

# PHYSIOLOGY



Lec:

28 + 29

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**General physiology**  
**Second semester 2023/2024**  
**Lecture 28 and L 29**

**Excitation and Contraction in smooth muscle  
and properties of smooth muscle contraction**

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# فرقے اور contraction میں اختلافات


① Involuntary

② Argument actin + myosin

③  $Ca^{+2}$  bind protein

actin > myosin  
↑

# Smooth Muscle Anatomical features

- Spindle shape 
- Cells are not striated *→ No specific argument*
- Fibers smaller than those in skeletal muscle 1 to 5 micrometers in diameter and only 20 to 500 micrometers in length. (*actin and myosin in smooth muscles are not arranged parallelly.*)
- single, centrally-placed nucleus

• **More actin than myosin**

• **No sarcomeres**

• Not arranged as symmetrically as in skeletal muscle, thus no striations.

• Dense bodies instead of Z disks *→ α-Actinin that connects actin to myosin*

• Contraction is non-voluntary *→ contraction لا إرادية*

• Contraction is modulated in a neuroendocrine (**neurotransmitter and hormones**) *motor neurons*

• **Types of smooth muscles**

- Unitary (single) smooth muscles
- Multiunit unit smooth muscles

Smooth muscle contraction  
حركات انقباض العضلات

Continuous contraction

بيننا الخلايا  
عنا الطبقة من الـ collagen  
والـ glycoprotein تغليف الـ SM  
عنه يعلمهم

1

بالزمن تُضيق  
كل خلية على حدة  
حتى يبرز عنا Contraction

# Multiunit Smooth Muscles

كل Smooth muscle تتخللها لحالها

• Different innervation

- Composed of discrete, separate smooth muscle fibers
- Each fiber operates and contract independently of the others, and often is innervated by a single nerve ending, as occurs for skeletal muscle fibers thus independent motor units
- Furthermore, the outer surfaces of these fibers, like those of skeletal muscle fibers, are covered by a thin layer of basement membrane-like substance, a mixture of fine collagen and glycoprotein that helps insulate the separate fibers from one another
- Important characteristics of multi-unit smooth muscle fibers are that each fiber can contract independently of the others, and their control is exerted mainly by nerve signal
- No coupling, no gap junctions.

لا يوجد تقنوت ايونية بين الخلايا

# Multiunit Smooth Muscles

Secrete NT that stimulate or inhibit smooth muscles

- Muscle fibers are heavily innervated by postganglionic fibers of the parasympathetic and sympathetic nervous systems, and it is these innervations that initiates their contraction and relaxation

Stimulation

- Contract only in response to its innervation and their control is exerted mainly by nerve autonomic signals

- Examples of multi-unit smooth muscle

- are the ciliary muscle of the eye, the iris muscle of the eye
- Piloerector muscles that cause erection of the hairs when stimulated by the sympathetic nervous system

excitatory → contraction  
inhibitory → relaxation

type of NT }  
type of receptor } AS ١٢٣٤٥

وین بکونیا  
multi-unit  
Smooth  
موسکول  
فیبر

also innervated by autonomic NS

4 مصطلحات لنفس  
الإشبي [بشغلوا كوصة  
واحدة

# Unitary or Single unit Smooth Muscles (Syncytial Smooth Muscle, Visceral Smooth Muscle)

→ found in GI

- Single units means :a mass of hundreds to thousands of smooth muscle fibers that contract together as a single unit.
- The fibers usually are arranged in sheets or bundles, and their cell membranes are adherent to one another at multiple points so that force generated in one muscle fiber can be transmitted to the next.

cell membrane  
المغلفات  
التي تبعد  
AP في خلية ينتقل لخلية

found in unitary  
but not work with  
to work as unit  
ion channel that  
transfers  $Na^+$ ,  $Ca^{2+}$   
between cells to  
transmit AP

• **Gap junctions** : Impulse (action potentials ) spreads through gap junctions

→ generate AP without stimulation (pacemaker)

• Often muscle cells are **autorhythmic** and exhibit spontaneous **pacemaker activity**, or slow waves depolarization

• The frequency of slow waves sets the pattern of action potentials within an organ, which then determines the frequency of contractions

اکثر ٹولج  
منہ ال  
multi-unit

## Unitary or Single unit Smooth Muscles (*Syncytial Smooth Muscle, Visceral Smooth Muscle*)

- Is innervated by autonomic nervous system (ANS).
- Muscle cells activity is modulated by ANS or hormones
- This type of smooth muscle is also known as syncytial smooth muscle because of its syncytial interconnections among fibers.
- Also called visceral smooth muscle because it is found in the walls of most viscera of the body, including the gastrointestinal tract, bile ducts, ureters, uterus, and many blood vessels , air ways and bladder.

Single unit  
SM



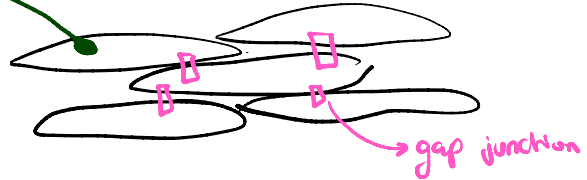
Mult unit  
Smooth  
muscle



Single unit  
Smooth  
muscle

Autonomic  
neuron

هم نعرف  
أماكن تواجد  
كل نوع



\* ال Autonomic neuron يكون متصلا بخلية واحدة فقط.  
\* بجزئها ال autolythmal, OR pace maker

\* ال Autonomic neuron يكون متصلا بكل خلية

\* كل خلية يتحفز بكاملها

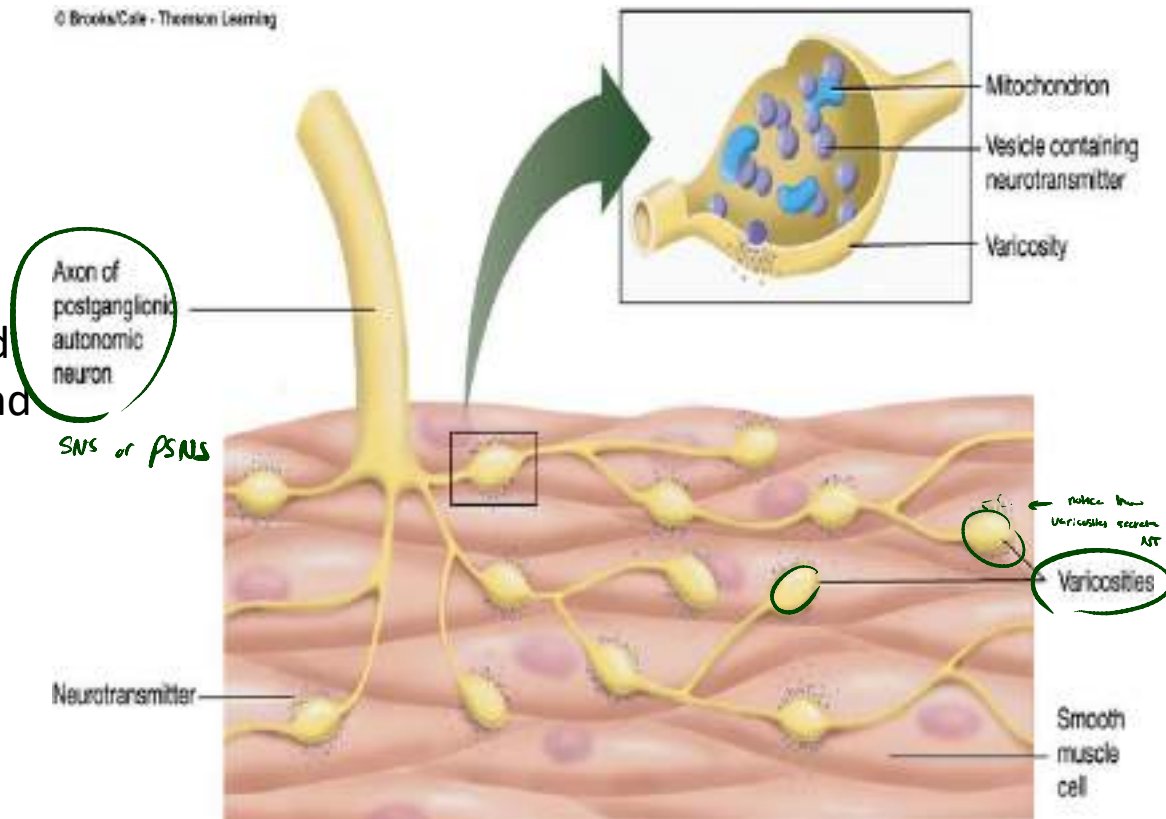
# Nervous and Hormonal Control of Smooth Muscle Contraction

- Unlike skeletal muscle which are excited by motor neurons signals, smooth muscle can be stimulated to contract by nervous signals, hormonal stimulation, stretch of the muscle.
- The principal reason for the difference is that the smooth membrane contains many types of receptor proteins that can initiate the contractile process. Still other receptor proteins inhibit smooth muscle contraction, which is another difference from skeletal muscle.

# Endings of postganglionic autonomic neurons on smooth muscle

The nerve fibers run along the membranes of the smooth muscle cells and sometimes groove their surfaces. The multiple branches of postganglionic neurons are beaded with enlargements (varicosities) and contain synaptic vesicles.

Neurotransmitter is released from the varicosities and diffuses to receptors on smooth muscle cell plasma membranes



# Neuromuscular Junction at smooth muscles

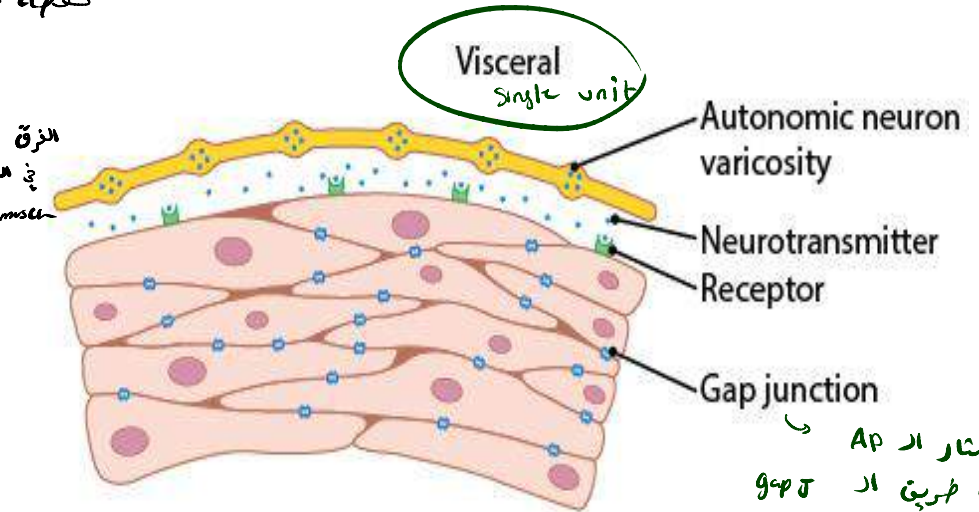
Smooth muscle و Autonomic Neuron بينہ از اتصال نقطہ

## Major points

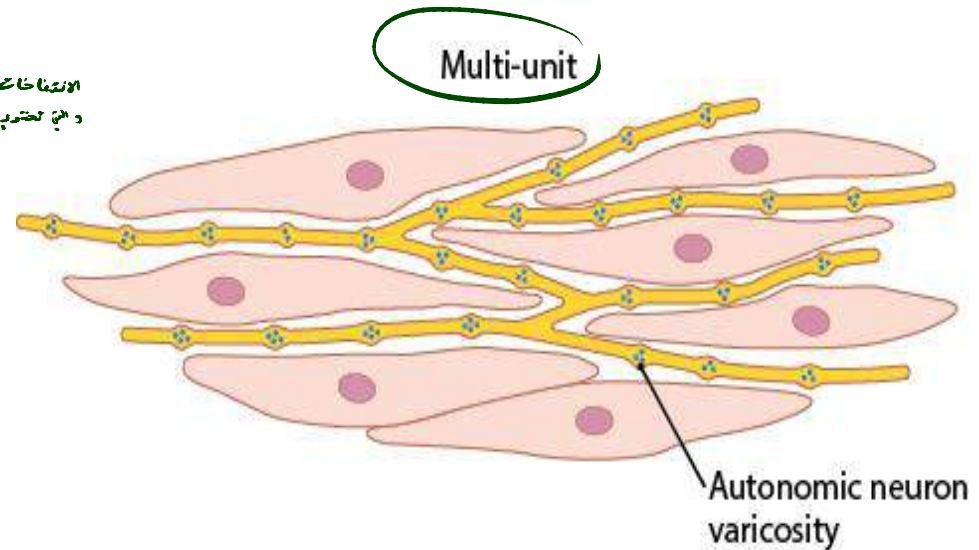
- Less complex and less well understood compared to Skeletal muscles
- Autonomic nerve fibers branch and form “diffuse junctions” with underlying smooth muscle fibers.
- **Varicosities** in the terminal axons contain neurotransmitter
- Neurotransmitter is secreted into the matrix coating and diffuses to the muscle cells
- Acetylcholine and NE are the neurotransmitters

الزرق بينہ از NMF  
في ال Smooth muscle  
vs skeletal muscle

الانتفاخات في ال  
الزرق  
و التي تحتوي على ال  
NT



انتشار ال AP  
عن طريق ال gap



# Contact junctions of in multiunit smooth muscles

- In multi-unit type of smooth muscle, the varicosities are separated from the muscle cell membrane by as little as 20 to 30 nanometers—the same width as the synaptic cleft that is found in the skeletal muscle junction.
- These are called contact junctions, and they function in much the same way as the skeletal muscle neuromuscular junction.
- The rapidity of contraction of these smooth muscle fibers is considerably faster than that of fibers stimulated by the diffuse junctions

# Smooth Muscle Sarcoplasmic Reticulum

Stores  $Ca^{2+}$

- A few slightly developed sarcoplasmic tubules that lie near the cell membrane in some larger smooth muscle cells.

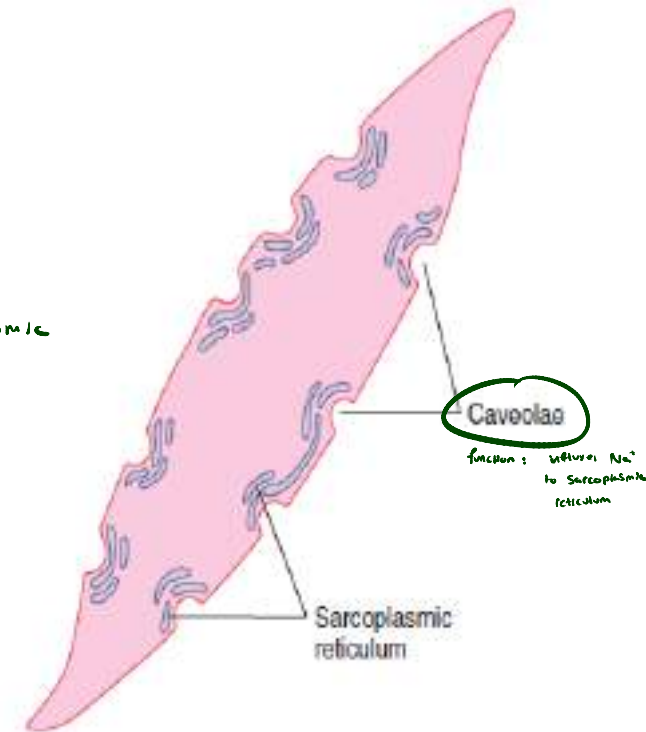
- No T tubule  $\Rightarrow$  No T-tubule

- **Caveolae** : Small invaginations of the cell membrane, called *caveolae*, neighboring surfaces of sarcoplasmic reticulum

- The caveolae suggest a rudimentary analog of the transverse tubule system of skeletal muscle.

- When an action potential is transmitted into the caveolae, is believed to excite calcium ion release from the adjacent sarcoplasmic

$\uparrow\uparrow$  intracellular  $Ca^{2+}$



# DEPOLARIZATION OF MULTI-UNIT SMOOTH MUSCLE WITHOUT ACTION POTENTIALS

- Multi-unit smooth muscle (examples smooth muscle of iris such as the muscle of the iris of the eye or the piloerector muscle of each hair)
- Normally contract in response to nerve stimuli.
- Autonomic nerve endings secrete acetylcholine smooth muscles and norepinephrine in the case of others.
- Neurotransmitter <sup>SNS</sup> depolarization of the smooth muscle membrane, and this depolarization in turn elicits contraction.
- Action potentials **usually do not develop** because the fibers are too small to generate an action potential.
- Thus local depolarization (called the *junctional potential*) caused by neurotransmitter substance itself spreads “electrotonically” over the entire fiber causing muscle.

PSNS

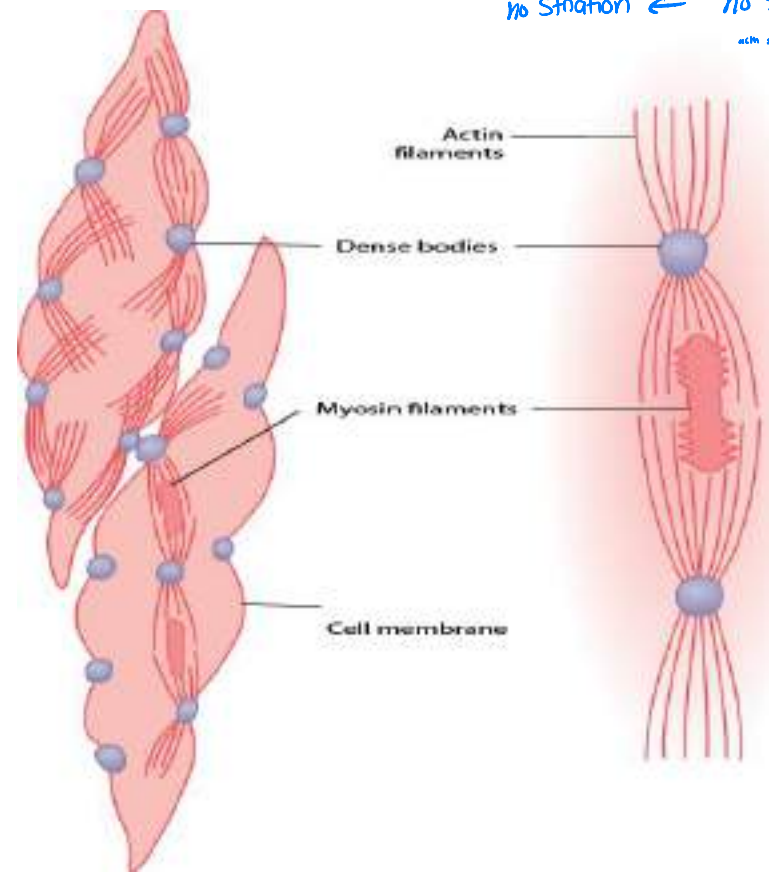
SNS

→ local depolarization that doesn't reach threshold to generate AP in multi-unit smooth muscle

## Contractile elements of smooth muscle ⇒ *سکون و حرکت* *Contraction*

سکون و حرکت  
Smooth muscle  
No striation ← No symmetry +  
actin of myosin 2  
مکانه سکون و حرکت 2

- Contains both *actin* and *myosin filaments*, similar to those of the actin and myosin filaments in skeletal muscle
- Interspersed among the actin filaments in the muscle fiber are myosin filaments. These filaments have a diameter more than twice that of the actin filament
- 5 to 10 times as many actin filaments as myosin filaments are usually found
- No regulatory arrangements in skeletal muscle
- No striation
- No troponin





- **Dense bodies in smooth muscles**

- Membrane associated and cytoplasmic dense bodies containing  $\alpha$  actinin (similar to Z lines in skeletal muscles)
- Some of these bodies are attached to the cell membrane, and others are dispersed inside the cell.
- Some of the membrane-dense bodies of adjacent cells are bonded together by intercellular protein bridges. It is mainly through these bonds that the force of contraction is transmitted from one cell to the next.

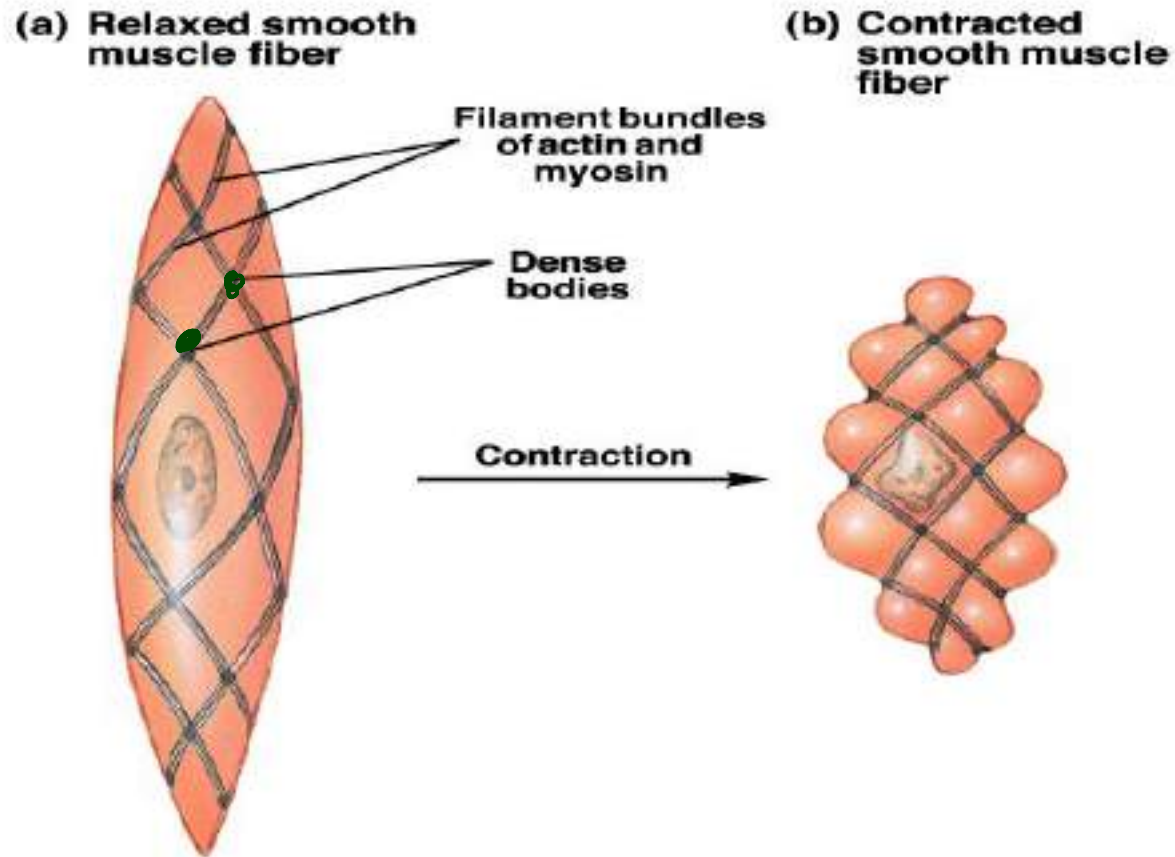
- **Contractile process**

- The contractile process is activated by calcium ions, and adenosine triphosphate (ATP) is degraded to adenosine diphosphate (ADP) to provide the energy for contraction
- Different mechanism of contraction, however contraction involve interaction of actin and myosin

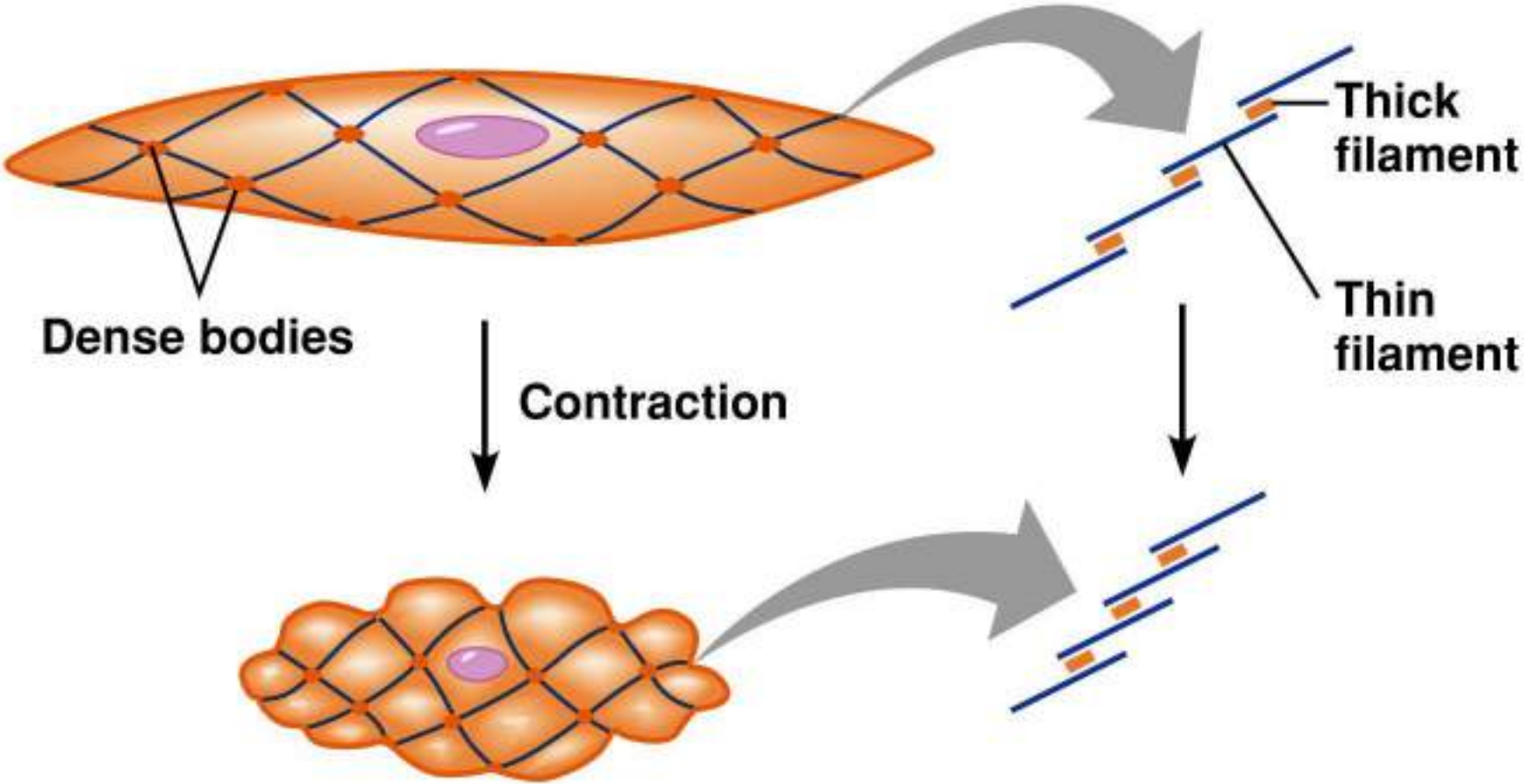
\* The mechanism of contraction in smooth muscles is different than skeletal muscle contraction mechanism.

actin  $\alpha$   $\rightarrow$  myosin  $\beta$   $\rightarrow$  smooth contraction  $\beta$   $\rightarrow$  skeletal contraction  $\beta$   $\rightarrow$   $\alpha$   $\rightarrow$   $\beta$

# Contractile fibers are arranged in oblique bundles rather than in parallel sarcomeres



# Smooth Muscle Cell



# Myosin of Smooth Muscle contractile elements

مختلف عن skeletal muscle  
بأنه skeletal muscle مختلف

شکل آخر

- Different isoform than that found in skeletal muscle
- Smooth muscle myosin ATPase activity is much slower, contraction is longer
- Myosin light chain in the myosin head regulates contraction and relaxation

velocity → duration →  
contraction → contraction  
↑ velocity ← ↓ duration ← ATPase activity

↓ velocity ← ↑ contraction time ← ATPase activity  
بال Smooth muscle

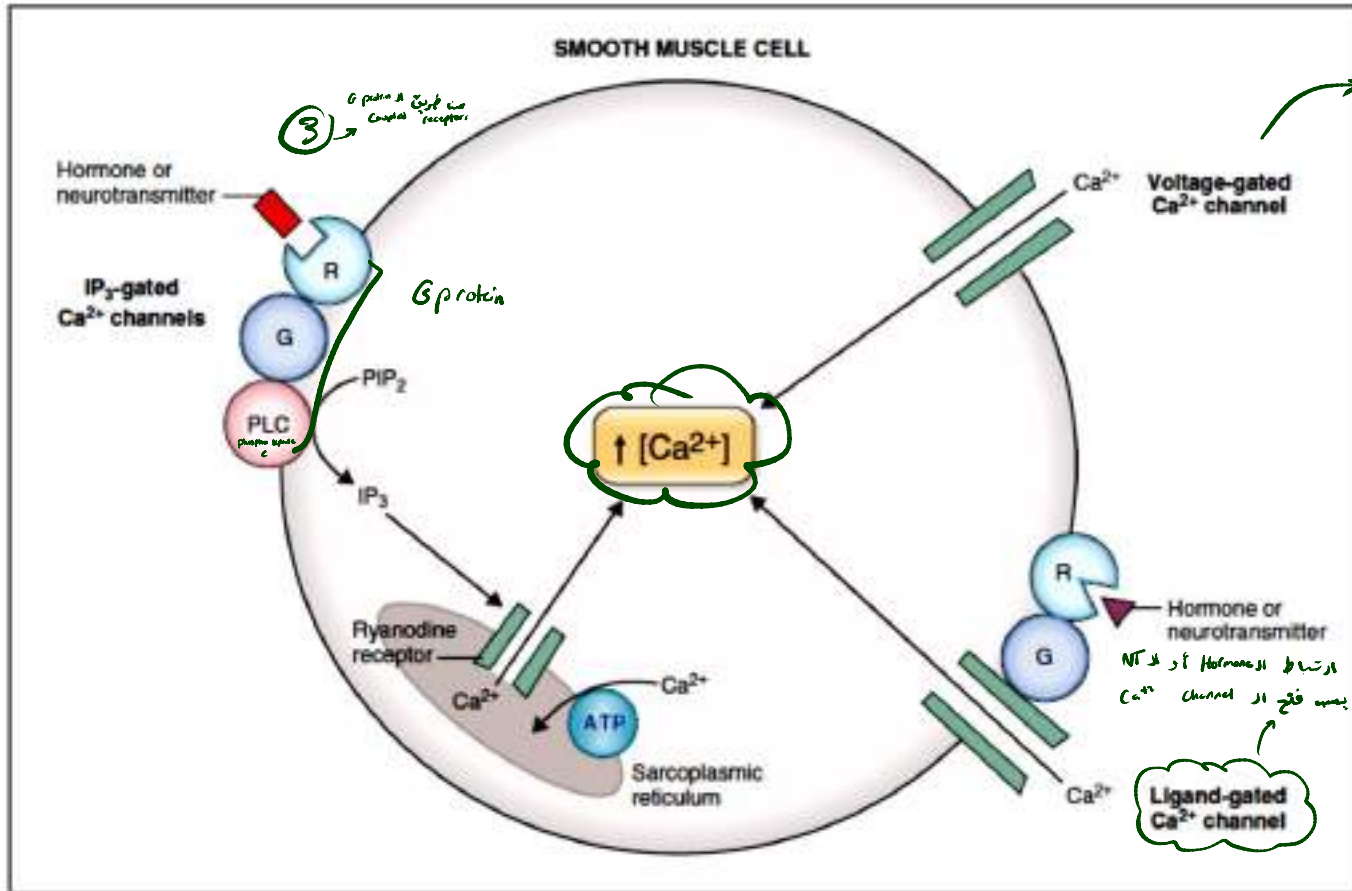
↳ 2 light chains  
+  
2 heavy chains

• Biochemical reaction ⇒ contraction

# Regulation of Contraction of smooth muscles by Calcium Ions

- Initiating stimulus for most smooth muscle contraction is an increase in intracellular calcium ions.
- This increase can be caused in different types of smooth muscle by nerve stimulation of the smooth muscle fiber, hormonal stimulation, stretch of the fiber, or even changes in the chemical environment of the fiber (Local factors )
- Smooth muscle does not contain troponin,. Instead, smooth muscle contraction is activated by an entirely different mechanism
- Calcium Ions Combine with Calmodulin to Cause Activation of Myosin Kinase and Phosphorylation of the Myosin Head
- Calmodulin initiates contraction by activating the myosin cross-bridges

# Mechanisms for increasing intracellular $[Ca^{2+}]$ in smooth muscle.



ATP, Adenosine triphosphate; G, GTP-binding protein (G protein); IP<sub>3</sub>, inositol 1,4,5-triphosphate; PIP<sub>2</sub>, phosphatidylinositol 4,5-diphosphate; PLC, phospholipase C; R, receptor for hormone or neurotransmitter