Properties of muscle

❖ All or None Law:

The all-or-none law is a physiological principle that states that the strength of a response of an excitable tissue (muscle fiber or nerve cell) is not dependent upon the strength of the stimulus. The intensity of response will be graded according to the intensity of the stimulus. If a stimulus is above a certain threshold, a nerve or muscle fiber will fire. The response of a nerve or muscle fiber to a stimulus at any strength above the threshold is the same. Essentially, there will either be a full response or there will be no response at all for an individual neuron or muscle fiber.

♣ Discovery of the All-or-None Law

The all-or-none law was first described in 1871 by an American physiologist Henry Pickering Bowditch. In his descriptions of the contraction of the heart muscle, he explained, "An induction shock produces a contraction or fails to do so according to its strength; if it does so at all, it produces the greatest contraction that can be produced by any strength of stimulus in the condition of the muscle at the time."

While the all-or-none law was initially applied to the muscles of the heart, the Cambridge physiologist Keith Lucas extended the "all-or-none" principle to skeletal muscle and nerve fibres in 1905.

♣ How does the All-or-None Law work?

If a stimulus is strong enough, an action potential occurs and a neuron sends information down an axon away from the cell body and toward the synapse. Changes in cell polarization result in the signal being propagated down the length of the axon.

The action potential is always a full response. There is no such thing as a "strong" or "weak" action potential. Instead, it is an all-or-nothing process. This minimizes the possibility that information will be lost along the way.

This process is similar to the action of pressing the trigger of a gun. A very slight pressure on the trigger will not be sufficient and the gun will not fire. When adequate pressure is applied to the trigger, however, it will fire.

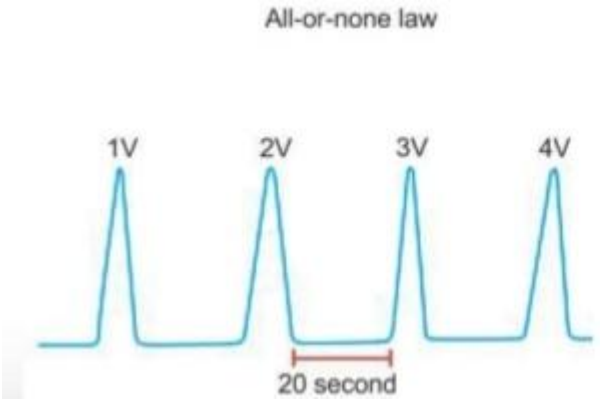
The speed and force of the bullet are not affected by how hard you pull the trigger. The gun either fires or it does not. In this analogy, the stimulus represents the force applied to the trigger while the firing of the gun represents the action potential.

♣ Determining stimulus strength

The body still needs to determine the strength or intensity of a stimulus. It's important to know, for example, how hot a cup of coffee is as you take an initial sip, or to determine how firmly someone is shaking your hand.

In order to gauge stimulus intensity, the nervous system relies on the rate at which a neuron fires and how many neurons fire at any given time. A neuron firing at a faster rate indicates a stronger intensity stimulus. Numerous neurons firing simultaneously or in rapid succession would also indicate a stronger stimulus.

If you take a sip of your coffee and it is very hot, the sensory neurons in your mouth will respond at a rapid rate. A very firm handshake from a co-worker might result in both rapid neural firing as well as a response from many sensory neurons in your hand. In both cases, the rate and number of neurons firing provide valuable information about the intensity of the original stimulus.



❖ What is Chronaxie and Rheobase?

Chronaxie is the minimum time required for an electric current to double the strength of the rheobase to stimulate a muscle or a neuron. Rheobase is the lowest intensity with indefinite pulse duration which just stimulated muscles or nerves. Chronaxie is dependent on the density of voltage-gated sodium channels in the cell, which affect that cell's excitability. Chronaxie varies across different types of tissue: fast-twitch muscles have a lower chronaxie, slow-twitch muscles have a higher one. Chronaxie is the tissue-excitability parameter that permits choice of the optimum stimulus pulse duration for stimulation of any excitable tissue.

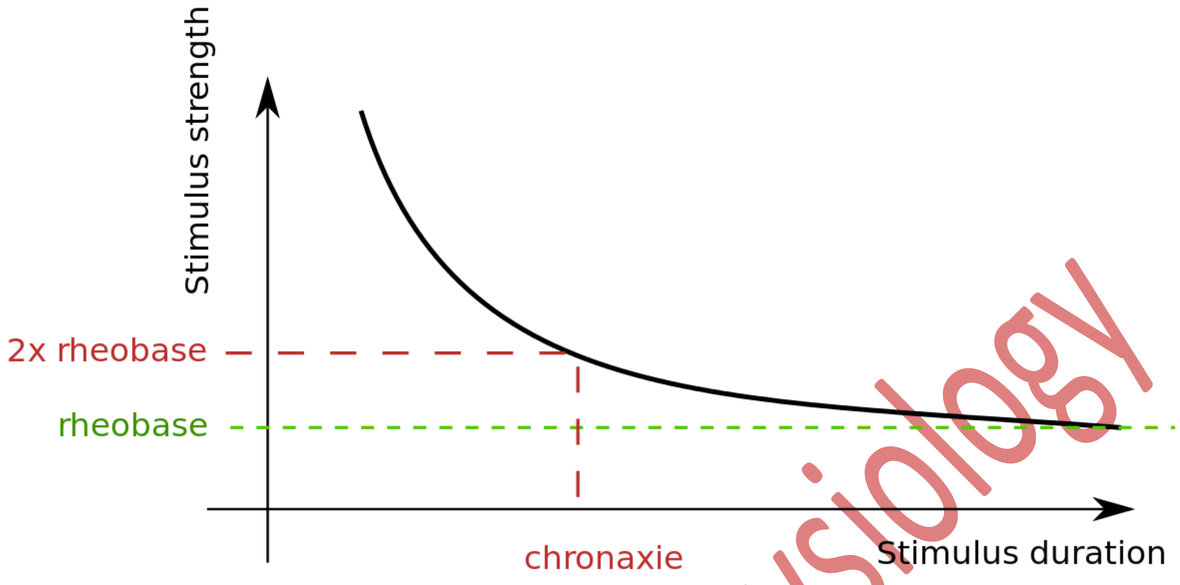
Chronaxie (c) is the Lapicque descriptor of the stimulus pulse duration for a current of twice rheobasic (b) strength, which is the threshold current for an infinitely long-duration stimulus pulse. Lapicque showed that these two quantities (c,b) define the strength-duration curve for current: $I = b(1+c/d)$, where d is the pulse duration.

However, there are two other electrical parameters used to describe a stimulus: energy and charge. The minimum energy occurs with a pulse duration equal to chronaxie. Minimum charge (bc) occurs with an infinitely short-duration pulse. Choice of a pulse duration equal to 10c requires a current of only 10% above rheobase (b). Choice of a pulse duration of 0.1c requires a charge of 10% above the minimum charge (bc).

Rheobase is a measure of membrane potential excitability. In neuroscience, rheobase is the minimal current amplitude of infinite duration (in a practical sense, about 300 milliseconds) that results in the depolarization threshold of the cell membranes being reached, such as an action potential or the contraction of a muscle. In Greek, the root *rhe* translates to "current or flow", and *basi* means "bottom or foundation": thus the rheobase is the minimum current that will produce an action potential or muscle contraction.

Rheobase can be best understood in the context of the strength-duration relationship. The ease with which a membrane can be stimulated depends on two variables: the strength of the stimulus, and the duration for which the stimulus is applied. These variables are inversely related: as the strength of the applied current increases, the time required to stimulate the membrane decreases (and vice versa) to maintain a constant effect. Mathematically, rheobase is equivalent to half the current that needs to be applied for the duration of chronaxie, which is a strength-duration time constant that corresponds to the duration of time that elicits a response when the nerve is stimulated at twice rheobasic strength.

The strength-duration curve was first discovered by G. Weiss in 1901, but it was not until 1909 that Louis Lapicque coined the term *rheobase*. Many studies are being conducted in relation to rheobase values and the dynamic changes throughout maturation and between different nerve fibers. In the past strength-duration curves and rheobase determinations were used to assess nerve injury; today, they play a role in clinical identification of many neurological pathologies, including diabetic neuropathy, CIDP, Machado–Joseph disease, and ALS.



❖ Indefatigability:

Indefatigability is the properties of nerve fiber. It indicates the incapable of being tired out; not yielding to fatigue; untiring. In the nerve muscle preparation, if the nerve fiber is stimulated repeatedly, then after a certain period the muscle fails to give any response. Now if the nerve is isolated from the muscle and placed on afresh muscle, then application of stimulus will excite the muscle. This shows that nerve is not fatigued.

Indefatigable comes from Latin indefatigabilis, formed from the prefix in- "not" plus defatigare "to tire out." Here the prefix de- means "entirely." You can remember the root fatigare because it sounds so much like the English fatigue.

❖ Beneficial effect:

Beneficial effect is obtained when the second stimulus falls after the complete relaxation of the first response. Super position or super imposition occurs when the second stimulus falls during the relaxation period of the 1st curve. Summation occurs when the second stimulus falls during the contraction period of the previous curve.

When multiple stimuli of same strength are applied at short intervals to the nerve muscle preparation, then an increase in the height of contraction is observed. This is called Treppe or Stair-case Phenomenon. This is due to the beneficial effect - decrease in viscosity, mild increase in temperature and increase in the level of calcium ions. Here each successive contraction is recorded separately (there is complete relaxation). Here each successive contraction is higher than the previous one due to beneficial effect.