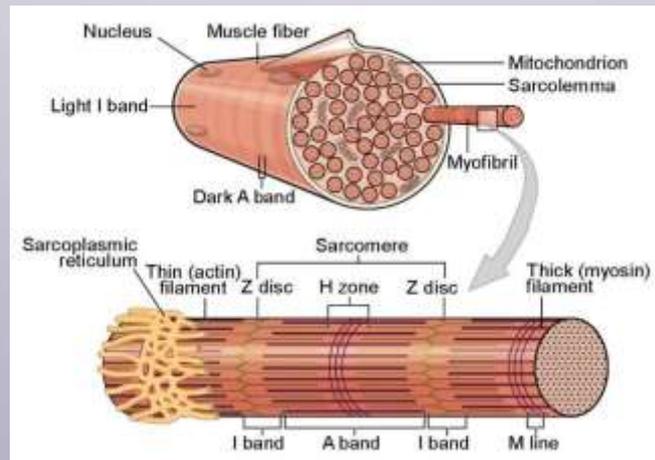




2- MUSCLE PHYSIOLOGY - II



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2021-2022

The simple muscle twitch

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

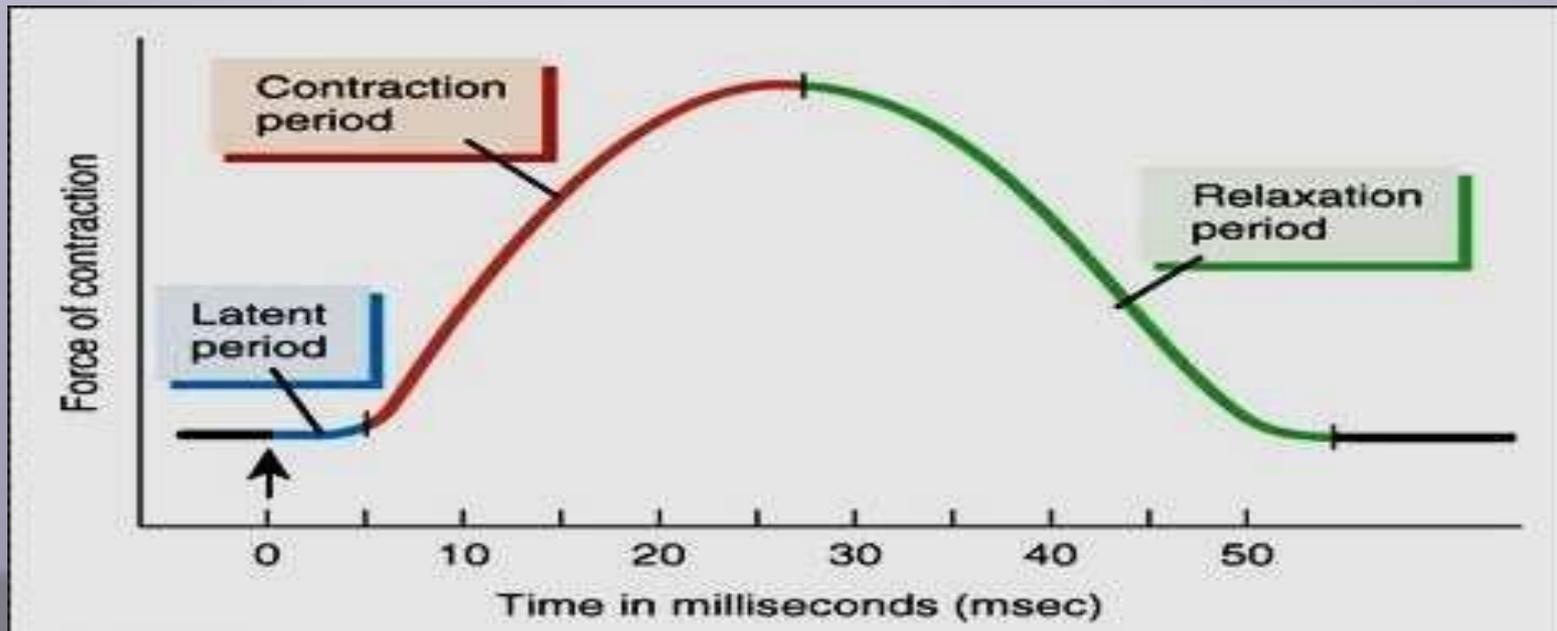
1) Latent period: -It is the time between time of stimulus & response.

-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.

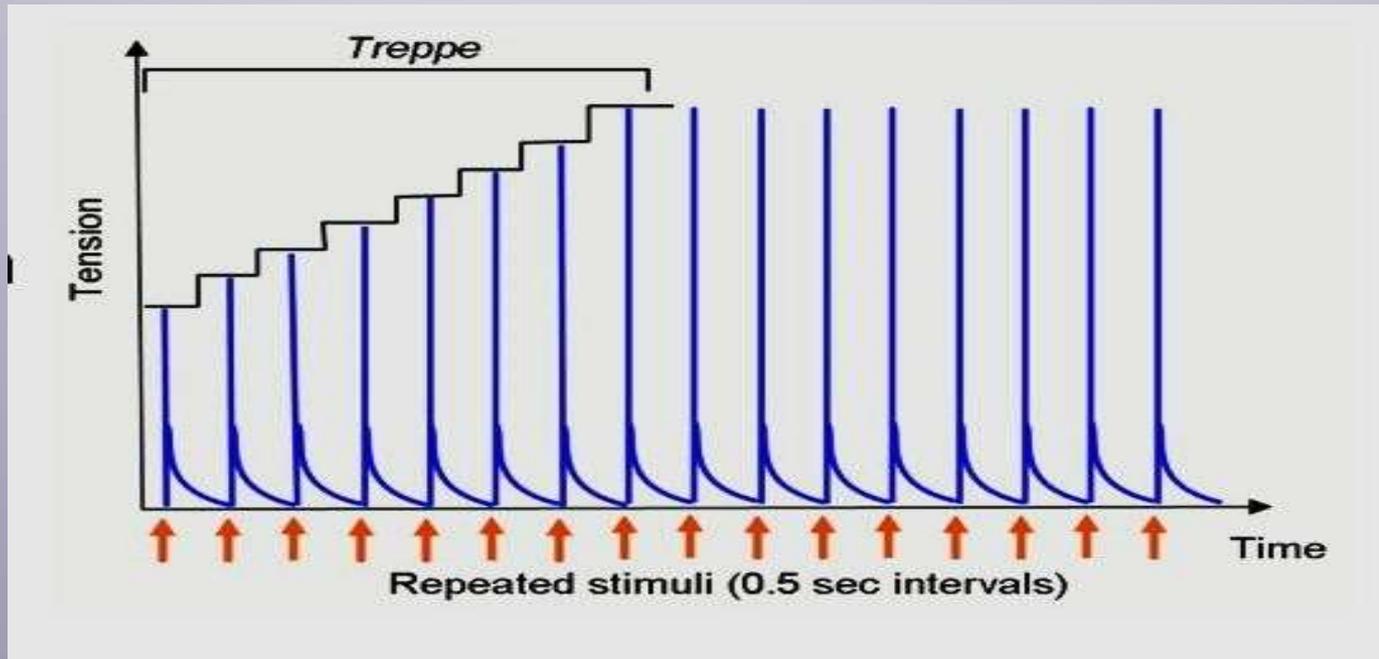
- 2- Decrease energy sources.

- 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:

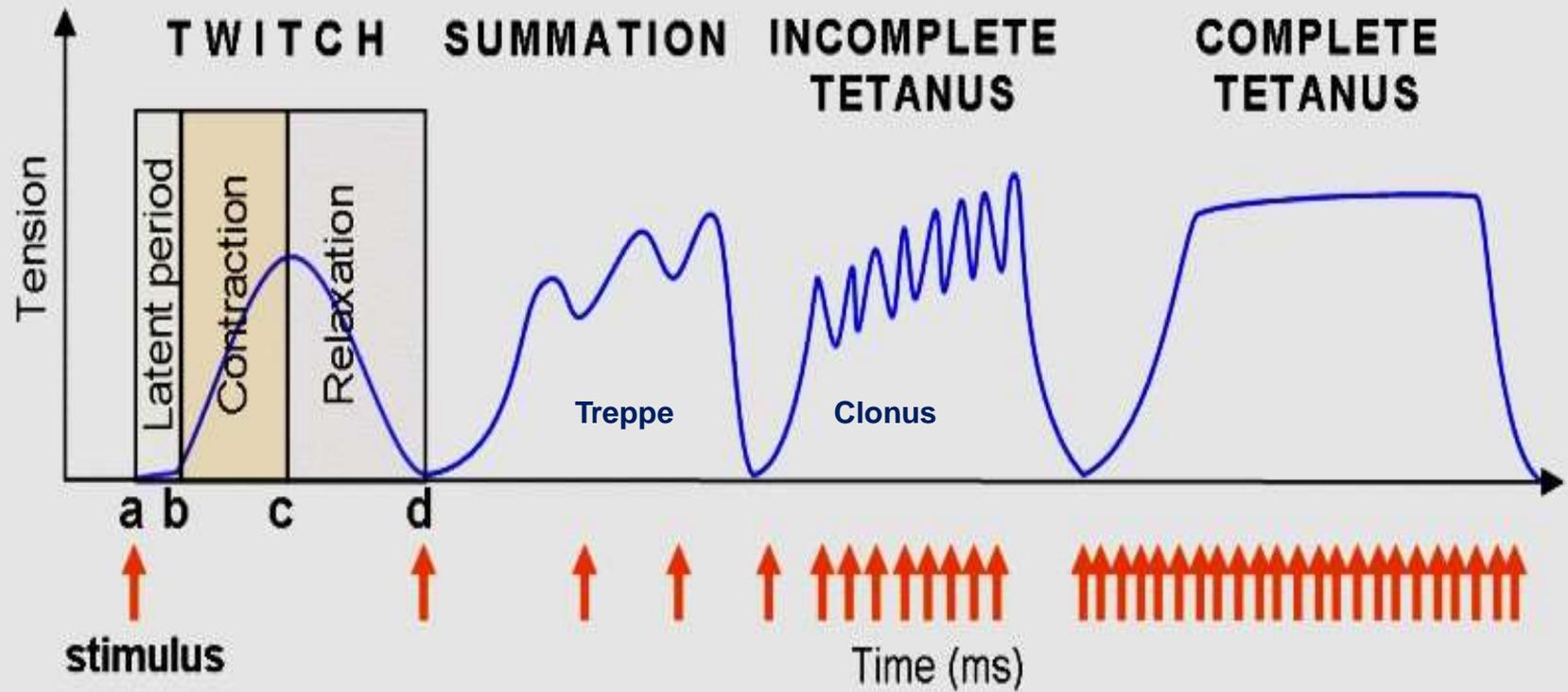
If the **2nd stimulus** falls in relation to preceding one:

- 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 & anti-cholinesterase (Eserine) change **clonus** into **complete tetanus**.
However, warmness and rest cause the reverse.



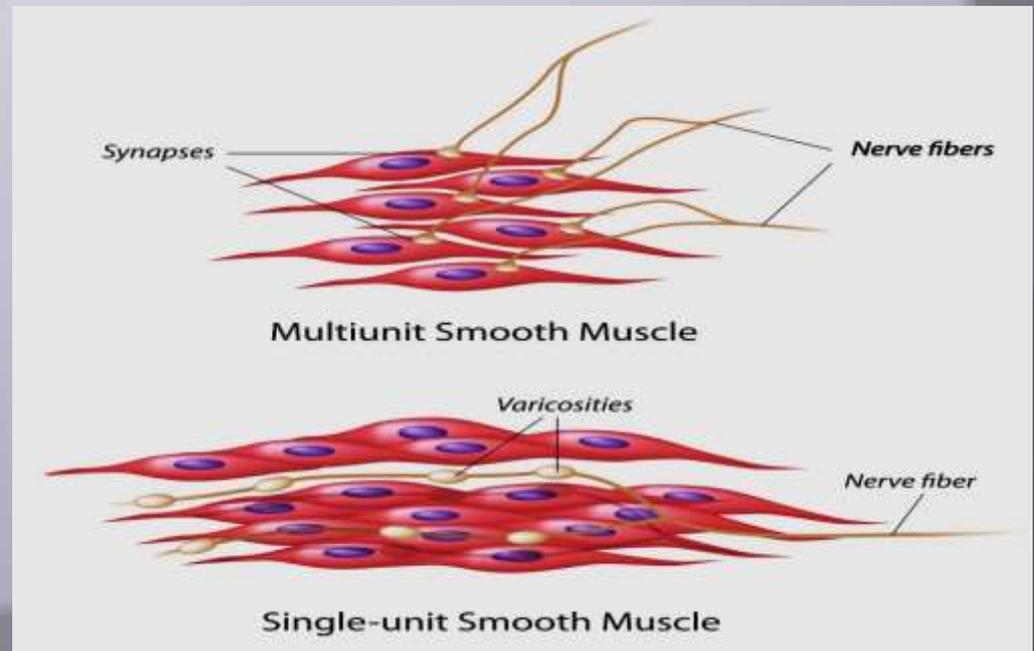
Smooth Muscle

•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:

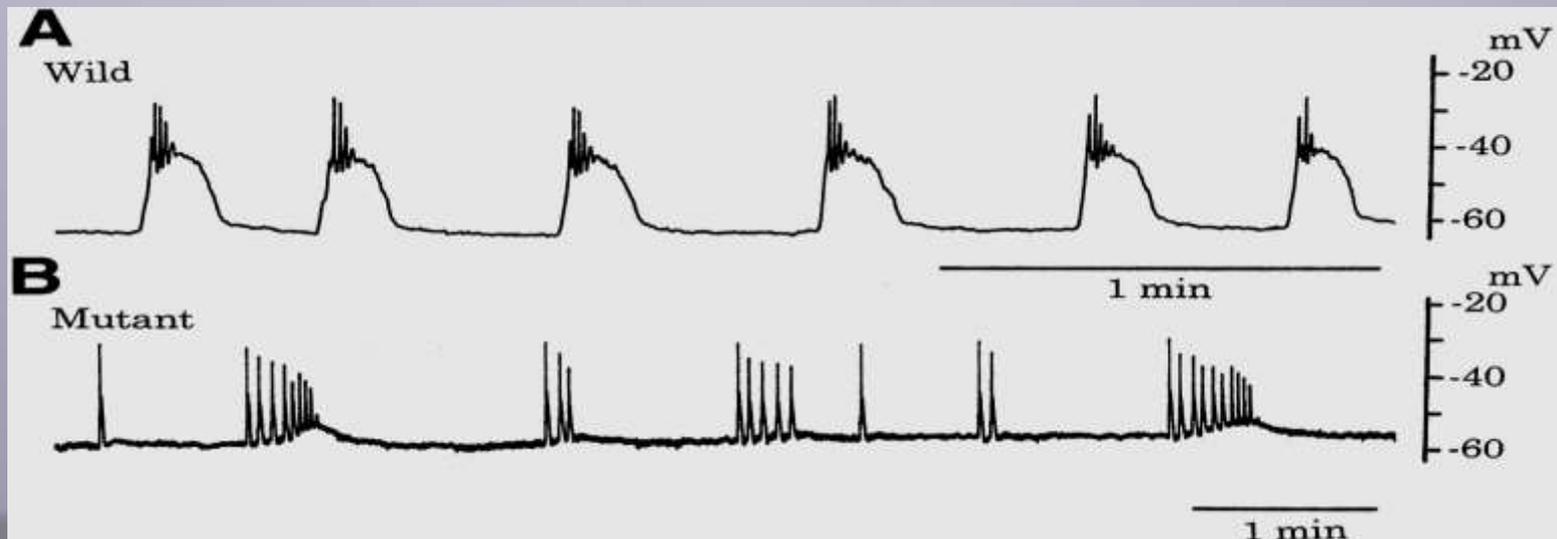
a-Spike potential as in sk. ms with duration of 50 msec. Present in the single unit S.M fibers.

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 Na^+-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 → ↑ 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.

4Energy 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.

6Its 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 of smooth muscle.

	↑ Excitability → contraction	↓ Excitability → relaxation.
<ul style="list-style-type: none"> -Motor neurons -Temperature -Stretch -pH⁺ -Osm. Pressure -Ions -Autonomic drugs -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, Progesterone

Thank You