4- MUSCLE PHYSIOLOGY

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The simple muscle twitch

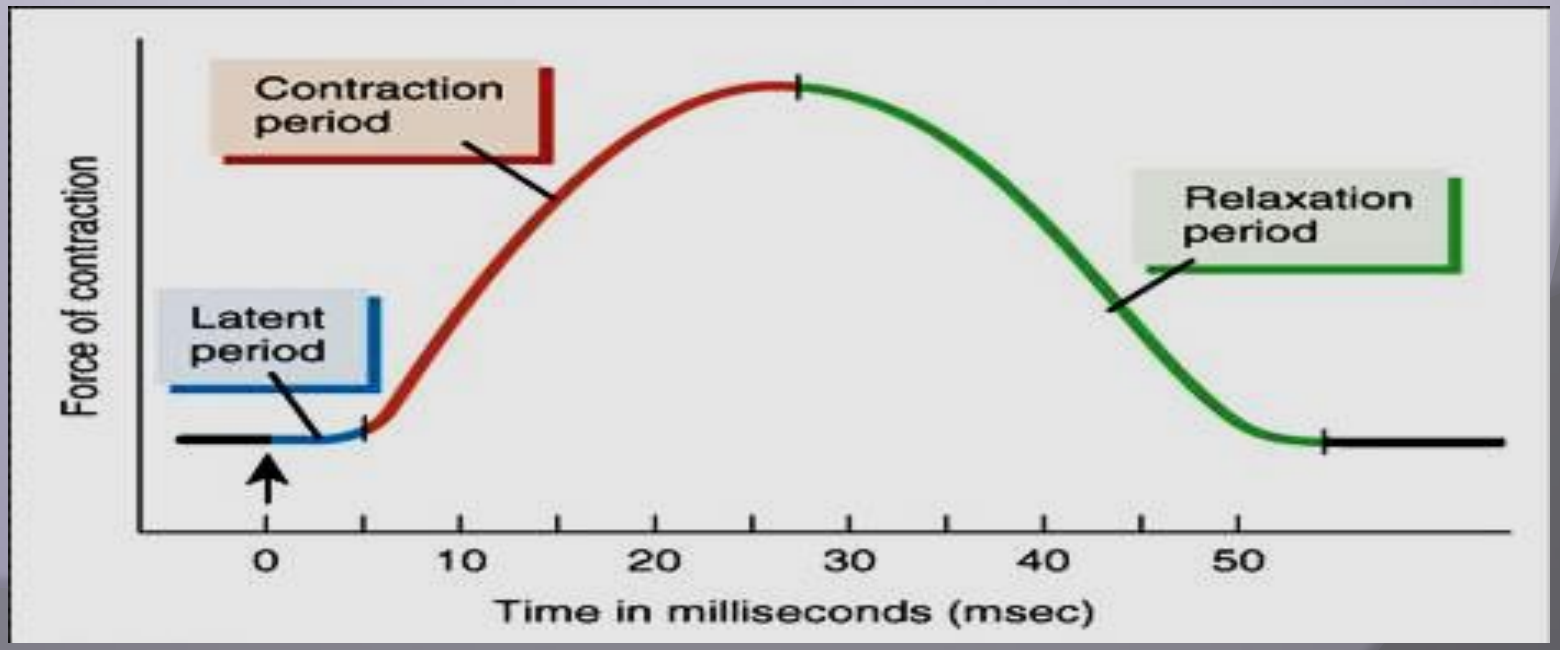
Definition: It is the response of the muscle to a single maximal stimulus and consists of:

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 isotonically.(0.04 sec.)

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



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

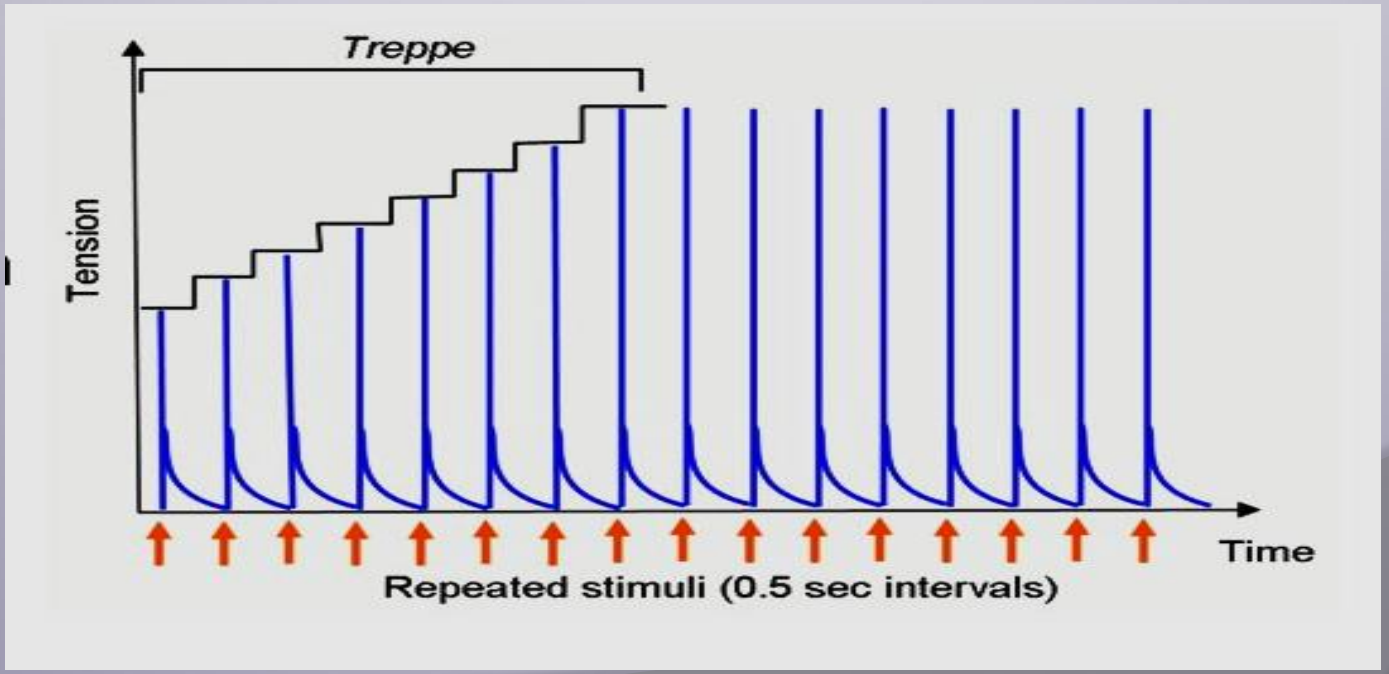
-It is a gradual increase in muscle contraction until plateau.

-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- ↑ temperature of the muscle.

3- ↓ K+ & ↑ Na+ intra-cellulary → ↑ Ca+2 release from sarcoplasmic reticulum→↑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.

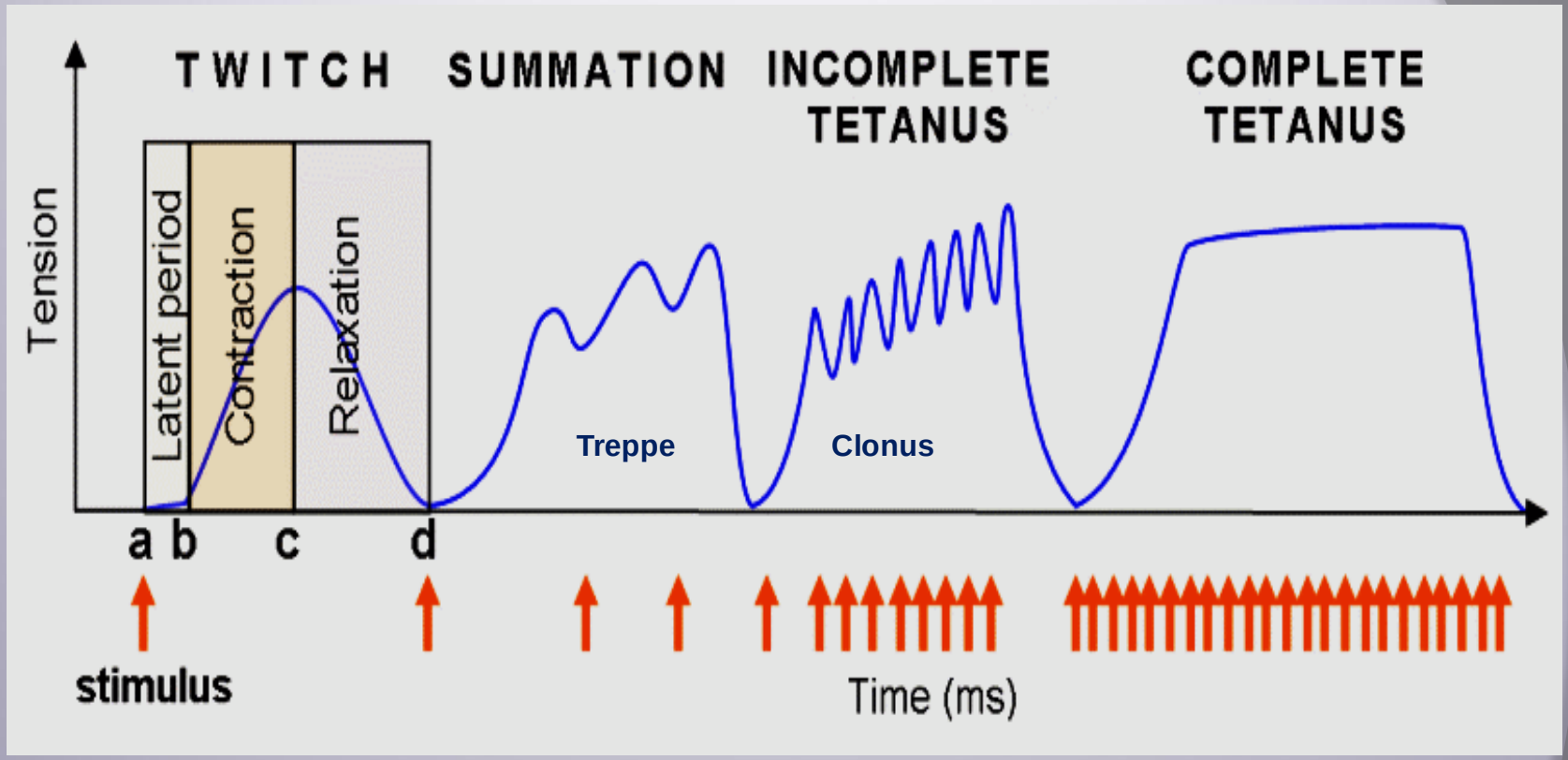
(b) Effect of multiple successive stimuli:

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.


TWITCH
SUMMATION
INCOMPLETE TETANUS
COMPLETE TETANUS
Tension
Latent period
Contraction
Relaxation
Treppe
Clonus
a b c d
stimulus
Time (ms)

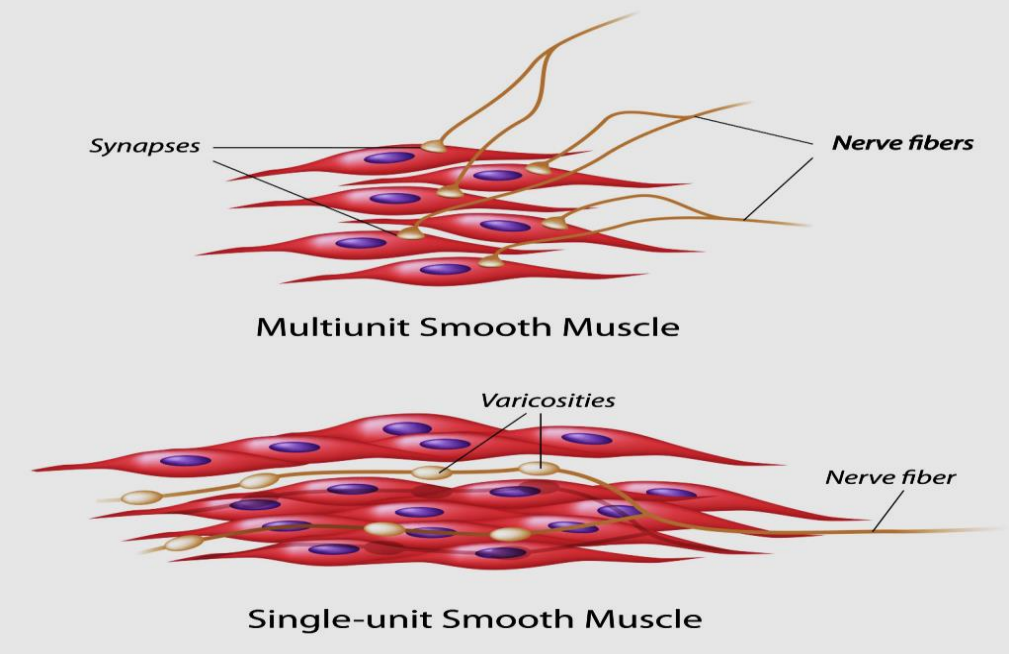
Smooth Muscle

•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)
-Separate fibers without connection. (Except via the chemical transmitters).	-Aggregated fibers attached by gap junctions facilitate conduction of action potential (functional syncytium).
- One nerve for each fiber	-one nerve for many fibers.
- Not obey all or none law	-Obey all or non law
-Sensitive to chemical transmitter	- less sensitive.
-Rare spontaneous cont. but controlled by nerve impulses.	-Contract spontaneously
-Not respond to stretch	- Respond to stretch
-e.g iris, wall of bl. vs., pilomotor muscle& ciliary muscle	- 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:

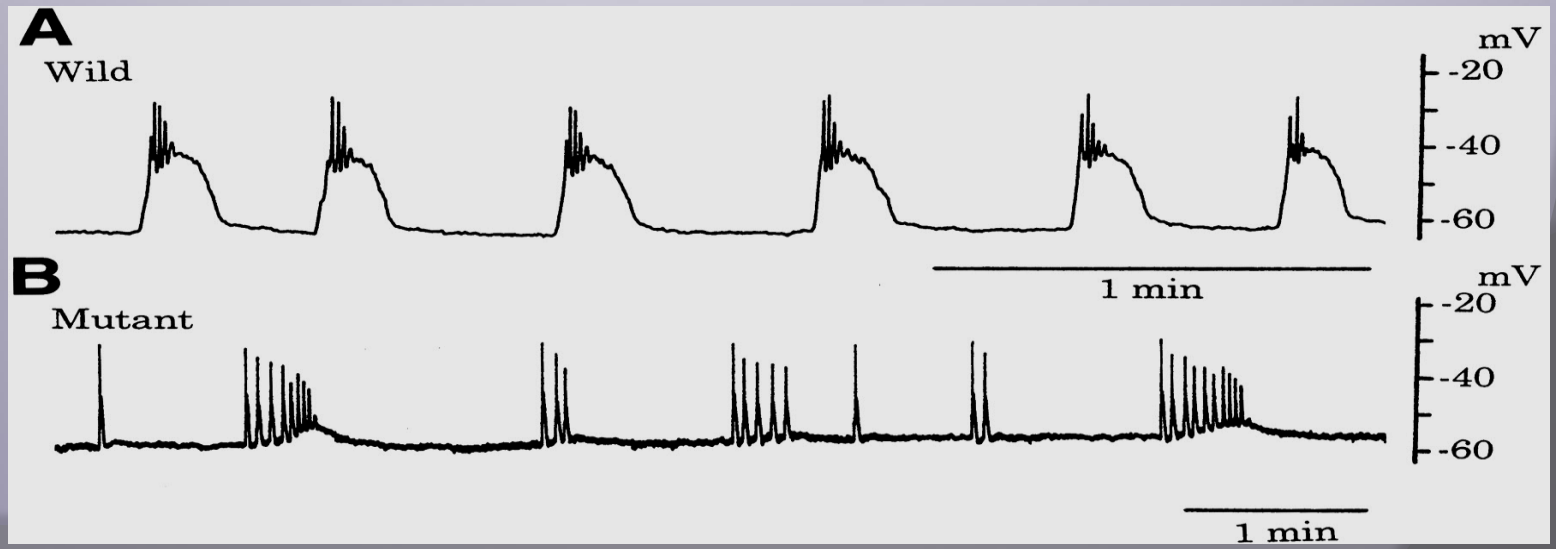
a-Spike potential as in sk. ms with duration of 50 msec. Present in the single unit S.M fibers.

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 Na+-K+ pump. When the wave reach the firing level (-35 mv) → 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→↑ intracellular Ca++ which combine with calmodulin → activate myosin light chain kinase enzyme → phosphorylation of the light chain of myosin → binding of actin & myosin → shortening (contraction).

-Relaxation: ↓ intra-celular Ca++ (by Ca++ pump) → stimulate myosin phosphatase enzyme → removal of phosphate from light chain of myosin → stop contraction → 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 O2 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 → 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.
-Motor neurons	Parasympathetic	Sympathetic
-Temperature	Cooling	Warmth
-Stretch	Rapid moderate stretch	Severe stretch
-pH^+	Alkalinity	Acidity
-Osm. Pressure	Low	High
-Ions	↓ Ca^{++} &↑ K^+	↑Ca^{++} &↓ K^+
-Autonomic drugs	Parasympathomimetics	Sympathomimetics
-Hormones	Vasopressin, Oxytocin and Estrogen.	Catecholamines, Progestrone

Thank You