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Properties of muscle

❖ Summation:

If an additional action potential were to stimulate a muscle contraction before a previous muscle twitch had completely relaxed then it would sum onto this previous twitch increasing the total amount of tension produced in the muscle. This addition is termed **summation**. Summation can be achieved by increasing the frequency of stimulation, or by recruiting additional muscle fibers within a muscle.

The rate at which a motor neuron fires action potentials affects the tension produced in the skeletal muscle. If the fibers are stimulated while a previous twitch is still occurring, the second twitch will be stronger. This response is called **wave summation**, because the excitation-contraction coupling effects of successive motor neuron signaling is summed, or added together. At the molecular level, summation occurs because the second stimulus triggers the release of more Ca^{++} ions, which become available to activate additional sarcomeres while the muscle is still contracting from the first stimulus. Summation results in greater contraction of the motor unit.

Summation, in physiology, the additive effect of several electrical impulses on a neuromuscular junction, the junction between a nerve cell and a muscle cell. Individually the stimuli cannot evoke a response, but collectively they can generate a response. Successive stimuli on one nerve are called **temporal summation**; the addition of simultaneous stimuli from several conducting fibres is called **spatial summation**.

Within a muscle summation can occur across motor units to recruit more muscle fibers, and also within motor units by increasing the frequency of contraction.



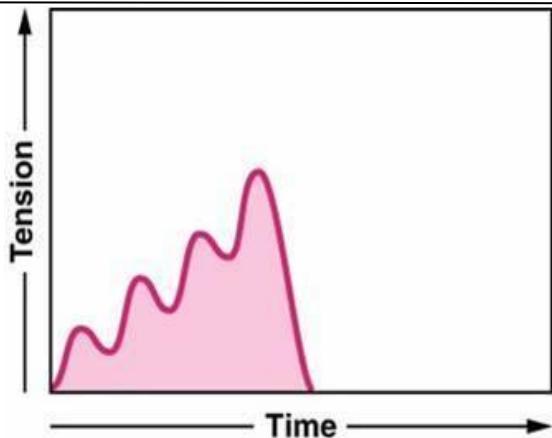
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*** Multiple fiber summation:**

When a weak signal is sent by the central nervous system to contract a muscle, the smaller motor units, being more excitable than the larger ones, are stimulated first. As the strength of the signal increases, more (and larger) motor units are excited. The largest motor units have as much as 50 times the contractile strength as the smaller ones; thus, as more and larger motor units are activated, the force of muscle contraction becomes progressively stronger. A concept known as the size principle allows for a gradation of muscle force during weak contraction to occur in small steps, which become progressively larger as greater amounts of force are required.

*** Frequency summation**

For skeletal muscles, the force exerted by the muscle can be controlled by varying the frequency at which action potentials are sent to muscle fibers. Action potentials do not arrive at muscles synchronously, and, during a contraction, only a certain percentage of the fibers in the muscle will be contracting at any given time. In a typical circumstance, when a human is exerting as much muscular force as they are consciously able, roughly one-third of the fibers in that muscle will be contracting at once. This relatively low level of contraction is a protective mechanism to prevent damage to the muscle tissue and attaching tendons and structures.



(a) Wave summation

Figure: Repeated twitch contractions, where the previous twitch has not relaxed completely are called a summation. The excitation-contraction coupling effects of successive motor neuron signaling is added together which is referred to as wave summation. The bottom of each wave, the end of the relaxation phase, represents the point of stimulus.

❖ **Tetanus:**

Tetanus is prolonged contraction without relaxation and results from rapidly repeating stimulation to a particular muscle before the muscle has a chance to relax at all and decrease of tension between stimuli cannot be detected.

If the frequency of action potentials generated increases to such a point that muscle tension has reached its peak and plateaued and no relaxation is observed then the muscle contraction is described as tetanus.

If the frequency of motor neuron signaling increases, summation and subsequent muscle tension in the motor unit continues to rise until it reaches a peak point. The tension at this point is about three to four times greater than the tension of a single twitch, a state referred to as **incomplete tetanus**. During incomplete tetanus, the muscle goes through quick cycles of contraction with a short relaxation phase for each. If the stimulus frequency is so high that the relaxation phase disappears completely, contractions become continuous in a process called **complete tetanus**.



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Mechanical response generated when a train of closely spaced stimuli is applied to muscle. An **unfused tetanus** occurs when the stimulation rate produces partial summation of individual twitches. A **fused tetanus** occurs when the stimulation rate produces full summation of individual twitches.

Tetanus is a serious disease caused by a bacterial toxin that affects your nervous system, leading to painful muscle contractions, particularly of your jaw and neck muscles. Tetanus can interfere with your ability to breathe and can threaten your life. Tetanus is commonly known as "lockjaw."

Thanks to the tetanus vaccine, cases of tetanus are rare in the developed countries. But the disease remains a threat to those who are not up to date on their vaccinations. It is more common in developing countries.

During tetanus, the concentration of Ca^{++} ions in the sarcoplasm allows virtually all of the sarcomeres to form cross-bridges and shorten, so that a contraction can continue uninterrupted (until the muscle fatigues and can no longer produce tension).

♣ Symptoms of tetanus:

Signs and symptoms of tetanus appear anytime from a few days to several weeks after tetanus bacteria enter your body through a wound. The average incubation period is seven to 10 days.

Common signs and symptoms of tetanus include:

- Spasms and stiffness in your jaw muscles (trismus)
- Stiffness of your neck muscles
- Difficulty swallowing
- Stiffness of your abdominal muscles
- Painful body spasms lasting for several minutes, typically triggered by minor occurrences, such as a draft, loud noise, physical touch or light.



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Possible other signs and symptoms include:

- Fever
- Sweating
- Elevated blood pressure
- Rapid heart rate

♣ Causes of tetanus:

Tetanus is caused by a toxin made by spores of bacteria, Clostridium tetani, found in soil, dust and animal feces. When the spores enter a deep flesh wound, they grow into bacteria that can produce a powerful toxin, tetanospasmin. The toxin impairs the nerves that control your muscles (motor neurons). The toxin can cause muscle stiffness and spasms — the major signs and symptoms of tetanus.

Nearly all cases of tetanus occur in people who have never been vaccinated or in adults who haven't kept up with their 10-year booster shots. You can't catch tetanus from a person who has it.

♣ Risk factors of tetanus:

The following increase your likelihood of getting tetanus:

- Failure to get vaccinated or to keep up to date with booster shots against tetanus
- An injury that lets tetanus spores into the wound
- A foreign body, such as a nail or splinter

Tetanus cases have developed from the following:

- Puncture wounds — including from splinters, body piercings, tattoos and injection drugs
- Gunshot wounds
- Compound fractures
- Burns



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- Surgical wounds
- Injection drug use
- Animal or insect bites
- Infected foot ulcers
- Dental infections
- Infected umbilical stumps in newborns born of inadequately vaccinated mothers

*** Prevention of tetanus:**

You can easily prevent tetanus by being vaccinated.

The primary vaccine series

The tetanus vaccine usually is given to children as part of the diphtheria and tetanus toxoids and acellular pertussis (DTaP) vaccine. This vaccination provides protection against three diseases: a throat and respiratory infection (diphtheria), whooping cough (pertussis) and tetanus.

The DTaP vaccine is a series of five shots, typically given in the arm or thigh to children at ages:

- 2 months
- 4 months
- 6 months
- 15 to 18 months
- 4 to 6 years

The booster

A booster of the tetanus vaccine is typically given in combination with a booster of diphtheria vaccine (Td). In 2005, a tetanus, diphtheria and pertussis (Tdap) vaccine was approved for use in teens and adults under age 65 to ensure continuing protection against pertussis, too.



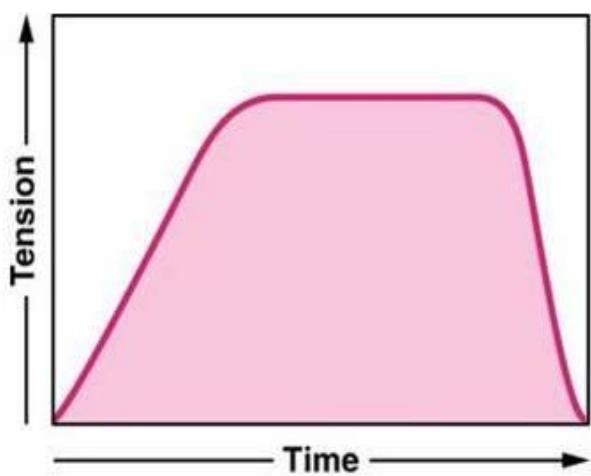
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It is recommended that adolescents get a dose of Tdap, preferably between the ages of 11 and 12, and a Td booster every 10 years thereafter. If you have never received a dose of Tdap, substitute it for your next Td booster dose and then continue with Td boosters.

If you are traveling internationally, particularly to a developing country where tetanus might be common, make sure your immunity is current.

To stay up to date with all of your vaccinations, ask your doctor to review your vaccination status regularly.

If you were not vaccinated against tetanus as a child, see your doctor about getting the Tdap vaccine.



(b) Tetanus

Figure: If the frequency of these contractions increases to the point where maximum tension is generated and no relaxation is observed then the contraction is termed a tetanus.