

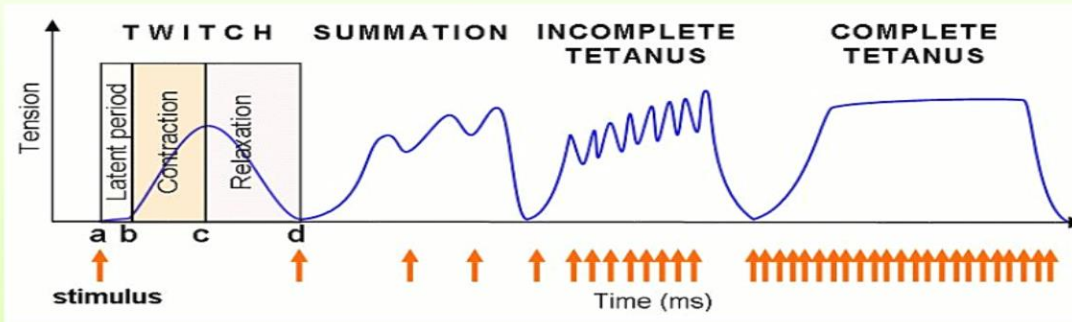
1st Year Medical Students PHYSIOLOGY (Lecture 17) (SUMMATION AND TETANIZATION)

By

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Tetanization



Simple Muscle Twitch (SMT)

Definition:

It is the mechanical response of a muscle fiber or whole skeletal muscle to a single action potential.

An example of a skeletal muscle connected to its somatic motor nerve that is commonly used in practical work is the **gastrocnemius muscle-sciatic nerve preparation of the frog** using Kymograph apparatus.



Phases of SMT

Phases of SMT:

It is formed of 3 phases:

(1) Latent period:

Definition: it is the time between application of the stimulus and start of contraction phase.

Duration: It is **0.01 second**.

Cause: In case of **indirect stimulation** → it is consumed at neuromuscular transmission of nerve impulse till development of mechanical response and conduction of the response to the recording drum.

(2) Contraction phase:

Definition: it is the phase at which shortening of the muscle occurs in isotonic contraction or its tension increases in isometric contraction.

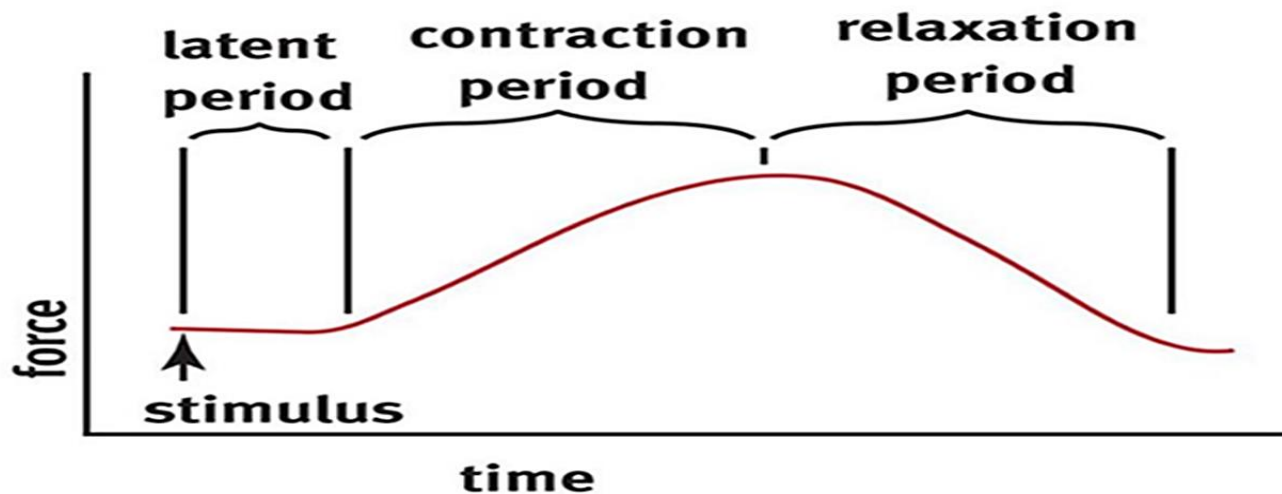
Duration: It is **0.04 second**.

(3) Relaxation phase:

Definition: it is the phase at which the length of the muscle returns to its resting length or its tension drops again.

Duration: It is **0.05 second**. Its duration is longer than the contraction phase.

The whole duration of SMT in case of frog's gastrocnemius muscle is 0.1 second.



Factors affecting SMT

1-Effect of Temperature:

✓ **Warming:**

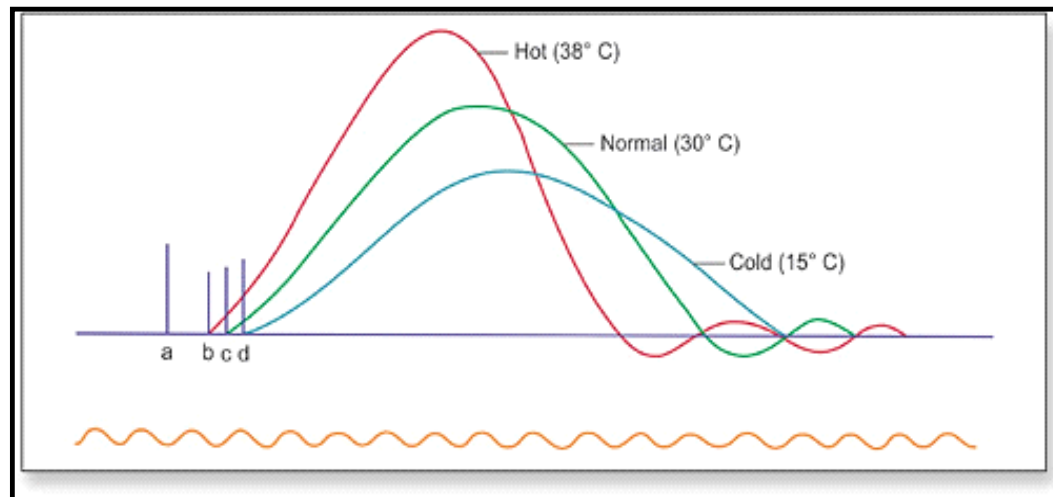
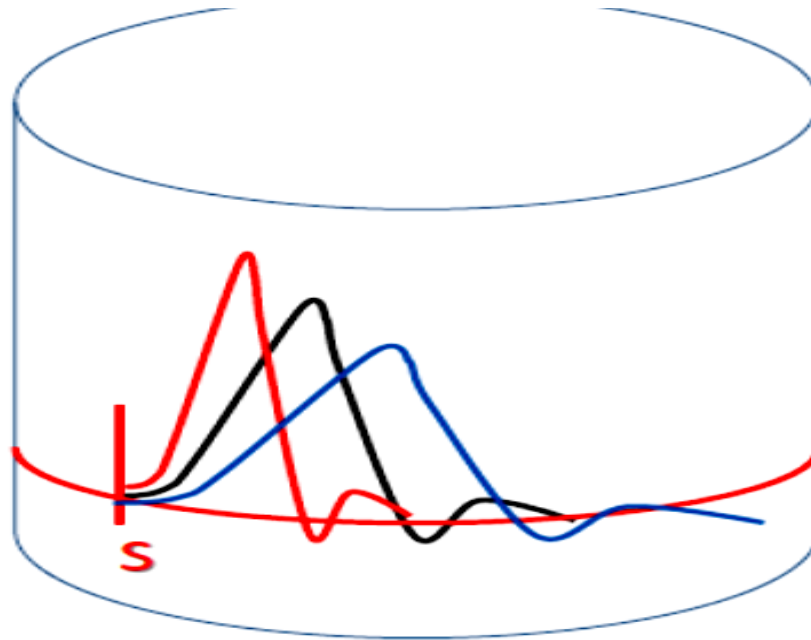
- Decreases all phases of SMT indicating acceleration of the SMT (shortening of its duration).
- Increases the strength (amplitude) of muscle contraction.

Cause;

- a) Increased enzymatic activity.
- b) Decreased viscosity of sarcoplasm leading to easy sliding of actin and myosin.

✓ **Cooling** Leads to the reverse.

Excessive heating > 45 °C → leads to damage or denaturation of muscle proteins → **heat contracture or heat rigor** that is **irreversible** maintained shortening (stiffing) of the muscle due to excessive heating.



Effect of temperature on SMT

2-Effect of Fatigue:

Definition:

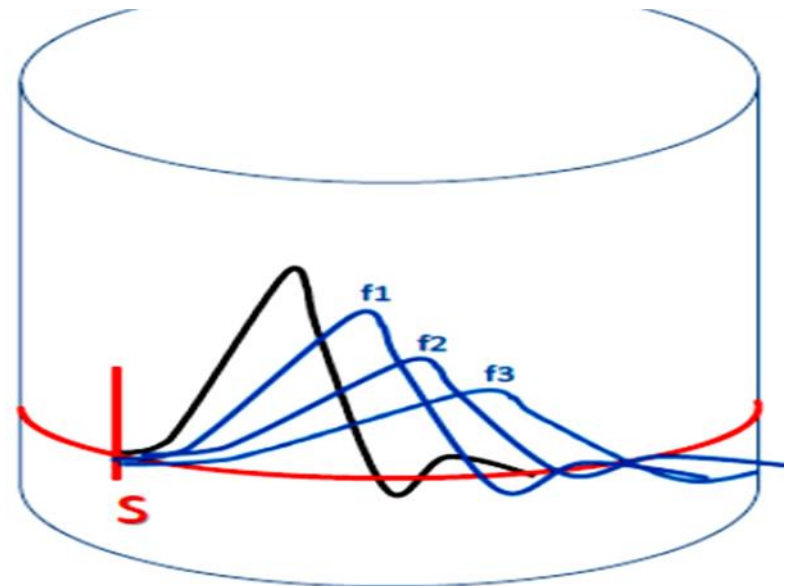
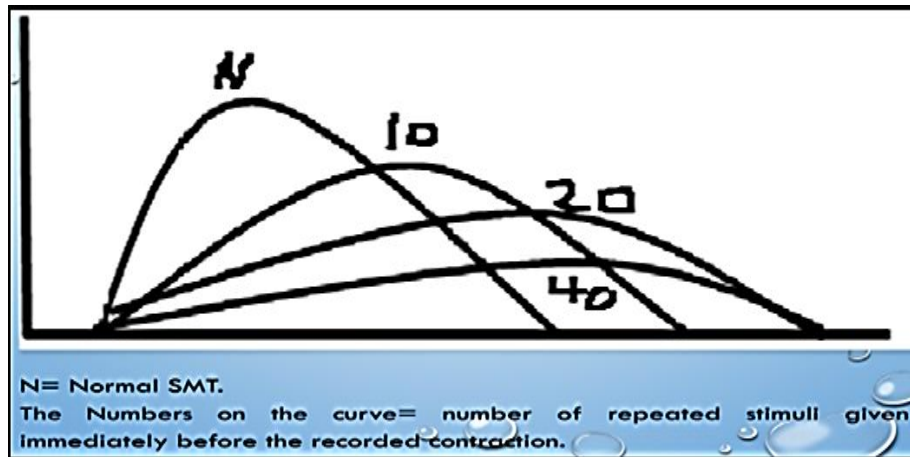
Transient and recoverable reduction in the force of muscle contraction.

Cause:

It is due to excessive repeated stimulation of the muscle.

Effects:

Gradual decrease in strength of contraction and increase in duration of SMT (like cooling).



Types and causes of Fatigue

1-Motor end plate fatigue (MEP fatigue):

It occurs in case of **indirect repeated stimulation** of skeletal muscle through **its somatic motor nerve**.

Cause: It is due to **depletion of ACh**.

N.B. the nerve never gets fatigued.

2-Muscle fatigue:

It occurs in case of **direct repeated stimulation** of the muscle itself.

Cause:

Depletion of the energy stores (ATP, CP and glycogen) and accumulation of metabolites (e.g. lactic acid).

N.B. Fatigue at **MEP** occurs **earlier** than fatigue at **muscle**.

Evidence that MEP fatigue occurs before muscle fatigue:

- 1-Nerve muscle preparation is repeatedly stimulated through nerve till development of fatigue.
- 2-The electrodes are rapidly transferred to stimulate the fatigued muscle directly to bypass the MEP.
- 3-The strength of muscle contraction is regained indicating that the early site of fatigue is the MEP not muscle fibers.
- 4-If the muscle is repeatedly stimulated directly afterwards >> the strength of contraction will decrease indicating late occurrence of fatigue in muscle itself.

N.B.

Physiological contracture :

- **Definition:** It is a state of **reversible** sustained muscle contraction not initiated by action potential.
- **Cause:**

It occurs when the muscle is overworked or fatigued.....depletion of ATP needed for relaxation. Just rest leads to recovery.

3-Initial length of the muscle:

Starling's law:

- ✓ The strength of muscle contraction in isotonic contraction (or developed tension in isometric contraction) is directly proportional within limits to the initial length of the muscle.
- ✓ Inside the body, the resting length of muscles is the length that gives maximal strength of contraction in case of isotonic contraction (or maximal tension in case of isometric contraction), and either an increase or decrease in this length would reduce the force of contraction or developed tension.

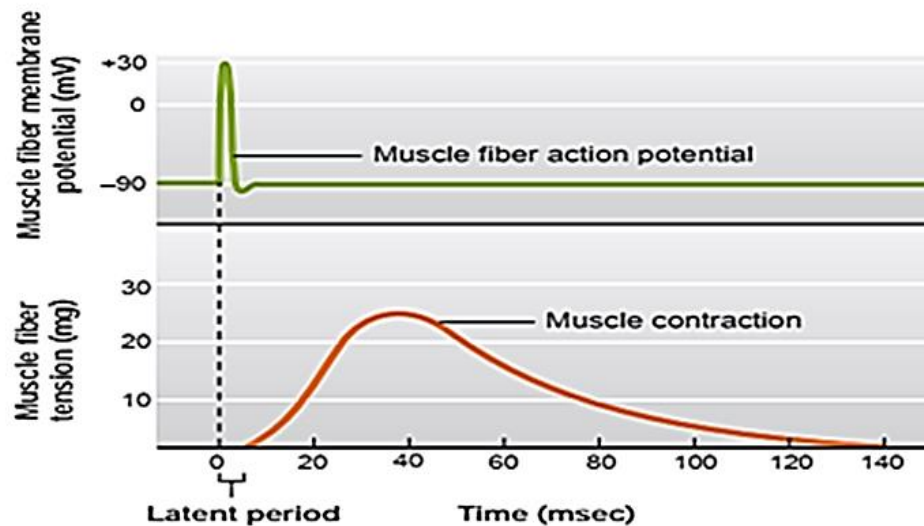
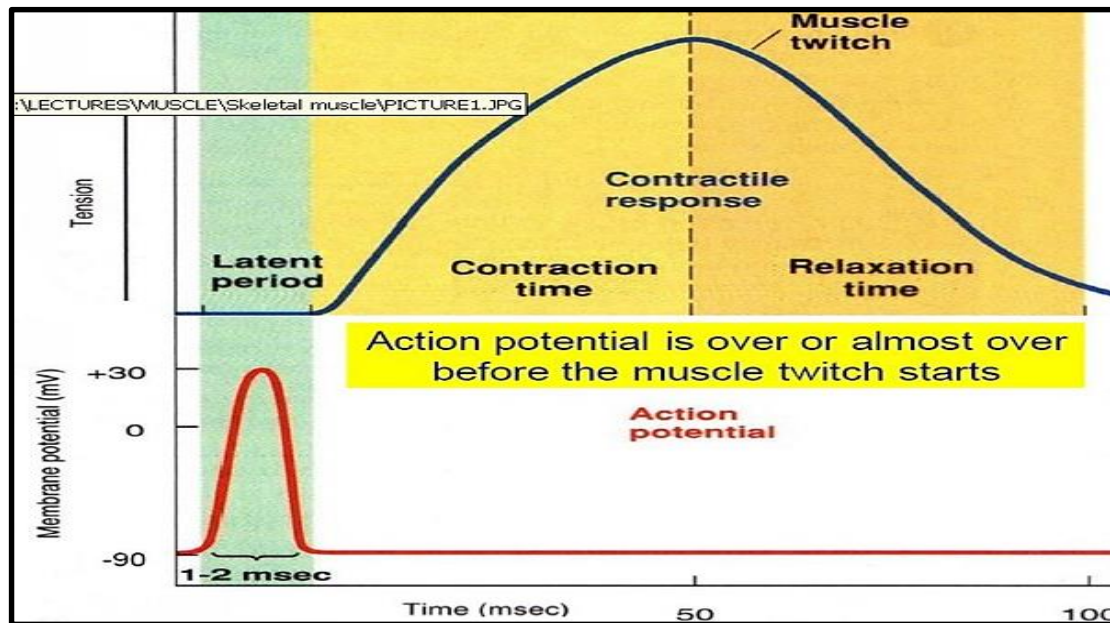
4-Type of skeletal muscle fibers:

Type I fibers: Slow and longer SMT.

Type IIB fibers: Rapid and short SMT.

Effect of Two Successive Stimuli

- A single action potential in a skeletal muscle fiber lasts only 1 to 2 msec but the twitch may last for 100 msec.
- The action potential (AP) in the skeletal muscle is **very short** and **occupies** the **latent period (LP)**.
- So, the muscle **regains** its excitability completely **just after** the beginning of contraction and **can respond to a second stimulus by another action potential**.
- The electric changes (action potentials) of the two successive stimuli can't summate while the mechanical responses can summate to produce stronger contraction.
- The stimuli applied should be **maximal** to stimulate **all motor units in the muscle**.



The effect of two successive stimuli depends on the time of application of the second stimulus as follows:

1-If the second stimulus (S_2) falls during the **latent period** of S_1 twitch → **ineffective** and we get the **SMT of S_1 ONLY**.

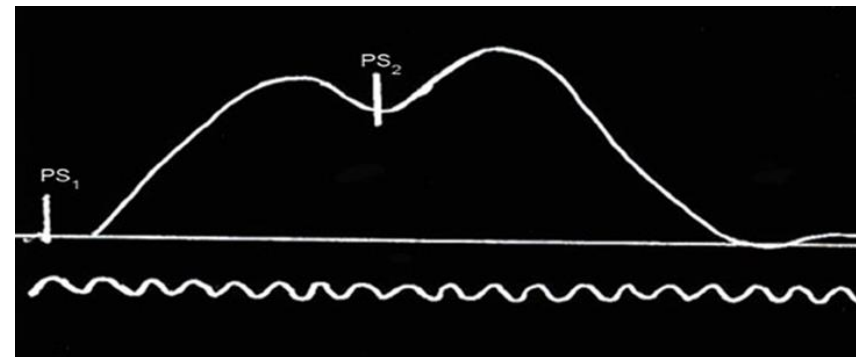
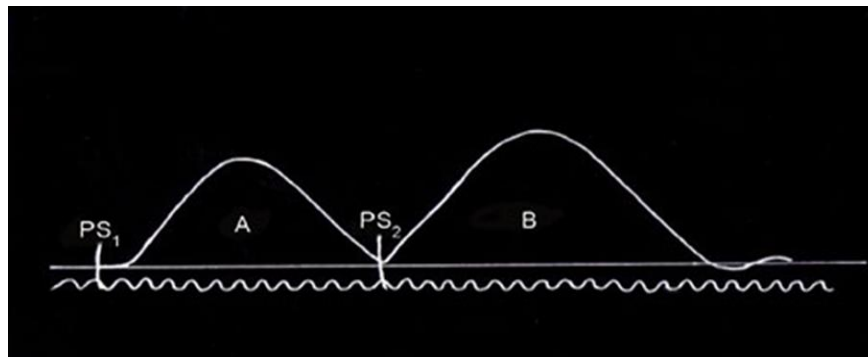
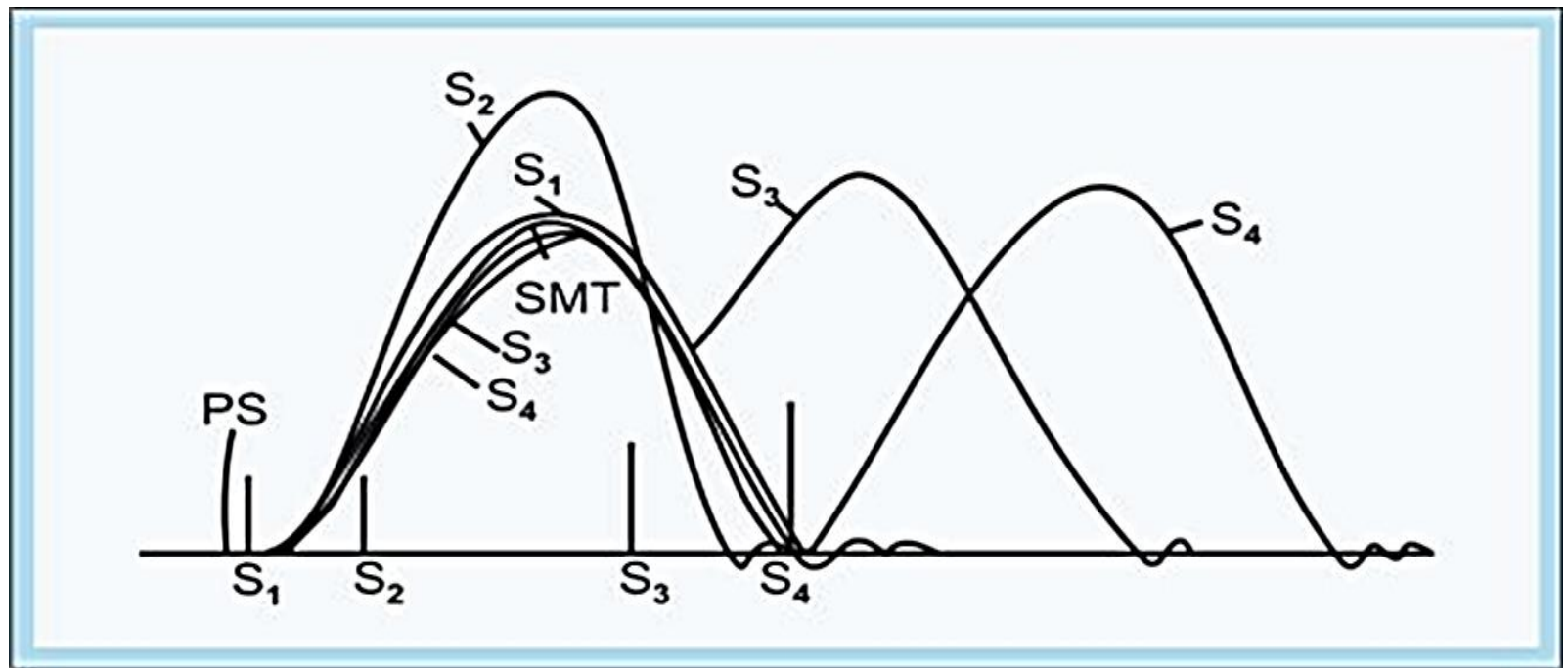
2-If S_2 falls during the **contraction phase** of S_1 twitch → a **stronger contraction** is obtained **due to summation of the mechanical responses** of the two stimuli; **Mechanical summation** (electric responses **never** summate).

3-If S_2 falls during the **relaxation phase** of S_1 twitch → **incomplete relaxation** of the first twitch then the muscle passes immediately into a **second stronger contraction** → **Curve with two summits**.

4-If S_2 falls after at the **end of relaxation phase** of S_1 twitch → **two successive complete twitches** are obtained, the second is usually **stronger** than the first.

N. B.

The **stronger contraction** (by the second stimulus) is produced **due to better physiologic conditions inside the muscle** (i.e. warming and increased Ca^{2+} release from SR) caused by the first contraction.



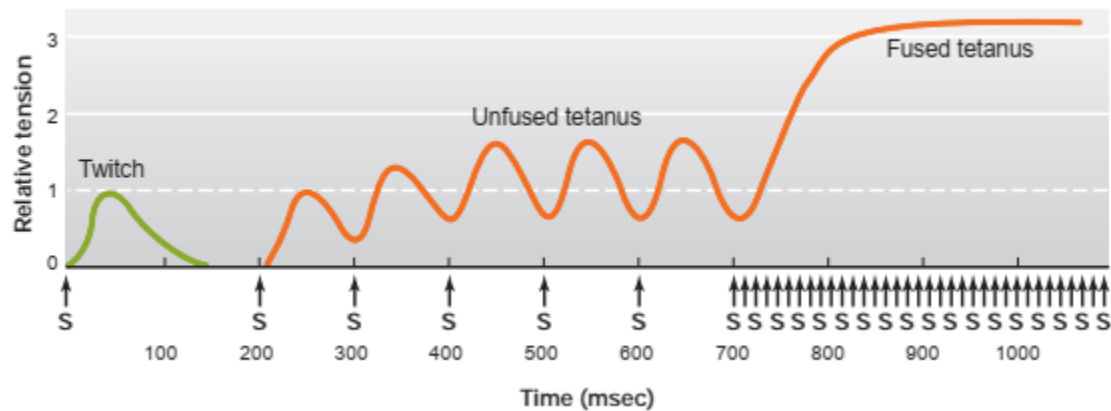
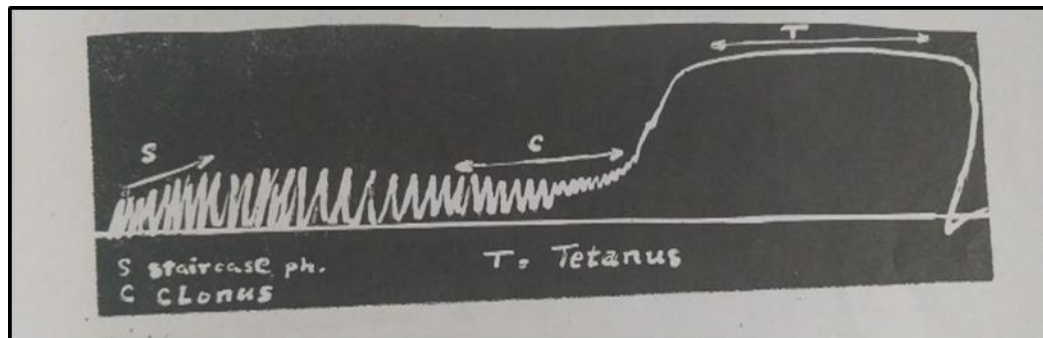
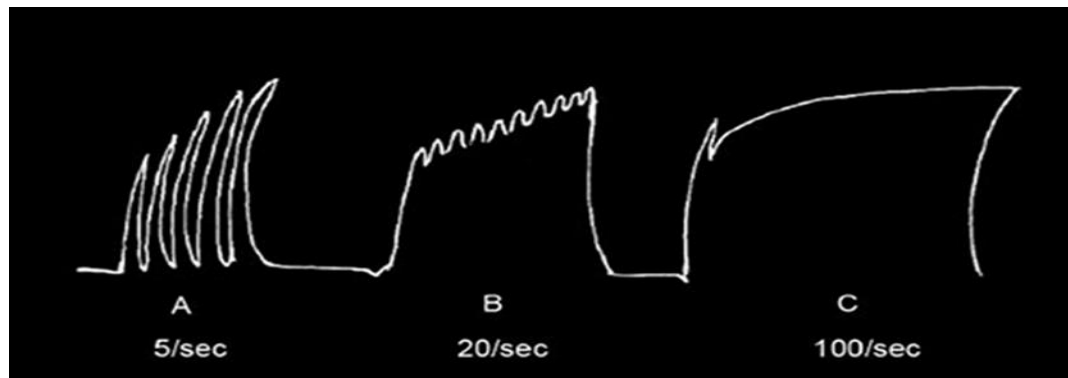
Effect of two successive stimuli on SMT

Effect of Repeated Successive Stimuli

- The effect of repeated successive stimuli **depends** on the **FREQUENCY** (i.e. number of stimuli/second) which **determines** the relation of the time of each stimulus to the contractile response of the preceding one.
- **The following effects are obtained:**
 - 1-If each stimulus **falls** immediately **after complete relaxation** of the preceding twitch → **separate twitches**; the first few show gradually increasing strengths (i.e. **staircase or treppe phenomenon**).
 - 2-If each stimulus **falls during the relaxation** phase of the preceding twitch → **unfused or incomplete tetanus (i.e. clonus)** → in which the **muscle partially relaxes** after each contraction. The **number of summits equals the number of stimuli (i.e. the frequency)**.

3-If each stimulus **falls during the contraction** phase of the preceding twitch → **continuous contraction of the muscle (i.e. fused or complete tetanus)** is obtained. **Relaxation** occurs **only** when the stimuli are stopped.

The frequency (i.e. number of stimuli) can **ONLY** be known from the **number of APs recorded** from the muscle **during fused or complete tetanus**, as electrical impulses can't be summated.



Effect of repeated successive stimuli on SMT.

