College of Medicine

SMOOTH MUSCLE

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Lec 8

- **Structure of smooth muscle:**
- Smooth muscle is distinguished anatomically from skeletal and cardiac muscle because it lacks visible cross-striations.
- In smooth muscle tissue, numerous actin filaments are anchored to dense bodies rather than Z lines, as seen in skeletal muscle. Each contractile unit comprises actin filaments extending from two opposing dense bodies, with a centrally positioned myosin filament overlapping the actin filaments.

Feature	Smooth Muscle	Skeletal Muscle
Appearance	Non-striated	Striated
Filament Organization	irregular; uses dense bodies	regular; uses Z-disc
Regulatory Proteins	Tropomyosin present; troponin absent; uses calmodulin	Contains both tropomyosin and troponin
Calcium Regulation	Calcium binds to calmodulin → activates MLCK	Calcium binds to troponin to initiate contraction
Sarcoplasmic Reticulum	Present but less extensive	Well-developed and extensive
Mitochondria	Few mitochondria	Numerous mitochondria
Energy Source	Primarily glycolysis	Primarily oxidative phosphorylation (aerobic metabolism)
Contraction Type	Slow, sustained contractions	Rapid, short-duration contractions

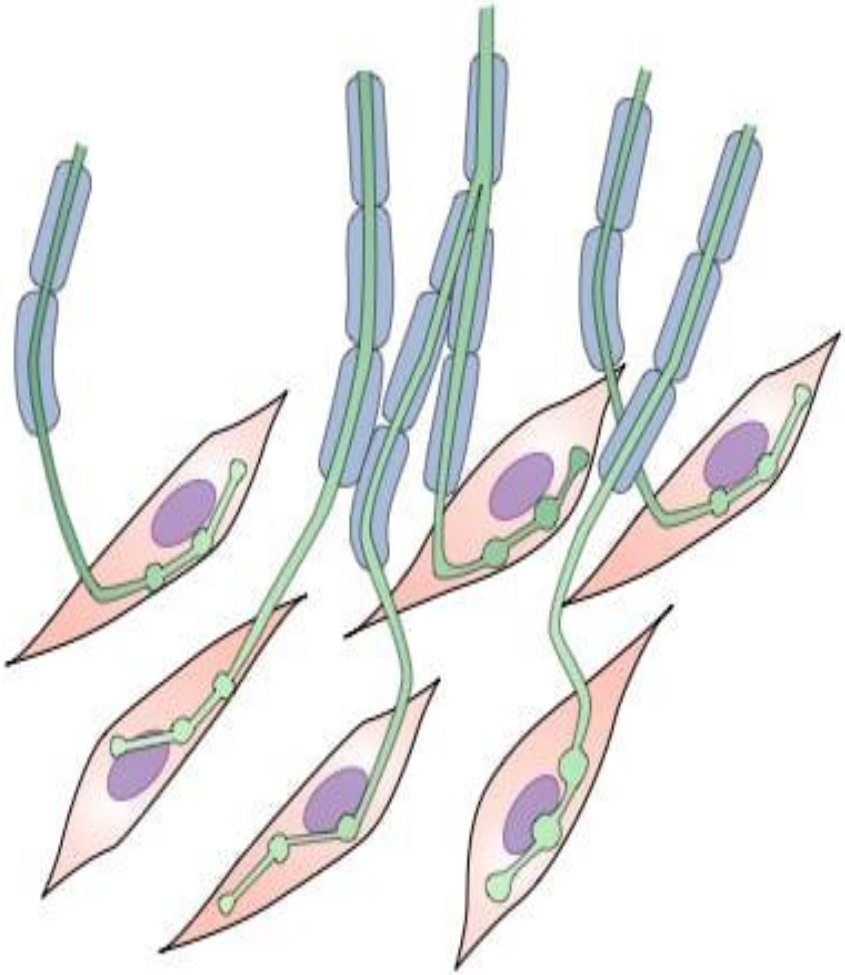
- **Types Of Smooth Muscle:**
- There is considerable variation in the structure and function of smooth muscle in different parts of the body. In general, smooth muscle can be divided **into two** types:

1. **Unitary (or visceral) smooth muscle**
2. **Multiunit smooth muscle**.

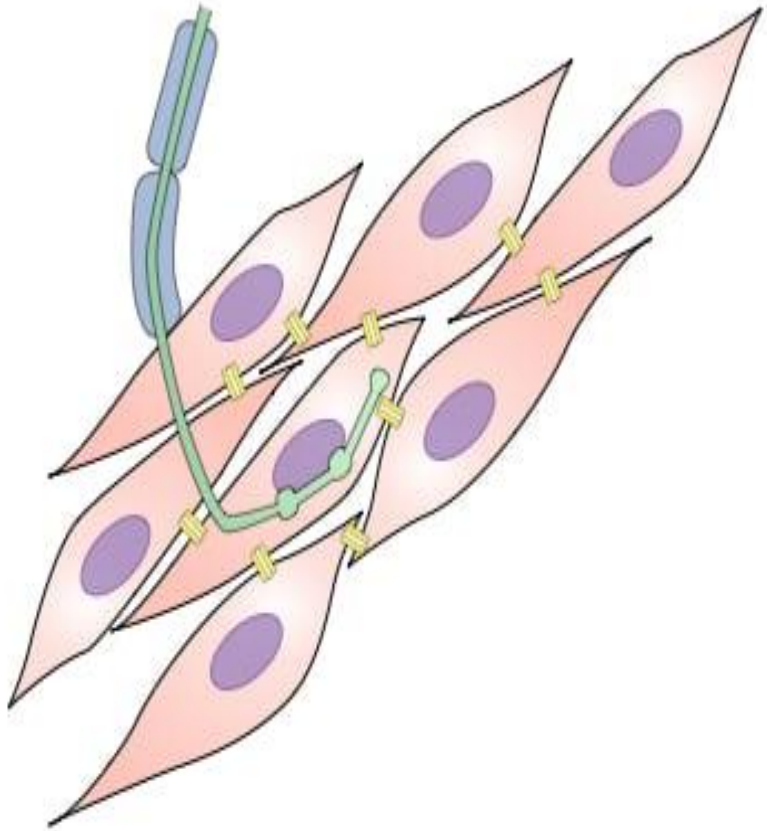
- **Unitary smooth** muscle occurs in large sheets, has many low-resistance gap junctional connections between individual muscle cells, and functions in a syncytial fashion. It consists of a mass of hundreds to thousands of smooth muscle fibers that contract together as a single unit.
- Unitary smooth muscle is found primarily in the walls of hollow viscera. The musculature of the intestine, the uterus, and the ureters.

- **Multi-unit Smooth Muscle**
- is composed of discrete, separate smooth muscle fibers with few or no gap junctions, allowing each to contract independently, similar to skeletal muscle.
- Found in areas like the iris, the piloerector muscles that cause erection of the hairs when stimulated by the sympathetic nervous system. it's controlled mainly by nerve signals, not voluntary effort.
- Blood vessels contain both unitary and multi-unit smooth muscle types.

Multiunit

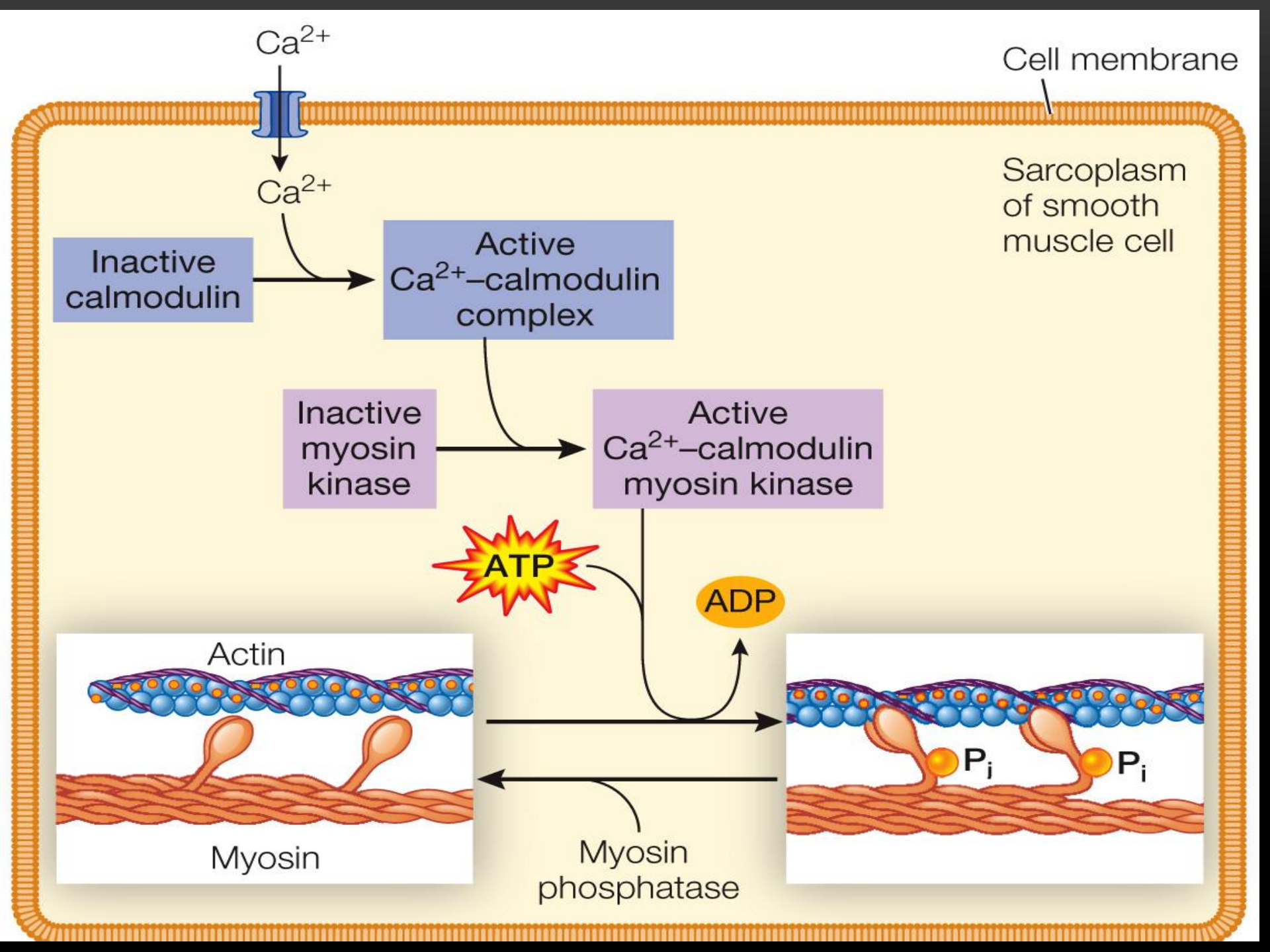


Unitary



Smooth Muscle Contraction

1. **Ca^{2+} Influx/Release**: Intracellular Ca^{2+} rises via voltage-gated or ligand-gated channels and SR release.
2. **Ca^{2+}-Calmodulin Complex**: Ca^{2+} binds to calmodulin, forming an active complex.
3. **MLCK Activation:** The Ca^{2+}-calmodulin complex activates myosin light chain kinase (MLCK).
4. **Myosin Phosphorylation:** MLCK phosphorylates the regulatory light chains on myosin heads, enhancing ATPase activity.
5. **Cross-Bridge Formation**: Phosphorylated myosin binds to actin, initiating contraction via ATP hydrolysis.
6. **Relaxation:** Myosin light chain phosphatase (MLCP) dephosphorylates myosin; Ca^{2+} is sequestered, ending contraction.

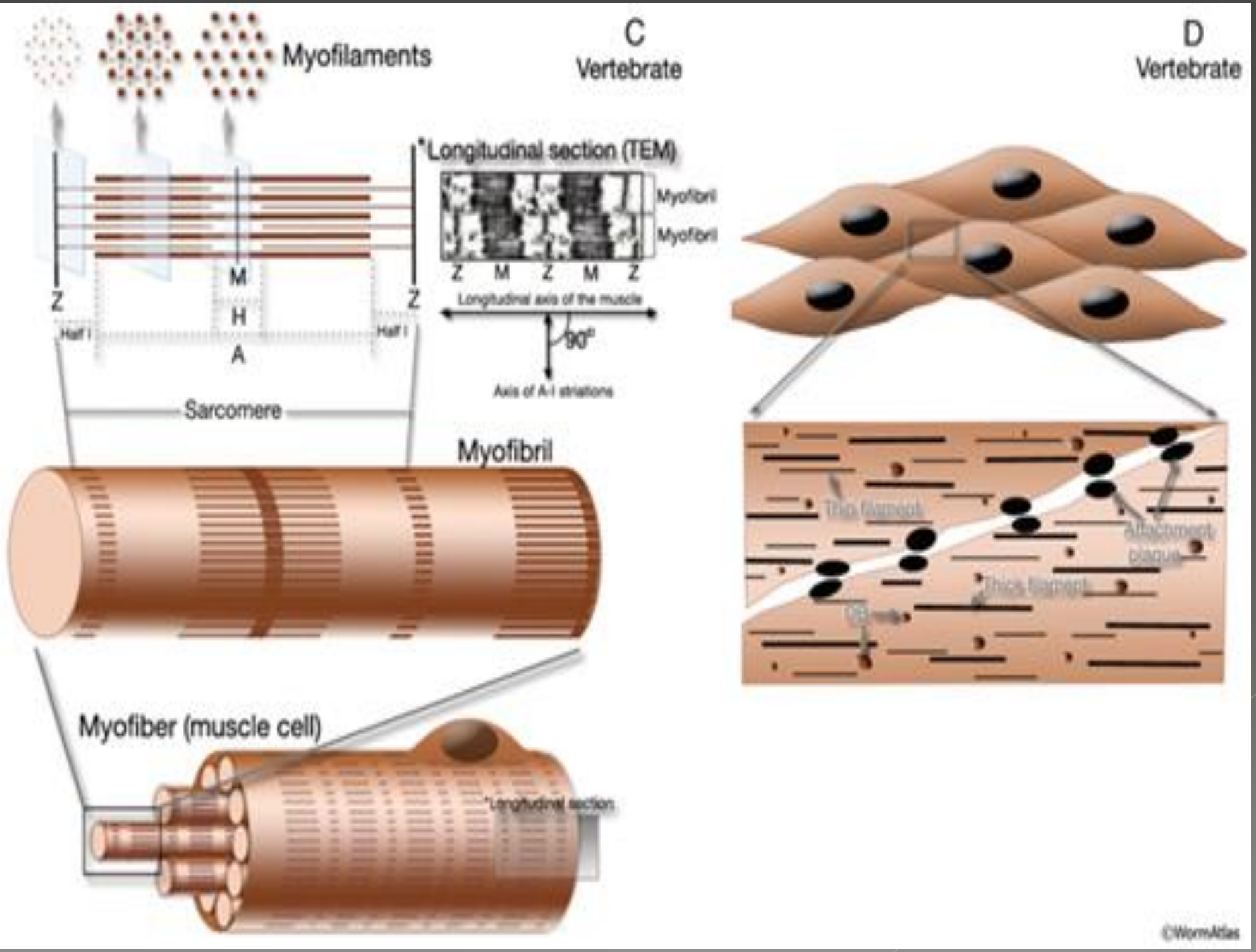

Ca^{2+}
Cell membrane
Ca^{2+}
Sarcoplasm of smooth muscle cell
Inactive calmodulin
Active Ca^{2+}–calmodulin complex
Inactive myosin kinase
Active Ca^{2+}–calmodulin myosin kinase
ATP
ADP
Actin
Myosin
P_i
P_i
Myosin phosphatase

The Latch Mechanism In Smooth Muscle:

- Refers to a physiological phenomenon that is a unique feature of smooth muscle contraction that allows the muscle to maintain force (tone) with minimal ATP consumption.
- It occurs after initial contraction, once myosin is dephosphorylated by myosin light chain phosphatase (MLCP) while still attached to actin.
- Despite dephosphorylation, myosin remains bound to actin, forming a slow-cycling cross-bridge — the latch bridge.
- This allows maintenance of tension with reduced ATP usage and Ca^{2+} levels.

- The latch mechanism occur in the following:

1. Blood vessels maintaining vascular tone.
2. Urinary bladder holding urine.
3. Esophageal sphincters staying closed.
4. Airways in the lungs regulating airflow resistance


Myofilaments
C
Vertebrate
*Longitudinal section (TEM)
Myofibril
Myofibril
Z M Z M Z
Longitudinal axis of the muscle
90°
Axis of A-I striations
Z
M
H
A
Z
Half I
Half I
Sarcomere
Myofibril
Myofiber (muscle cell)
*Longitudinal section
D
Vertebrate
Thin filament
Attachment plaque
Thick filament
©WormAtlas

Stress-Relaxation.

- Stress relaxation in smooth muscle occurs due to its unique ability to adjust tension over time despite being held at a constant length. This phenomenon is also called "plasticity" and is crucial for organs like the bladder, stomach, and intestines that need to stretch without generating high internal pressure.
- For e.g when the bladder fills with urine it first increases tension and pressure. However, over a short period (seconds to a minute), the muscle relaxes and the pressure drops back to normal, even though the muscle is still stretched.
- This allows the muscle to accommodate more volume without continuous pressure increase. When the volume increases again, the process repeats.

- Why Calcium Channels are Important in Smooth Muscle
- Calcium Does Two Jobs:

  Calcium helps create the action potential by entering the cell and depolarizing the membrane Unlike skeletal muscle, smooth muscle has many voltage-gated calcium channels and very few sodium channels .
- The influx of Ca^{2+} not only contributes to depolarization but also directly triggers contraction by increasing intracellular calcium levels. They also stay open longer, which leads to a longer-lasting action potential (called a plateau phase in some types of smooth muscle).

Control of Smooth Muscle Contraction

1. Nervous control :

- Smooth muscle is innervated by postganglionic autonomic fibers. These axons contain varicosities (axon swellings) that release neurotransmitters such as acetylcholine (ACh) or norepinephrine (NE) into the interstitial space, where they diffuse to activate receptors on the smooth muscle membrane, initiating contraction.

2. Local control:

- Non-Neuronal Activation of Smooth Muscle Contraction
- Approximately 50% of smooth muscle contraction occurs via direct stimulation of the contractile apparatus, independent of action potentials.

A. Local Tissue Chemical Factors:

Especially in vascular smooth muscle, which modulate vascular tone in response to metabolic demand:

- Hypoxia ($\downarrow O_2$) → Vasodilation
- Hypercapnia ($\uparrow CO_2$) → Vasodilation
- Acidosis ($\uparrow H^+$) → Vasodilation
- These changes promote increased blood flow to meet local tissue needs.

B. Hormones:

- Such as norepinephrine, epinephrine, oxytocin, can regulate smooth muscle contraction. The effect depends on the type of receptors on the muscle cell membrane:
- Excitatory receptors (e.g., α-adrenergic receptors for norepinephrine) cause contraction.
- Inhibitory receptors (e.g., β-adrenergic receptors for epinephrine) cause relaxation.
- These hormonal influences help control functions like blood flow, organ contraction, and labor.