Summation and tetanization Comparison of smooth and skeletal contraction

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Objectives

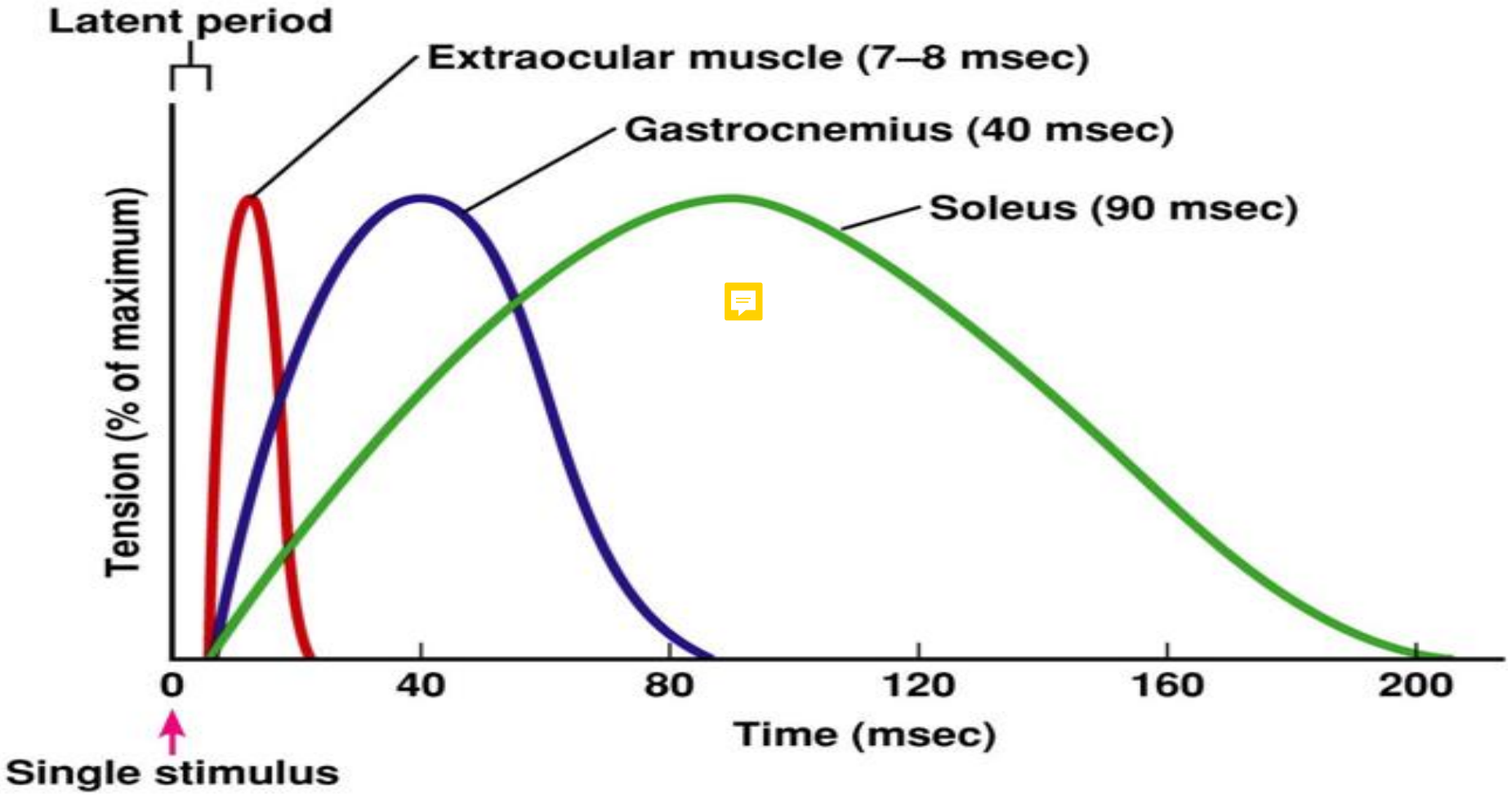
- Types of skeletal muscle
- Summation and tetanus
- Fatigue
- Comparison between skeletal and smooth muscle contraction

Properties of Skeletal Muscle Fiber Types

	Slow oxidative (red)	Fast oxidative (red)	Fast glycolytic (white)
Oxidative capacity	High	High	Low
Glycolytic capacity	Low	Intermediate	High
Speed of contraction	Slow	Intermediate	Fast
Myosin ATPase activity	Low	Intermediate	High
Mitochondrial density	High	High	Low
Capillary density	High	High	Low
Myoglobin content	High	High	Low
Resistance to fatigue	High	Intermediate	Low
Fiber diameter	Small	Intermediate	Large
Motor unit size	Small	Intermediate	Large
Force-generating capacity	Low	Intermediate	High

Types of muscle fibers

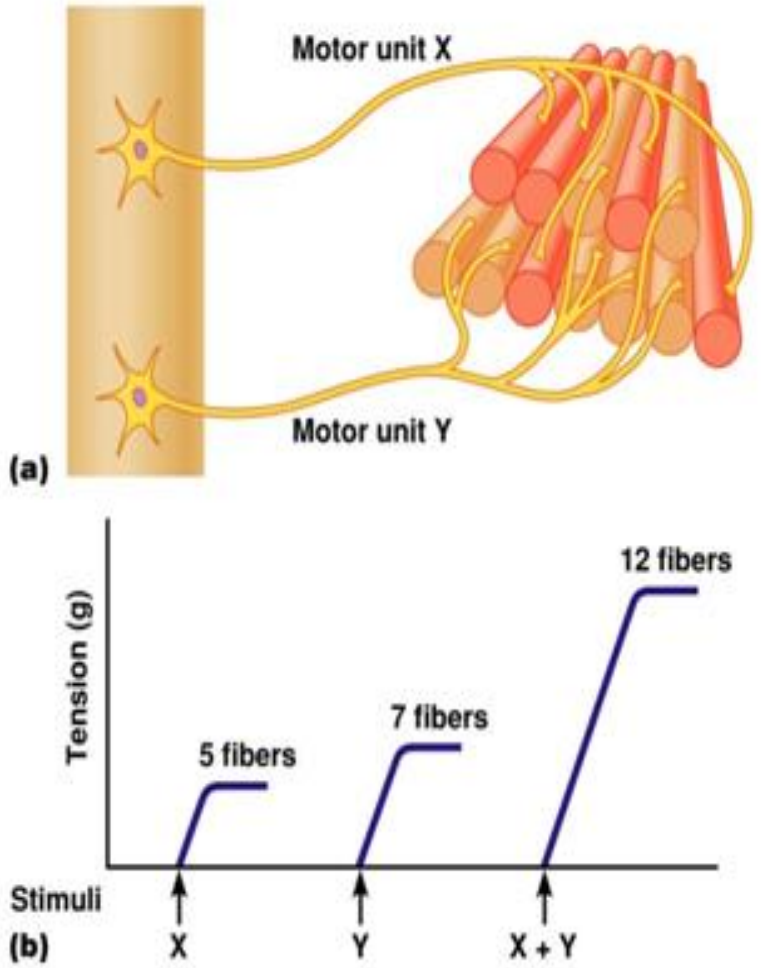
- Various muscles contract at different speed → composed of different types of muscle fibers



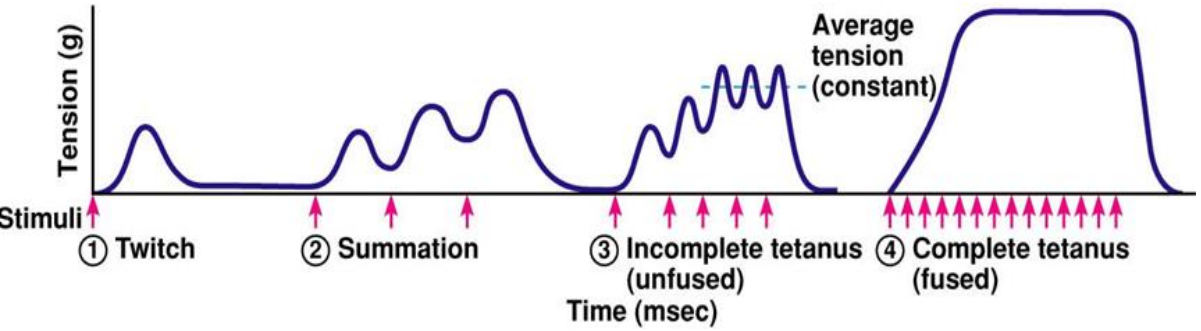
Recruitment

Henneman's size principle states that under load, motor units are recruited from smallest to largest. In practice, this means that slow-twitch, low-force, fatigue-resistant muscle fibers are activated before fast-twitch, high-force, less fatigue-resistant muscle fibers.

This has two very important physiological benefits. First, it minimizes the amount of fatigue an organism experiences by using fatigue-resistant muscle fibers first and only using fatigable fibers when high forces are needed. Secondly, the relative change in force produced by additional recruitment remains relatively constant.



Summation and tetanus

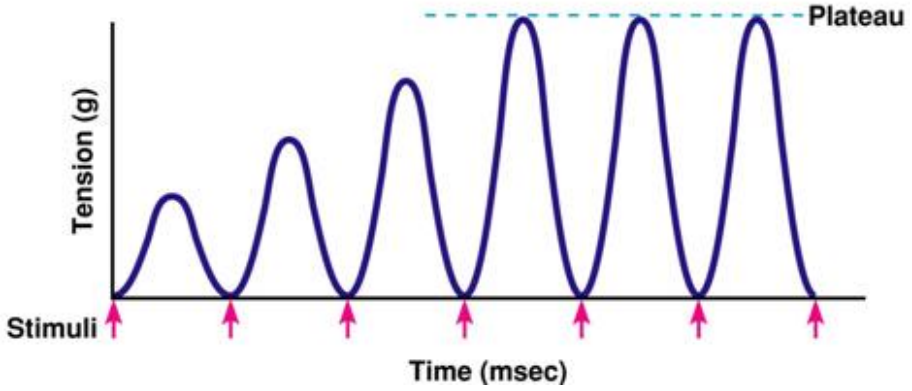


- Summation: Rapid sequence of stimuli→ muscle twitches fuse into each other, each subsequent one being stronger that its precedent

- Tetanus: very rapid sequence of stimuli: no relaxation

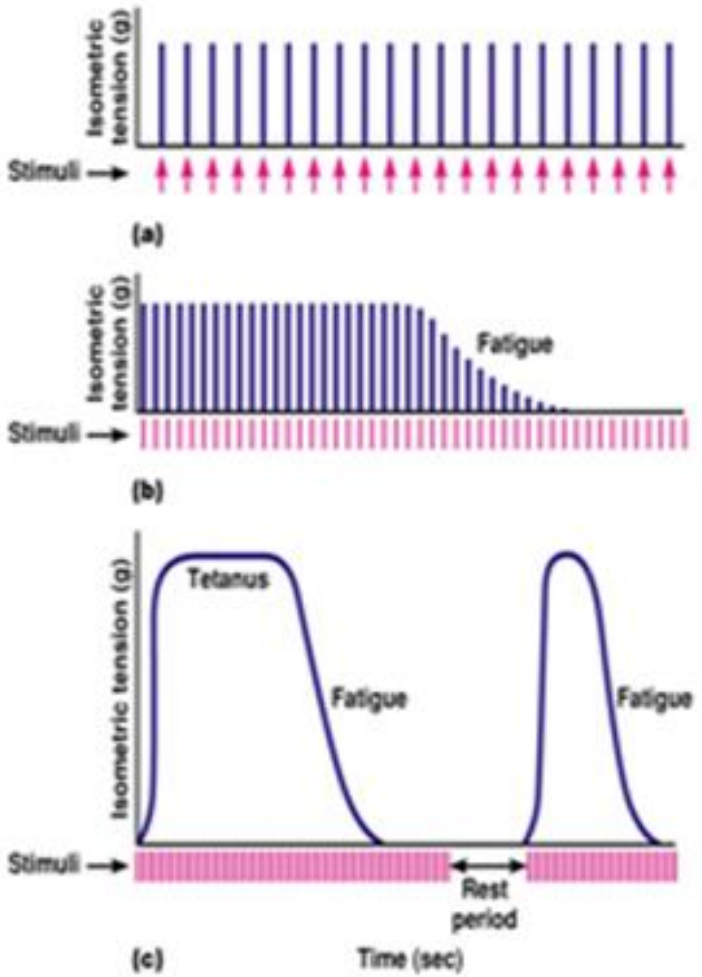
Effect of consecutive stimuli: Treppe

Treppe (warm-up): gradual increase in contraction intensity during sequential stimulation



Muscle fatigue

- Muscle fatigue: a decline in the ability of the muscle to sustain the strength of contraction

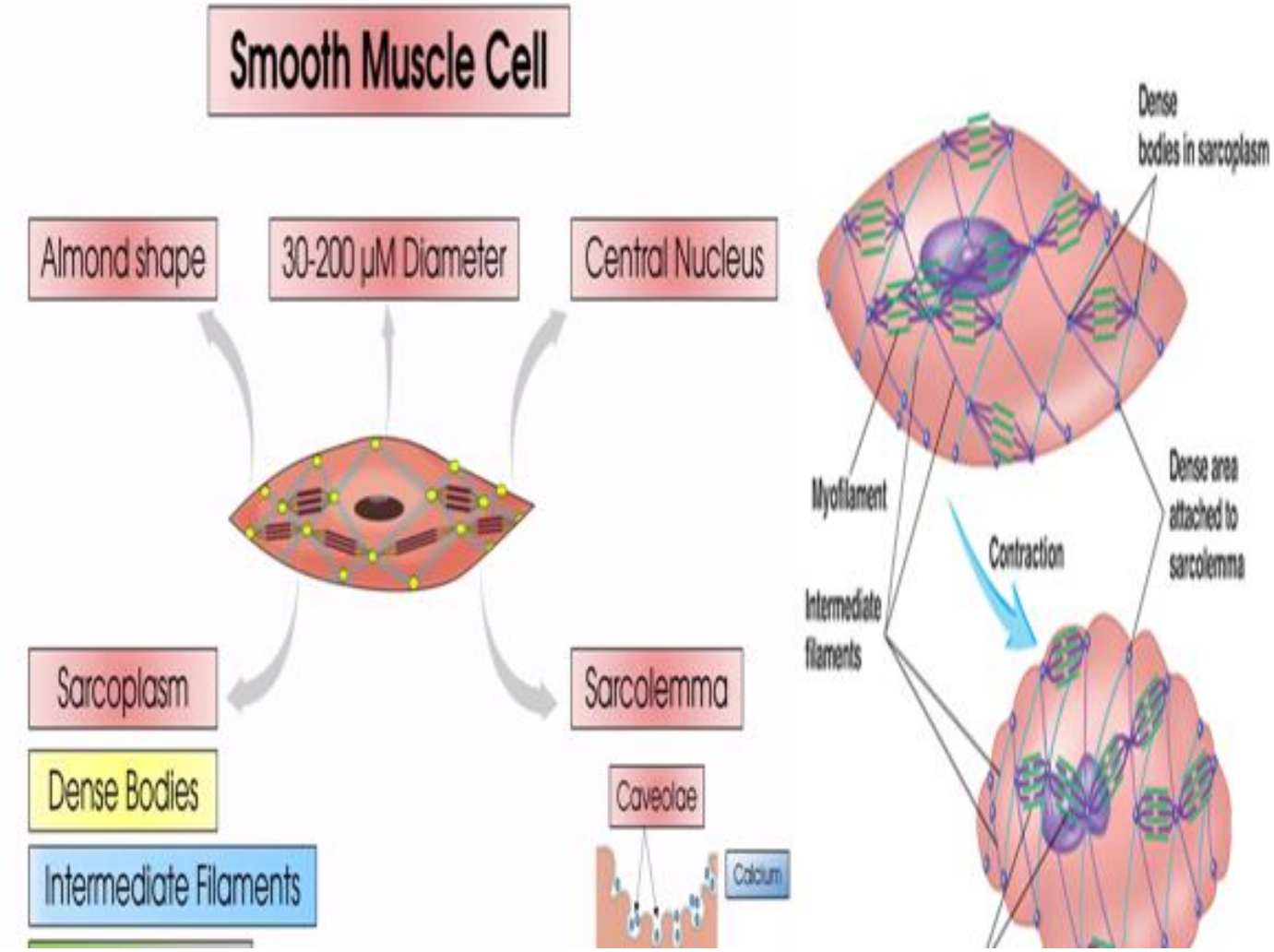


- Causes:

- Rapid build-up of lactic acid
- Decrease in oxygen supply
- Decrease in energy supply (glucose, glycogen, fatty-acids)
- Decreased neurotransmitter at the synapse

Structure of Smooth Muscle

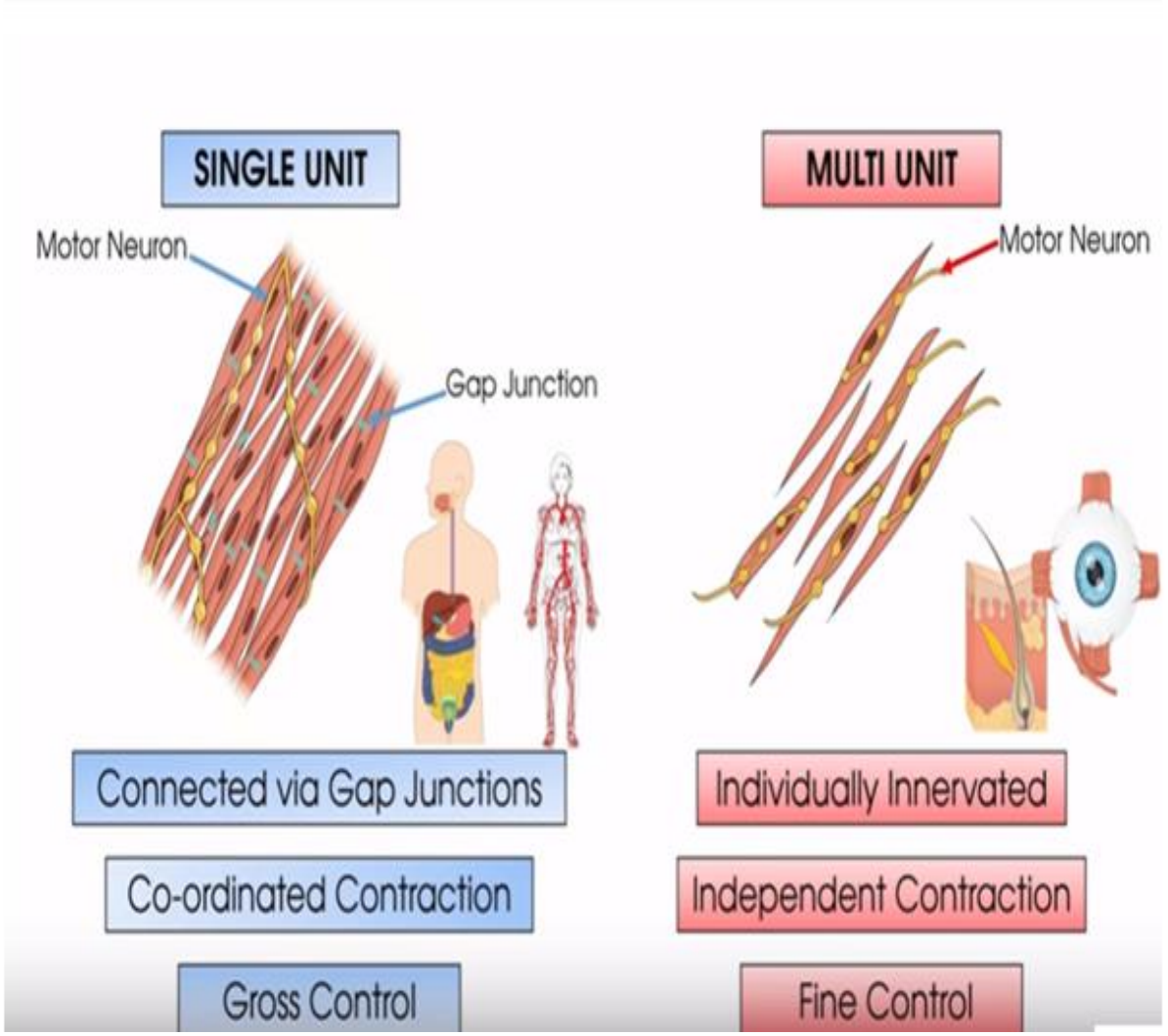
- Fibers smaller than those in skeletal muscle
- Spindle-shaped; single, central nucleus
- More actin than myosin
- No sarcomeres
  - Not arranged as symmetrically as in skeletal muscle, thus NO striations.
- Caveolae: indentations in sarcolemma;
  - May act like T tubules
- Dense bodies instead of Z disks
  - Have noncontractile intermediate filaments



Types of smooth muscle

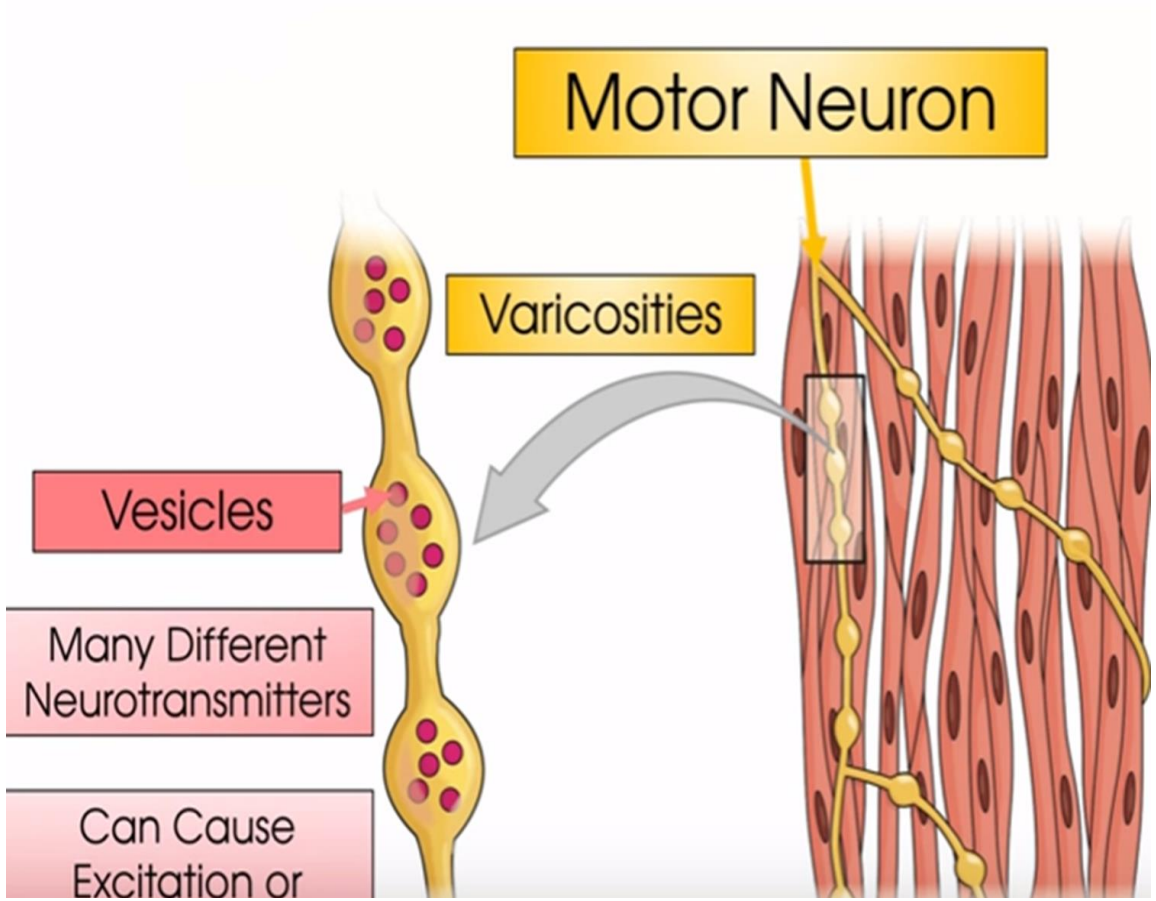
- **Multi-Unit Smooth Muscle.** This type of smooth muscle is composed of discrete, separate smooth muscle fibers.. Some examples of multi-unit smooth muscle are the ciliary muscle of the eye, the iris muscle of the eye, and the piloerector muscles that cause erection of the hairs when stimulated by the sympathetic nervous system.

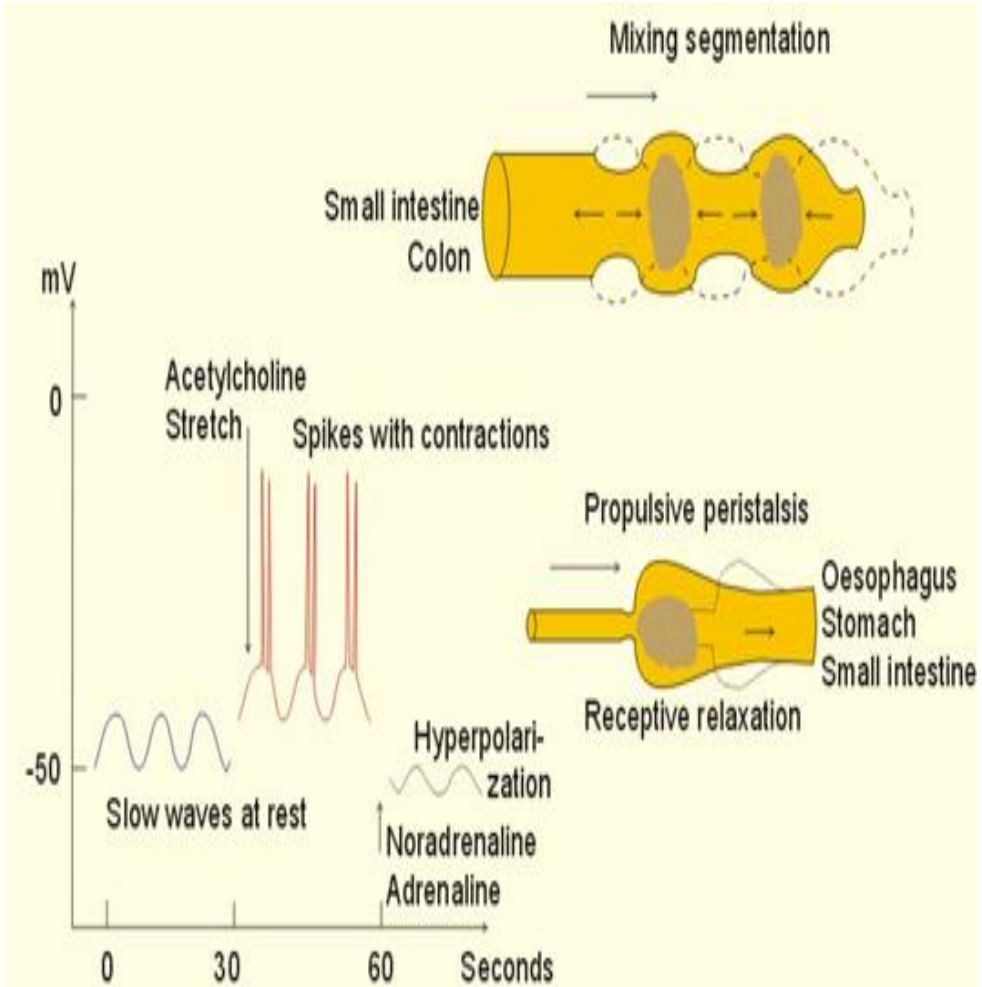
- **Unitary Smooth Muscle.** The term “unitary” is confusing because it does not mean the muscle fibers. Instead, it means a mass of hundreds to thousands of smooth muscle fibers that contract together as a single unit. the cell membranes are joined by many *gap junctions* through which ions can flow freely from one muscle cell.



Varicosities

Axons of neurons in the Autonomic nervous system do not form the highly organized NMJs with smooth muscle, as seen between motor neurons and skeletal muscle fibers. Instead, there is a series of neurotransmitter-filled bulges called varicosities as an axon courses through smooth muscle, loosely forming motor units . A varicosity releases neurotransmitters into the synaptic cleft.

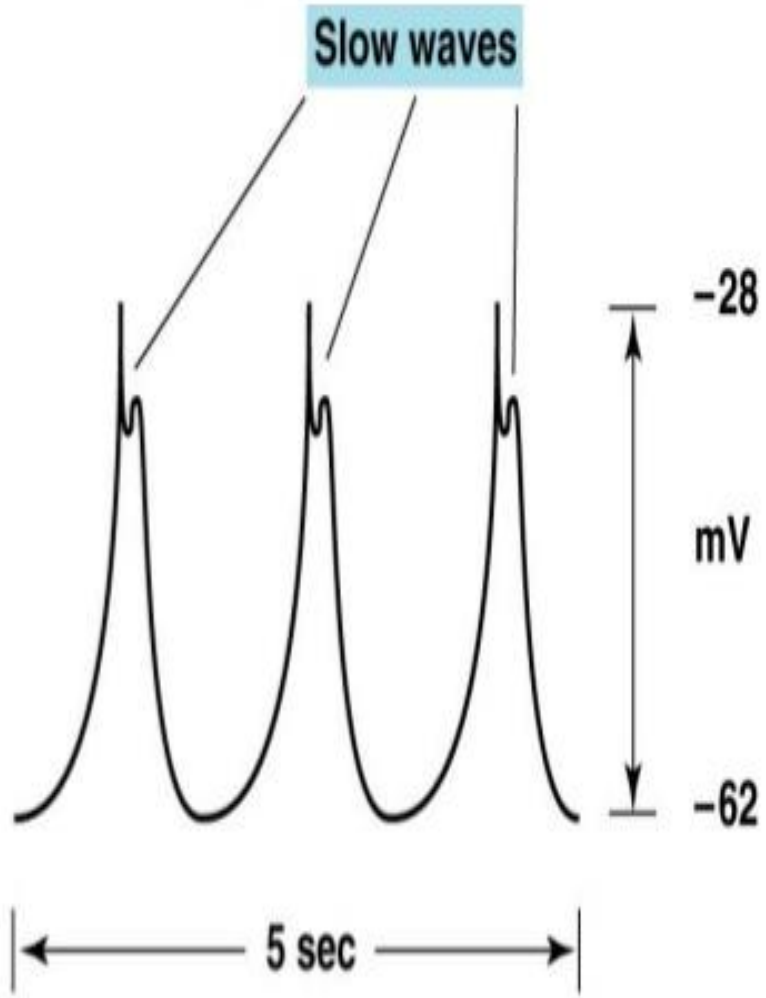




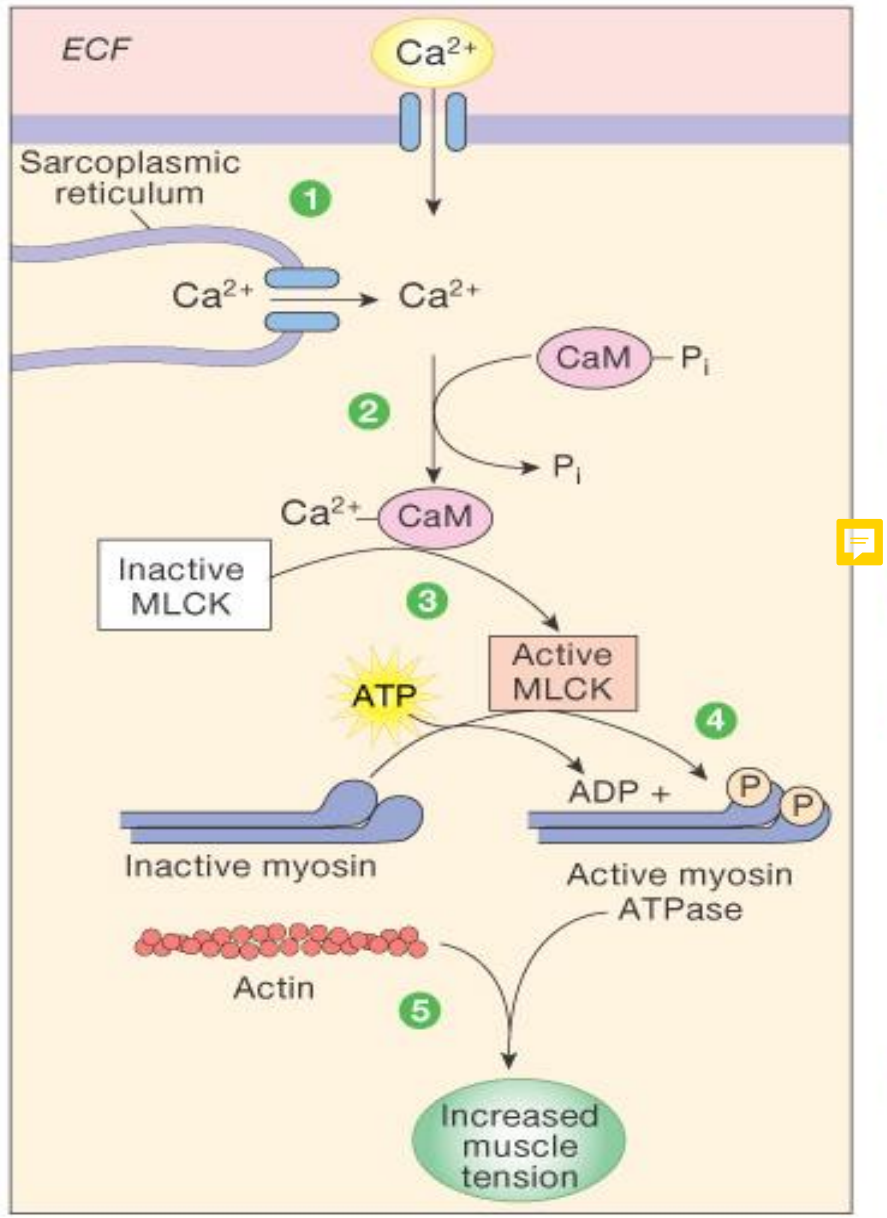
Occur automatically in response to endogenous pacemaker activity.

Rhythm of contractions is paced by graded depolarizations called slow waves.

- Slow waves produced by interstitial cells of Cajal.
- Slow waves spread from 1 smooth muscle cell to another through nexuses.

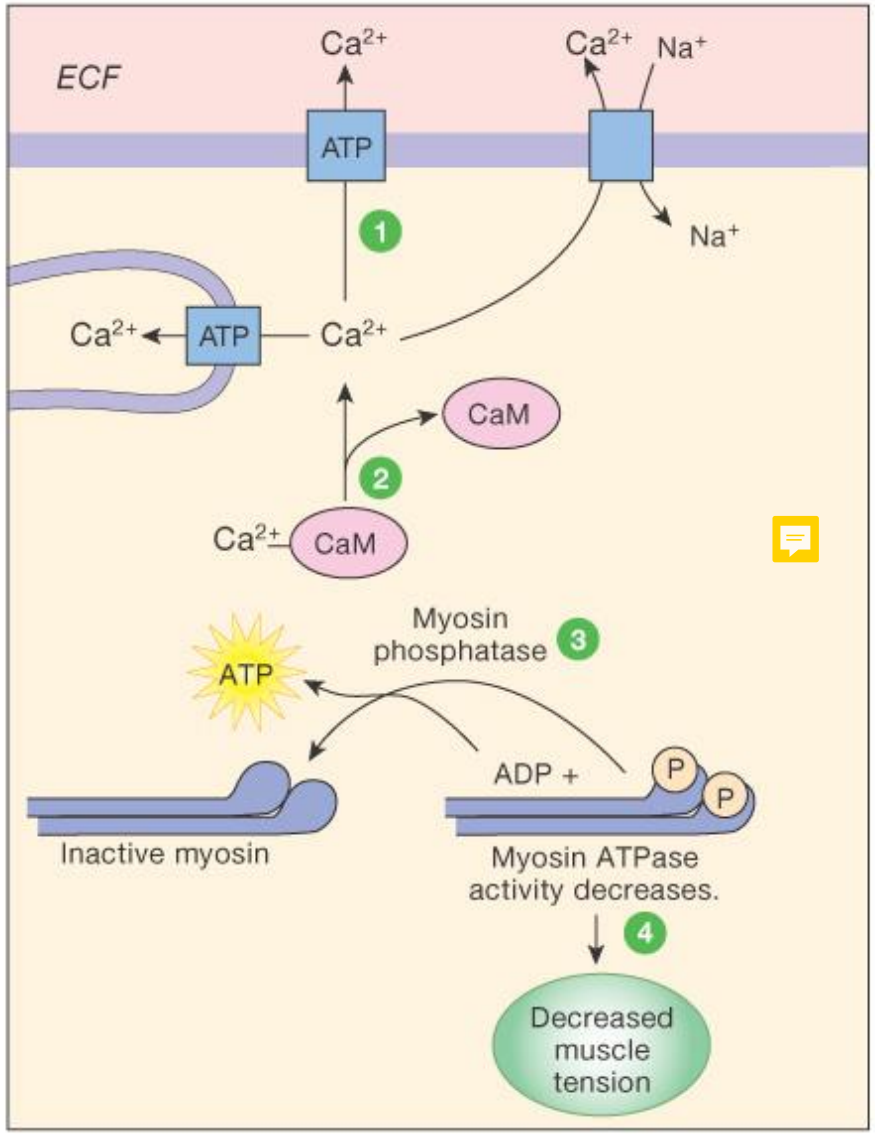


Smooth muscle contraction: mechanism



1. Intracellular Ca^{2+} concentrations increase when Ca^{2+} enters cell and is released from sarcoplasmic reticulum.
2. Ca^{2+} binds to calmodulin (CaM).
3. Ca^{2+}–calmodulin activates myosin light chain kinase (MLCK).
4. MLCK phosphorylates light chains in myosin heads and increases myosin ATPase activity.
5. Active myosin crossbridges slide along actin and create muscle tension.

Smooth muscle relaxation: mechanism



1. Free Ca^{2+} in cytosol decreases when Ca^{2+} is pumped out of the cell or back into the sarcoplasmic reticulum.

2. Ca^{2+} unbinds from calmodulin (CaM).

3. Myosin phosphatase removes phosphate from myosin, which decreases myosin ATPase activity.

4. Less myosin ATPase results in decreased muscle tension.