There is a great deal to learn about muscle contraction based on the long history of research on in vitro animal models where entire muscles have been removed and connected end-to-end to force transducers. The muscle preparations are then artificially stimulated to cause a contraction, or repeatedly stimulated causing contractions with different durations of recovery. Contractions can also be induced different high frequencies and intensities of stimulation to assess aspects of summation and eventual contractile failure. However, despite these comments, I hope you are aware, and immediately concerned at the degree to which this model of researching muscle contraction differs to in vivo human muscle contraction. What is different? I will leave that for you to decide at this time, though I will provide some answers within this Topic.

A rapid and short muscle contraction is referred to as a muscle twitch. The twitch results from a single action potential received by the muscle, followed by relaxation. The physiology of the muscle twitch is studied using whole muscles extracted from animals that are artificially stimulated using short duration bursts of low voltage current. Such artificial laboratory procedures are referred to as in vitro. The force-time profile of the twitch is measured and the graphic presentation of this force-time curve is called a myogram.

Figure 1 presents the phases of the muscle twitch for a generic muscle type. Note the 2 to 3 ms latent period, or delay, between the action potential stimulus and the start of contraction, and the two phases of contraction; contraction and relaxation. Figure 2 presents the duration of a muscle twitch for representative muscles that are either comprised mainly of SO, FOG and FG motor units.

Figure 2. Comparison of twitch tension and velocity between slow, fast oxidative and fast glycolytic muscle samples.
The Muscle Twitch

This muscle twitch preparation has been a useful model for studying the physiology of muscle contractions, and especially of the force profile of repeated muscle stimulation and different stimulation frequencies. Although the muscle twitch differs to the in-vivo recruitment of motor units, the results of the muscle twitch experiments can be applied to motor unit recruitment, where the muscle twitch is somewhat synonymous to the all or none contraction of a motor unit.

**Summation**

When a second, or continued stimulus is received by muscle prior to complete recovery of the initial muscle contraction, the force output of the muscle twitch increases. To a certain extent, the force of the second contraction is partially summed to the force of the prior contraction, and hence the term **summation** to describe this phenomenon. Two summed muscle twitches are presented in Figure 3. Interestingly, this response means that the muscle twitch from one stimulus is not a complete or full contraction. This is true, as an artificial electrical stimulus to an in-vitro muscle preparation needs to be large (higher in voltage) to be able to recruit all muscle fibers of the muscle. Of course, this differs to the motor unit recruitment response of in-vivo muscle, which results in a maximal motor unit contraction for every stimulation, and where added muscle force results from added motor unit recruitment. Thus, view the muscle twitch response from multiple stimuli as representative of what would happen if two or more motor units are recruited consecutively. Again, the result is an increased force output.

For increased rates of stimulation, the muscle twitch continues to increase through summation, revealing a staircase, or **treppe effect**, until the muscle twitch force no longer increases with increased stimulation frequency. This fused twitch response is termed **tetanus**.

![Figure 3. Muscle twitch summation leading to conditions called treppe and tetanus.](image)

**Synchronous vs. Asynchronous Motor Unit Recruitment**

As explained above, the repeated stimulation of motor units at different times leads to summation and increased force output. The different absolute times of this stimulation causes the stimulation profile to be **asynchronous**, and hence is referred to as asynchronous stimulation. When this concept is applied to motor unit recruitment, it is referred to as **asynchronous recruitment**. This phenomenon explains how multiple
The Muscle Twitch

motor units can be recruited, yet the contraction of muscle in vivo responds in a more smooth contraction and force-time profile.

Interestingly, muscle physiologists have shown that with resistance training, there is neurological evidence of increased synchronous motor unit recruitment. The motor unit recruitment is still overwhelmingly asynchronous, but with training this asynchronous response decreases slightly. As more and motor units are recruited consecutively, there is increased muscular force development, and therefore greater strength. This response will be discussed again in the Topics on resistance training, but an accepted theory is that such increased synchronous motor unit recruitment can explain the initial strength gains from strength training prior to muscle hypertrophy.

Glossary Words

**muscle twitch** is the single contraction of a muscle in response to artificial stimulation.

**artificial stimulation** involves the electrical stimulation and subsequent contraction of muscle resulting from a non-biological voltage source.

**in vitro** refers to a preparation contrived outside of the body.

**myogram** is the force profile resulting from a muscle twitch.

**in-vivo** refers to the living condition of tissue within an organism.

**summation** is the increase in contractile force resulting from two or more closely sequenced stimulations of muscle or motor units.

**treppe effect** is the pattern of increasing contractile force resulting from closely sequenced repeated stimulations of muscle or motor units.

**tetanus** is the relatively steady force output from muscle during high frequency artificial stimulation.

**asynchronous** refers to inconsistent time intervals.

**synchronous** refers to occurring at the same time.

**asynchronous motor unit recruitment** is the stimulation of motor units that occurs at inconsistent time intervals.

**synchronous motor unit recruitment** is the stimulation of motor units at the same time.