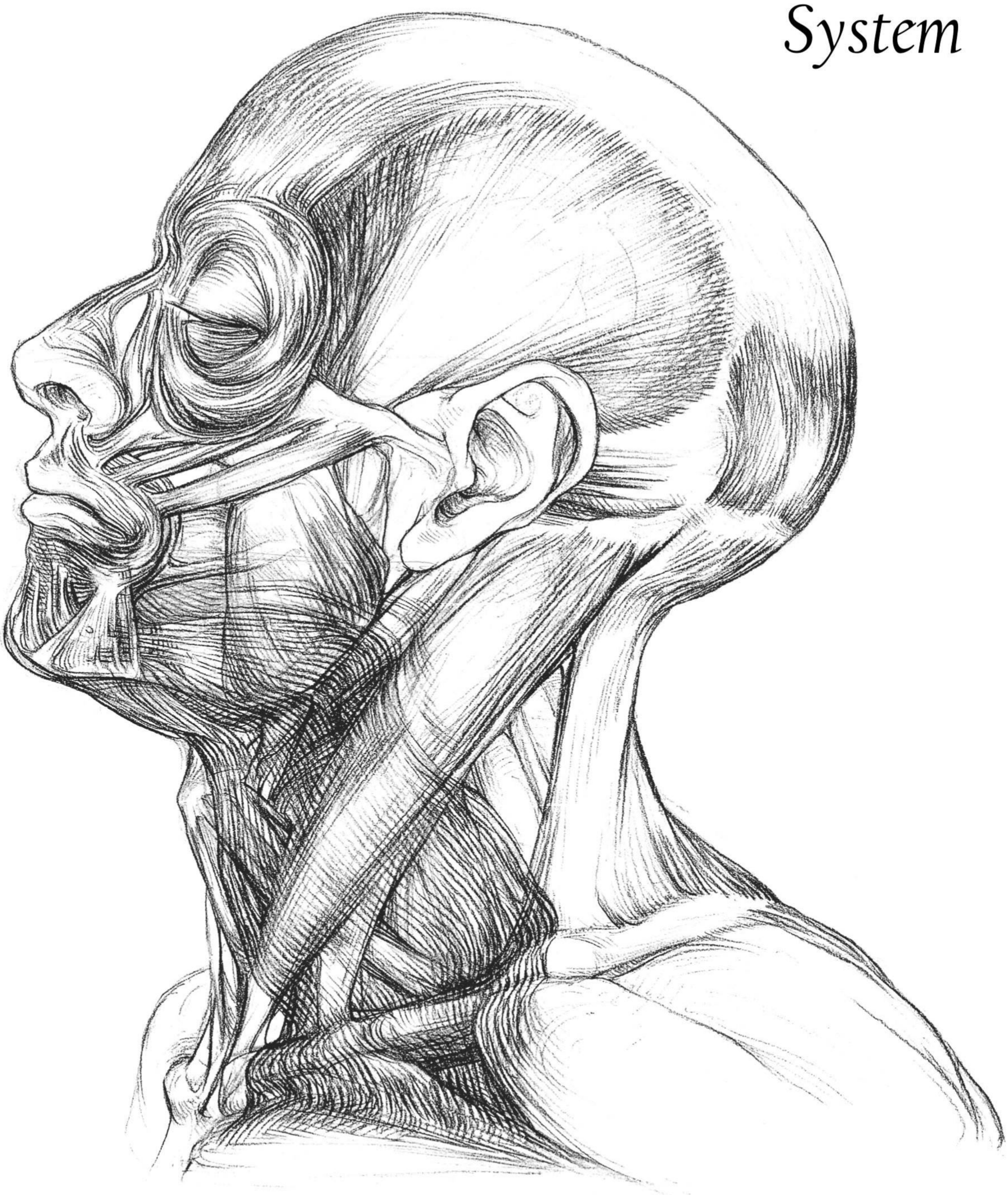
Medical Committee
The University of Jordan

The Skin and MUSCULOSKELETAL System



PHYSIOLOGY

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SHEET ■ DONE BY: **Aseel Al-Khatib**

LECTURE # **lab theory**

By Mohamed F. Abu Alia

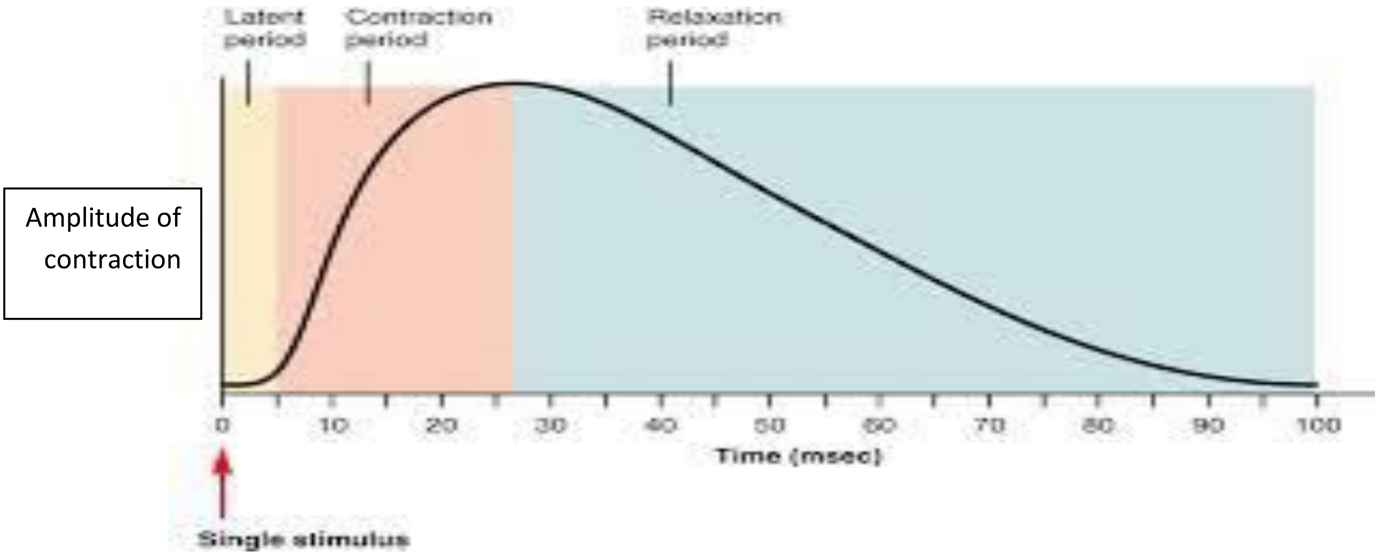
Muscle Physiology

As discussed last time, there are two types of muscle contraction:

1. Isotonic Contraction : No change in tension/ Change in length
2. Isometric Contraction : No change in length

Today we will focus on Isotonic Contraction.

If we have a muscle preparation, with the head of the muscle attached to an L-shaped lever system, the lever system will move during contraction (stimulation) of the muscle depending on the shortening of the muscle fibers (remember that the muscle shortens since we're talking about Isotonic contraction). The long stylus of the lever system (a small stick used as a pen) will go up, and go back down during relaxation. So once you have shortening of that muscle, this will pull the short arm while the long arm is going up and recording the change, and there is a fulcrum (نقطة ارتكاز) for the stylus. This is how we study contraction of muscle preparations in the lab. This movement of the stylus (up and down) which reflects changes in muscle length according to time can be recorded and analyzed. If the muscle is fixed and the speed is zero, you won't be able to record curves in the time vs amplitude graph. As the speed increases, the distance between curves increases and can be recorded using a cylindrical drum (the one we saw in the lab), depending on the relationship between speed, distance and time.

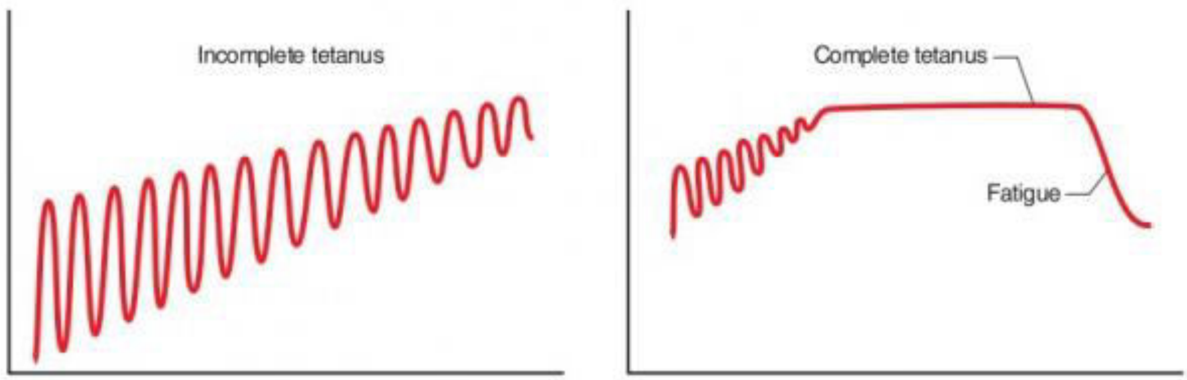


Contraction of the muscle begins after stimulation, when the long stylus rises and the curve begins. The relaxation period begins at the tip of the curve. So each curve represents a contraction and relaxation period. Stimulation begins when the arm of the Drum (the same one we use to record the results) closes an electrical circuit connected to a stimulator. At this point, the speed is almost zero. The time required for the stimulus to cause contraction of the muscle is called the latent period. This single recording (Latent period, contraction and then relaxation) is called a Simple Muscle Twitch.

The concentration of calcium ions in the muscle will begin to increase at the start of the contraction period, and decrease during the relaxation period. During **the latent period,** a series of events will take place and cause the release of calcium ions from the sarcoplasmic reticulum into the sarcoplasm, causing the contraction period to begin (so anything that happens before calcium release is considered in the latent period).

We have an option of introducing a second stimulus in the muscle, by dividing the arm of the drum into two parts which close separate circuits. How will this second stimulus affect the simple muscle twitch?

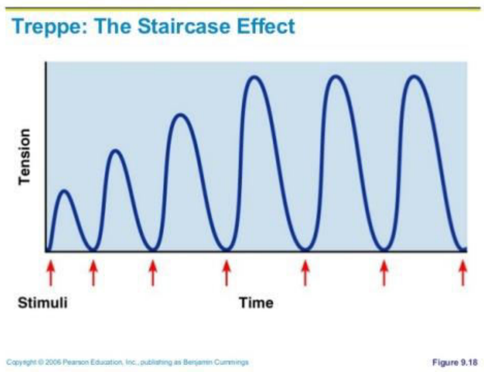
Before answering this question we should first differentiate between the mechanical events we are recording (contraction/ relaxation) and the electrical events (action potential). The electrical events that occur in the muscle start and end during the latent period, which means that the refractory period has taken place in a very short time and ended during the latent period, and the muscle can respond to a second stimulus during contraction or relaxation. This stimulus will cause a second twitch, and **Frequency Summation** will occur. In this type of summation, the time between two stimuli will decrease gradually (more frequent stimuli; instead of 10 stimuli per second, we give 100 stimuli for example) until it is less than the contraction period, causing the muscle to **contract without relaxation**. This is known as **Tetanization** (Also called Incomplete Tetanization when there are short periods of relaxation, or Complete Tetanization when there is constant contraction with no relaxation. All of these are examples of Frequency Summations). Note that we assume that ALL muscle fibers are contracted.



At one point during tetanization, the curve will descend back to the baseline at which it started, and the muscle will not respond to further stimuli. The explanation is that each stimulus will cause the release of neurotransmitter (Acetyl Choline) into the neuromuscular junction. After consecutive stimuli, the concentration of neurotransmitter at the nerve ending will decrease due to consumption for muscle contraction, and we will eventually reach a point where neurotransmitter is depleted and the stimulus will not be transmitted to the muscle. We call this point Fatigue. (Note: the fatigue that occurs during exercise and movement isn't a true Fatigue that is caused by neurotransmitter depletion, it's just muscle pain caused by the accumulation of lactate and increased acidity in muscles due to anaerobic glycolysis).

Treppe phenomenon (staircase effect)

It refers to the constant increase of contraction amplitude following each consecutive stimulus; we have higher amplitude after the second stimulus and so on (assuming there is a short time between stimuli). The reason behind this effect is the increased availability of calcium ions in the sarcoplasm following each stimulus, which increase the probability of Troponin-C binding to calcium ions, more active troponin-C means more interactions with actin filaments thus increasing contraction amplitude. In other words, calcium concentration and amplitude will increase after each stimulus, until we reach a point (after 5-10 stimuli) where calcium ions have achieved equilibrium in the sarcoplasm, and the amount of ions getting pumped out is equal the amount pumped in, and the amplitude remains constant for all the following stimuli. **Treppe phenomenon** is NOT considered a kind of summation.



Note that the results achieved at room temperature (about 20°C) are different from normal body temperature (37°C). We can submerge the muscle preparation in a special solution to change the temperature to 37°**.** With a higher temperature, we will notice that the latent period is shorter, and the contraction and relaxation periods are also shorter with higher amplitudes (shorter muscle twitch with higher amplitude). If we use a cold solution, we will achieve opposite results; longer muscle twitch (longer contraction and relaxation times) with lower amplitude. It is important to know the effects of temperature on muscle contraction, although most preparations are kept at room temperature.

How can we explain the change in contraction speed according to temperature?

At higher temperature, the viscosity (thickness) of fluids in the muscle tissue is lower than that of lower temperatures, which means the sliding of thick and thin filaments in the muscle tissue is easier and faster, due to decreased resistance from the tissue fluids (less energy is required to overcome resistance). Higher temperature also increases calcium concentration, which causes the increase in amplitude. In colder temperatures, the viscosity is high, which means there is more resistance against the sliding of thick and thin filaments, making the muscle twitch longer and amplitude lower due to less calcium concentration.