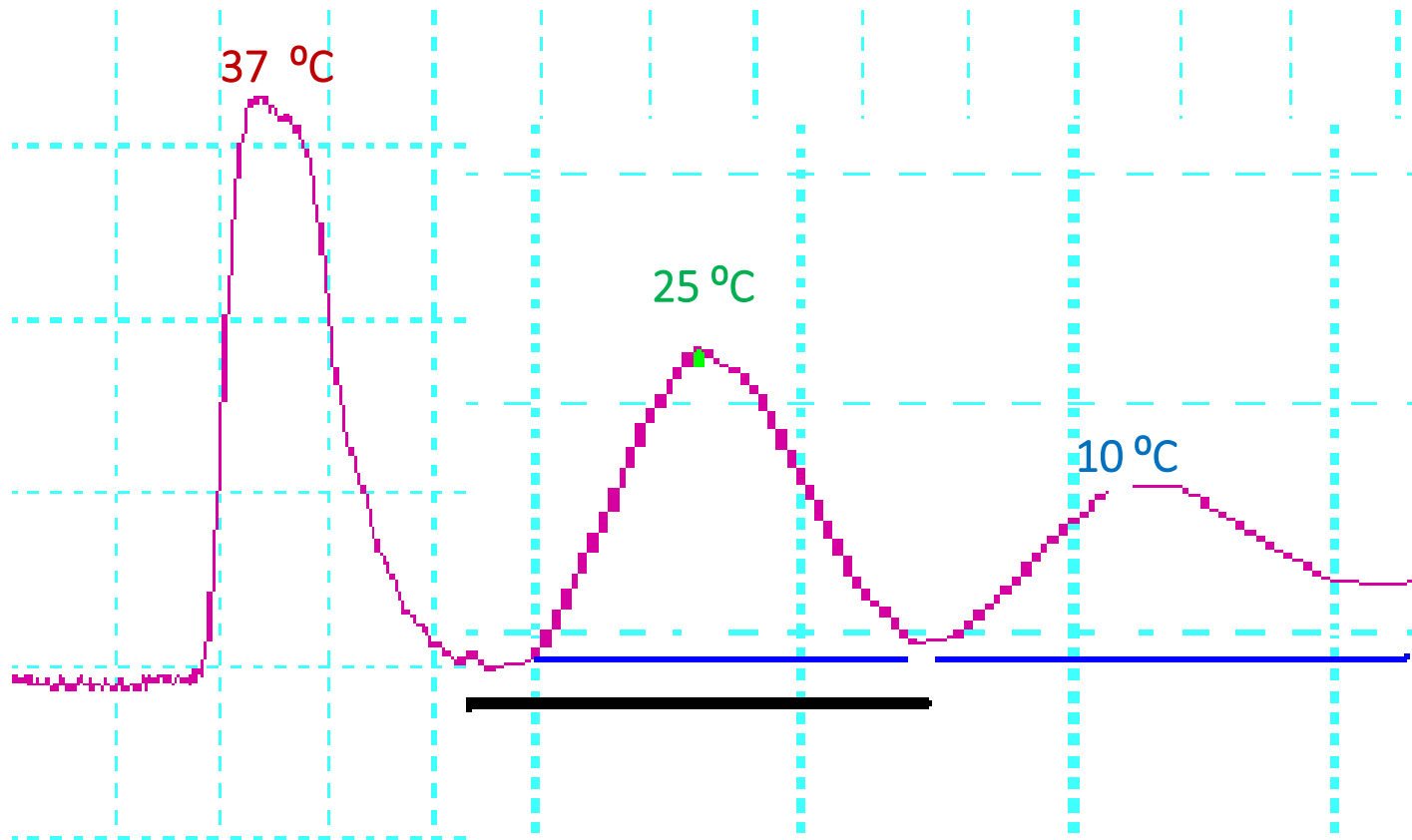
- Treppe effect happens when a muscle begins to contract after a long period of rest, its strength of contraction will gradually increase with every successive stimulus till a plateau is reached.
- Warming Up
- It is believed to be caused by:
 1. The rise in muscle temperature.
 2. Increased concentration of calcium ions in the cytosol

Effect of Temperature on muscle twitch



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

	Low Temp	Room Temp	High Temp
Latent period	Longest	Between	Shortest
Duration of Contraction	Longest	Between	Shortest
Amplitude	Lowest	Between	Highest



Thank you