



2- MUSCLE PHYSIOLOGY - II

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The simple muscle twitch

Definition: It is the response of the muscle to a single maximal stimulus and consists of:

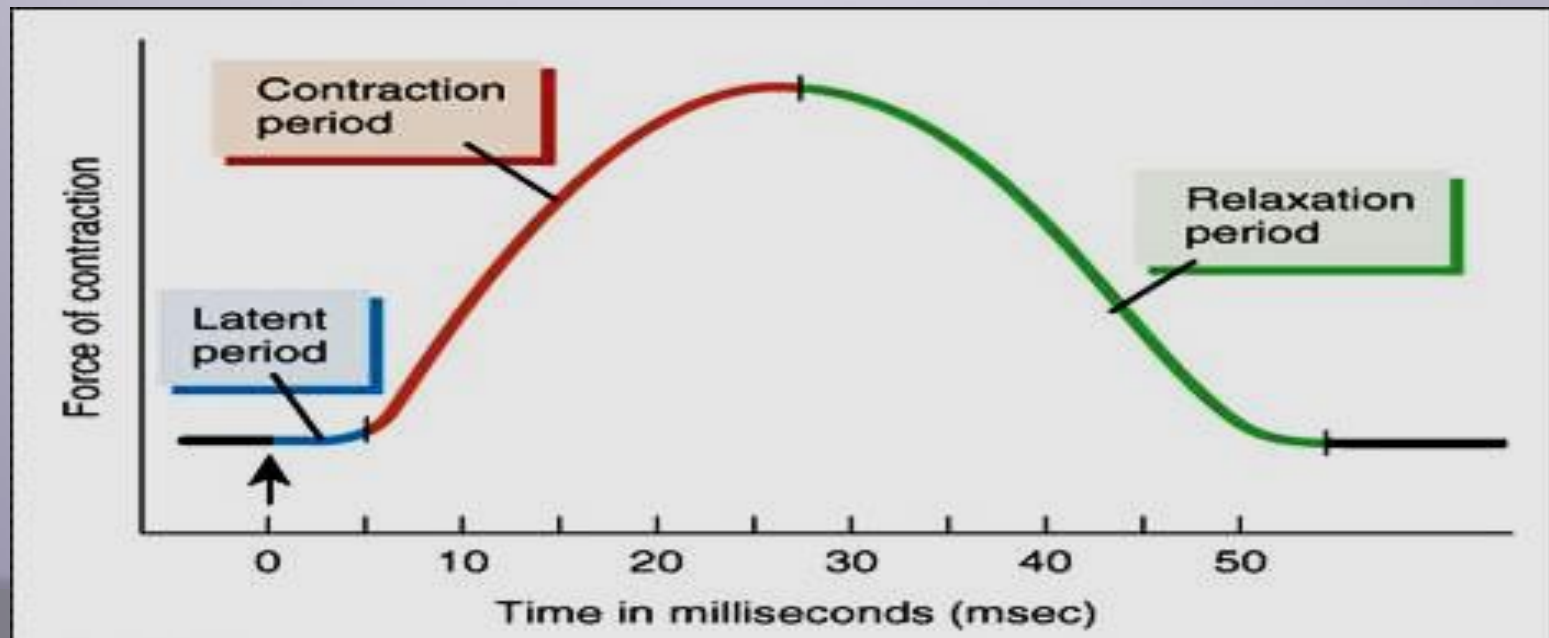
1) Latent period: -It is the time between time of stimulus & response.

-About 0.01 second duration. - Due to: 1- conduction of impulse in nerve 2- production of MEP potential. 3-conduction of impulse in the muscle. 4- contraction and 5- the time of recording.

2) Contraction period: during it the muscle contracts either isometrically or isotonicly.(0.04 sec.)

3) Relaxation period: the muscle relaxed (= 0.05 sec. In isotonic relaxation).

N.B.: The simple muscle twitch can be studied in the nerve muscle preparation (siatic – gastrocnemius frog muscle).



Factors affecting the simple muscle twitch:

1-Type of muscle: there are 2 types of muscle fibers:

Red muscle fibers	White (pale) muscle fibers
1- Of type I & slow fibers.	- of type II fibers & fast fiber
2- Rich in myoglobin (red)	- poor in myoglobin (pale)
3-fibres are small in size	- the fibers are large in size
4-supplied by small, slow nerve	- supplied by large rapid nerve
5- More blood supply	- less blood supply
6-Contain large number of mitochondria and depend on aerobic metabolism	-contains few number of mitochondria and depend on anaerobic metabolism
7-Respond slowly but with long duration	-it responds rapidly but with short duration
8- Not early fatigued	- it early fatigued
9-Adapted for prolonged muscle activity (Static function)	-Adapted for rapid, fine, skilled Movement (Phasic function)
10- e.g antigravity muscles to maintain body posture.	-e.g. extraocular muscle

N.B.: most muscle contain both types but one is predominant.

2- Temperature:

Warming of the muscle as in muscular exercise leads to stronger and rapid contraction by acceleration of the chemical reactions and decrease the muscle viscosity. But overheating ($> 45^{\circ}\text{C}$) \rightarrow heat rigor (stiffness).

3- Initial length:

The strength of contraction (in isotonic contraction) and the developed tension (in isometric contraction) are directly proportional to the initial length of the muscle fibre up to limit (Starling's law).

4- Fatigue:

• Definition:- It is the gradual decrease in the muscle contraction and prolonged duration of all phases of the SMT, especially relaxation due to repeated and strong stimulation of the muscle. • The effect: decrease strength and prolonged duration of contraction and incomplete or absent relaxation

• The cause of **fatigue**: - In case of **indirect** stimulation (via stimulation of its motor nerve) is the gradual exhaustion of Ach at the MEP.

- Also **direct** stimulation of the muscle may lead to fatigue due to exhaustion of energy sources (ATP) or accumulation of metabolites.

- In living muscle (after exercise), **fatigue** is caused by:

1- Decrease blood supply to the muscle.

2- Decrease energy sources.

3- Accumulation of metabolites which depress the brain and spinal cord (central effect).

- **Contracture** may occur with fatigue due to decrease in ATP required for separation between the thin and thick filaments and muscle relaxation.

5- Stair-case (Treppe) phenomenon:

-It occurs in the skeletal and cardiac muscle.

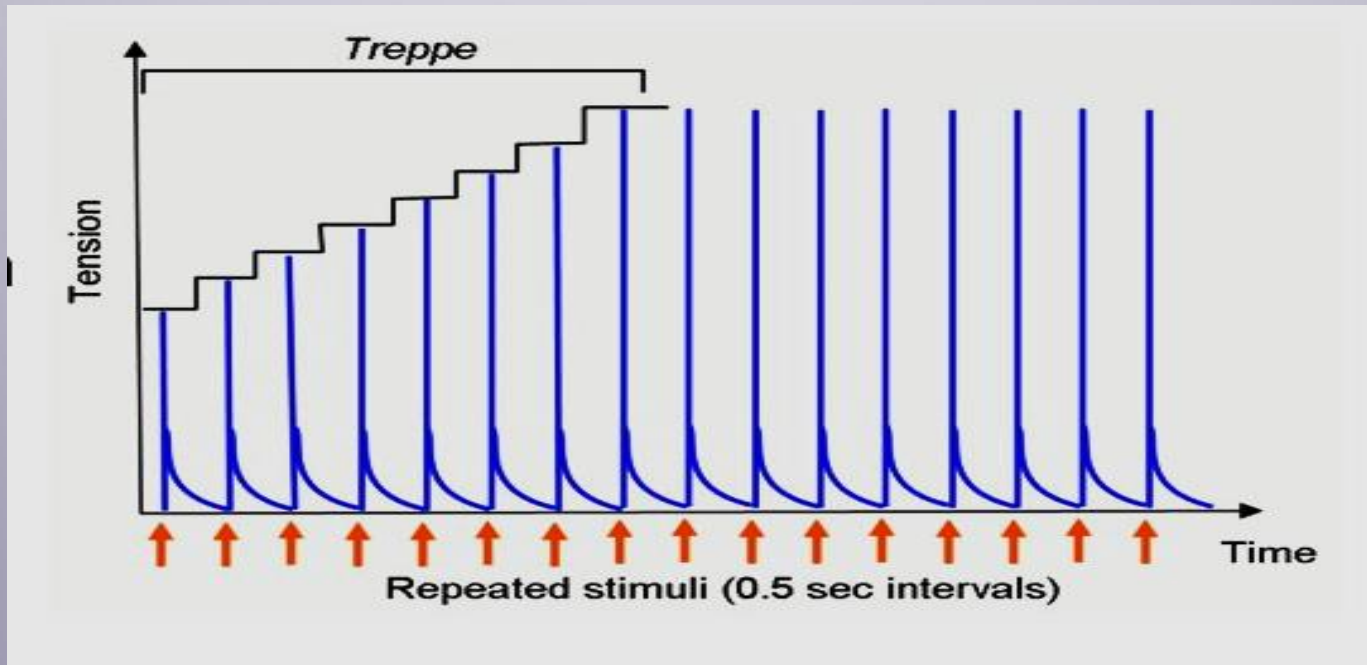
-It is a gradual increase in muscle contraction until plateau.

-This occurs by application of series of maximal stimuli just after relaxation period of each muscle twitch.

-This is due to: 1- accumulation of Ca^{++} intracellular.

2- \uparrow temperature of the muscle.

3- $\downarrow \text{K}^+$ & $\uparrow \text{Na}^+$ intra-cellular $\rightarrow \uparrow \text{Ca}^{+2}$ release from sarcoplasmic reticulum $\rightarrow \uparrow$ contraction.



Summation of muscle contractions

Since the contraction phase in the skeletal muscle starts with the relative refractory period, the muscle respond to another stimulus during either cont. or relaxation → summation of contraction.

(a) Effect of two successive stimuli:

According to frequency of stimulation:

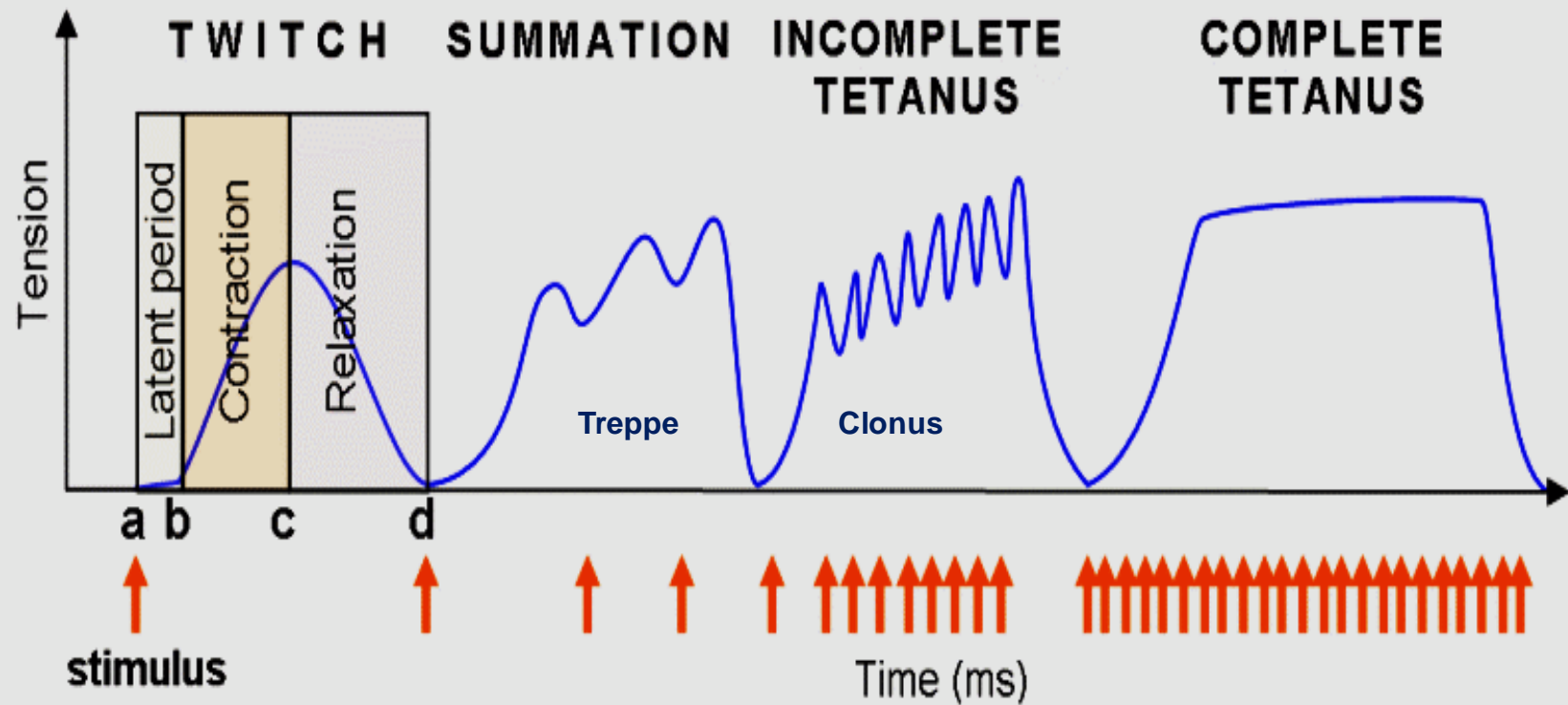
If the 2nd **stimulus** falls in relation to preceding one:

- 1- During the **latent period** → no response (during ARP).
- 2- During the **contraction period** → more strong contract.
- 3- During the **relaxation period** → 2 peaks contraction.
- 4- Just **after the relaxation period** → stair-case phenomenon.
- 5- **After relaxation** → normal second contraction.

(b) Effect of multiple successive stimuli:

- 1- If the frequency is low → separate twitches with Stair – case phenomenon.
- 2- If the frequency increases and stimuli falls during relaxation phase of preceding twitch → Clonus (incomplete tetanus).
- 3- If the frequency increases more and stimuli falls during contraction phase → sustained contraction (complete tetanus).

N.B.: **Cooling, fatigue & anticholinesterase** (Eserine) change **clonus into complete tetanus**.
However, **warmness and rest** cause the reverse.



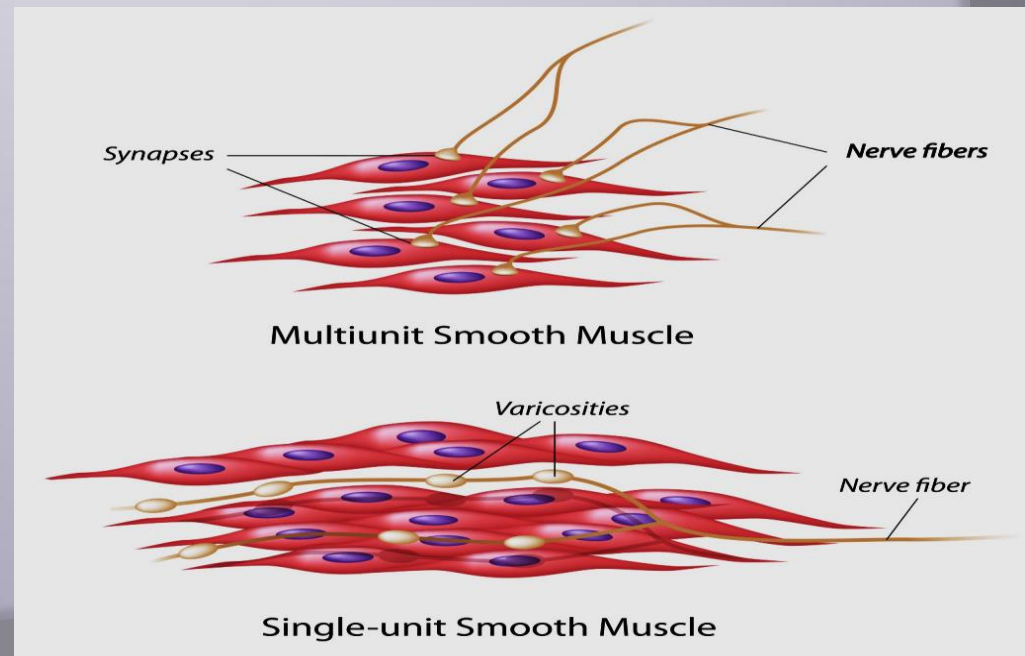
Smooth Muscle

•Site: it presents in wall of most viscera, bl. vessels, some glands, intraocular muscles and erector pilae ms. So, it controls the involuntary activities.

•Structure:

- Smooth muscle fibers are spindle-shaped, non striated (plain) cells with central long nuclei.
- Fiber's length is 20-500 microns and diameter 2-5 microns.
- S.M. contains **more** actin filaments which attached to each other and to dense bodies .
- S.M contain **calmodulin** instead of troponin-tropomyosin.
- S.M contain **less** mitochondria and endoplasmic reticulum.
- S.M innervated by autonomic nervous system.

Types of smooth muscles



•**S.M of two types:**

-S.M has no motor end plate but at nerve endings (sympathetic or parasympathetic) there are special nodes (varicosities) via it neuromuscular transmission occurs → depolarization followed by contraction or hyperpolarization followed by relaxation according to the type of chemical transmitter.

Multi-unit S.M.	Single unit S.M (unitary)
<ul style="list-style-type: none"> -Separate fibers without connection. (Except via the chemical transmitters). - One nerve for each fiber - Not obey all or none law -Sensitive to chemical transmitter -Rare spontaneous cont. but controlled by nerve impulses. -Not respond to stretch -e.g iris, wall of bl. vs., pilomotor muscle& ciliary muscle 	<ul style="list-style-type: none"> -Aggregated fibers attached by gap junctions facilitate conduction of action potential (functional syncytium). -one nerve for many fibers. -Obey all or non law - less sensitive. -Contract spontaneously - Respond to stretch - e.g wall of viscera as uterus, GIT, ureter,.....

Excitability of S.M

- RMP: is **unstable** and about -40 to -60 mvolt. with slow sine waves.

- Action potential of **four** types:

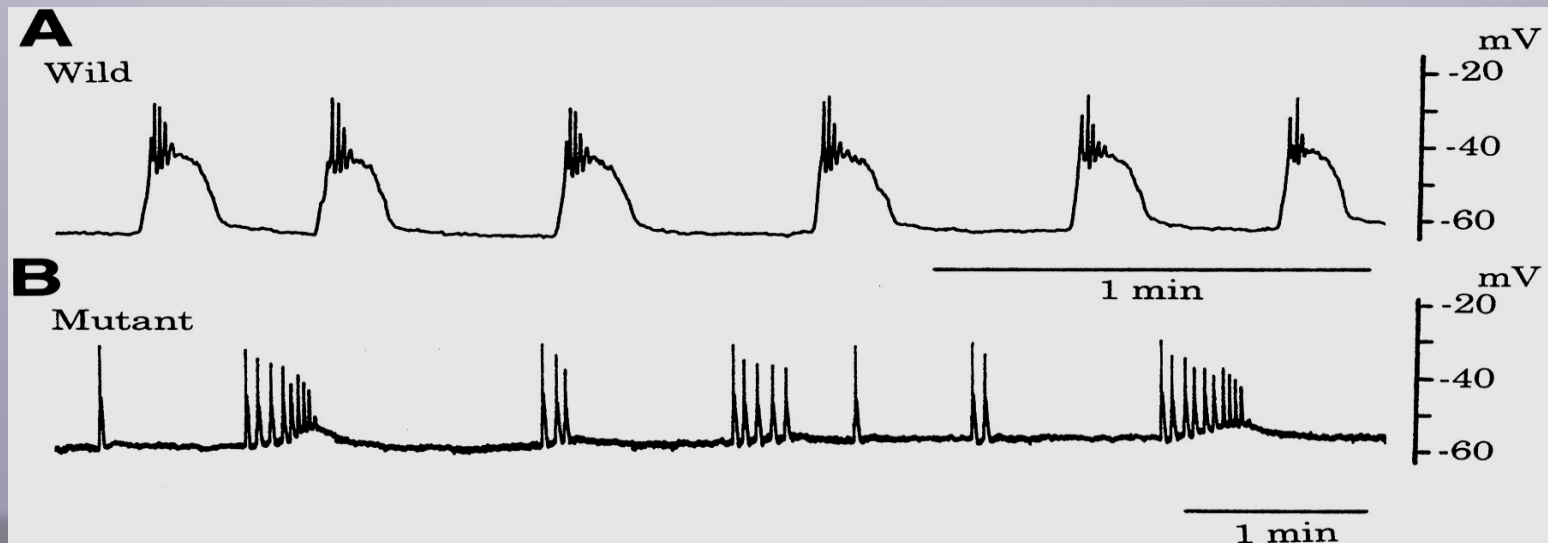
- a-Spike potential** as in sk. ms with duration of 50 msec. Present in the single unit S.M fibers.

- b-Action potential with prolonged plateau** (hundreds of m.sec) due to delayed repolarization as in uterus (similar to cardiac potential).

- c-Spike pot. with serrations** as in small intestine.

- d-Pacemaker potential** (slow – wave potential): It occurs due to rhythmical activity of $\text{Na}^+ - \text{K}^+$ pump. When the wave reach the firing level (-35 mv) \rightarrow action potentials which spread over the muscle. This type of potential initiates rhythmical contraction of GIT (as in the automatic cardiac fibers).

- Ionic base of action potential:** may due to Na^+ influx or Ca^{++} influx or both.



Contractility of S.M.

•Excitation contraction coupling:

-**Contraction:** Extracellular Ca^{++} influx or intracellular Ca^{++} release from the sarcoplasmic reticulum \rightarrow \uparrow intracellular Ca^{++} which combine with calmodulin \rightarrow activate myosin light chain kinase enzyme \rightarrow phosphorylation of the light chain of myosin \rightarrow binding of actin & myosin \rightarrow shortening (contraction).

-**Relaxation:** \downarrow intra-celular Ca^{++} (by Ca^{++} pump) \rightarrow stimulate myosin phosphatase enzyme \rightarrow removal of phosphate from light chain of myosin \rightarrow stop contraction \rightarrow relaxation.

-Characters of S.M. contractility:

1-Spontaneous contraction but under nervous regulation.

2-**Slow** cycling of cross bridges

3-**Slow** onset of contraction and relaxation.

4-Energy and O_2 consumption is **low** and depends mainly on anaerobic glycolysis. So it is not easily fatigued.

5-SM has great ability to shorten as far greater percentage of its length.

6-Its contraction is **sluggish** and excitation / contraction coupling is **very slow** also Ca^{++} pump is slow so contraction is maintained than in skeletal muscle.

7-**Latch mechanism**, as prolonged tonic contraction needs less energy, less nervous or chemical stimulation than initial activity. So this **delays fatigue**.

8- **Stress relaxation (plasticity)** in which if SM is slowly stretched \rightarrow increased tension at first then the tension gradually decreases inspite of continuous stretch (e.g., the urinary bladder can receive large volumes of urine without marked increase in wall tension).

9-Visceral SM shows: **Tone** = continuous mild contraction

Rhythm = irregular cont. due to repetitive discharge of spike potential.

Factors affecting excitability & contractility

	↑Excitability contraction	→	↓Excitability → relaxation.
<ul style="list-style-type: none"> -Nervous system -Temperature -Stretch -pH⁺ -Osm. Pressure -Ions -Autonomic -Hormones 	<ul style="list-style-type: none"> Parasympathetic Cooling Rapid moderate stretch Alkalinity Low ↓ Ca⁺⁺ & ↑ K⁺ Parasympathomimetics Vasopressin, Oxytocin and Estrogen. 		<ul style="list-style-type: none"> Sympathetic Warmth Severe stretch Acidity High ↑Ca⁺⁺ & ↓ K⁺ Sympathomimetics Catecholamines, Progestrone

Thank You

