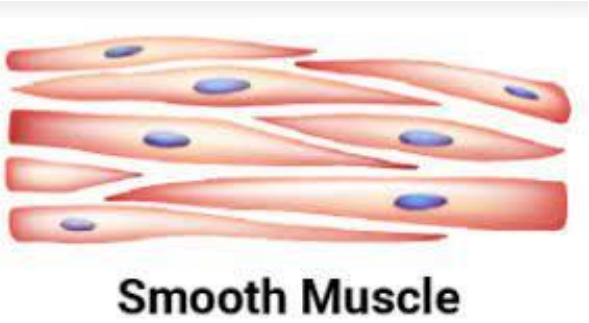
Ashur University
College of Medicine

Grade 2
Neuroscience

Physiology of Nervous System

Smooth Muscles



Ass. Professor Internal Medicine

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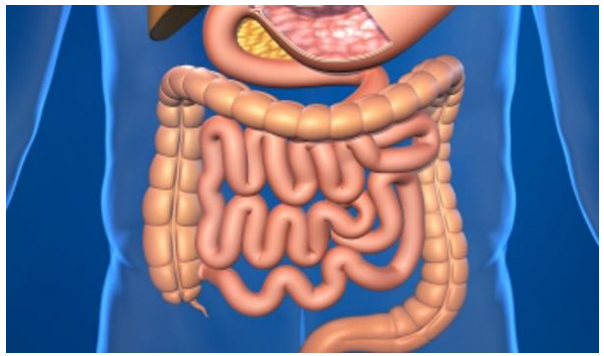
21/10/2024



Objectives:

1-Describe the morphology of smooth muscles.

2-Recognize the types of smooth muscles and their properties.

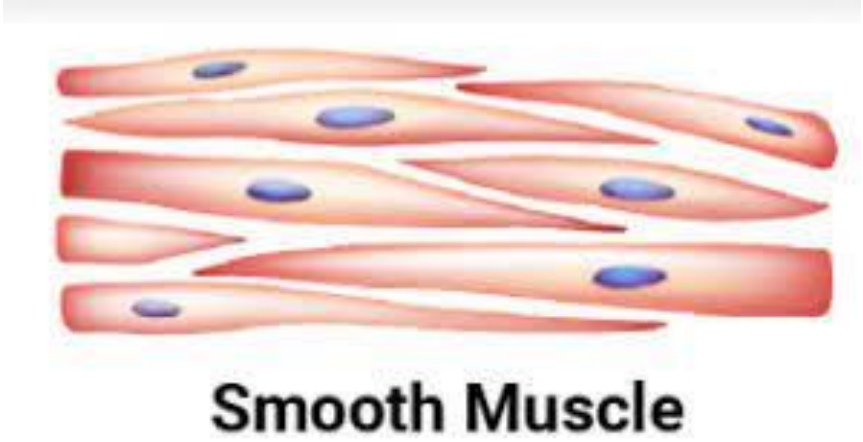
3-List the steps in smooth muscle contraction.

4-Outline the factors affecting smooth muscle contraction.

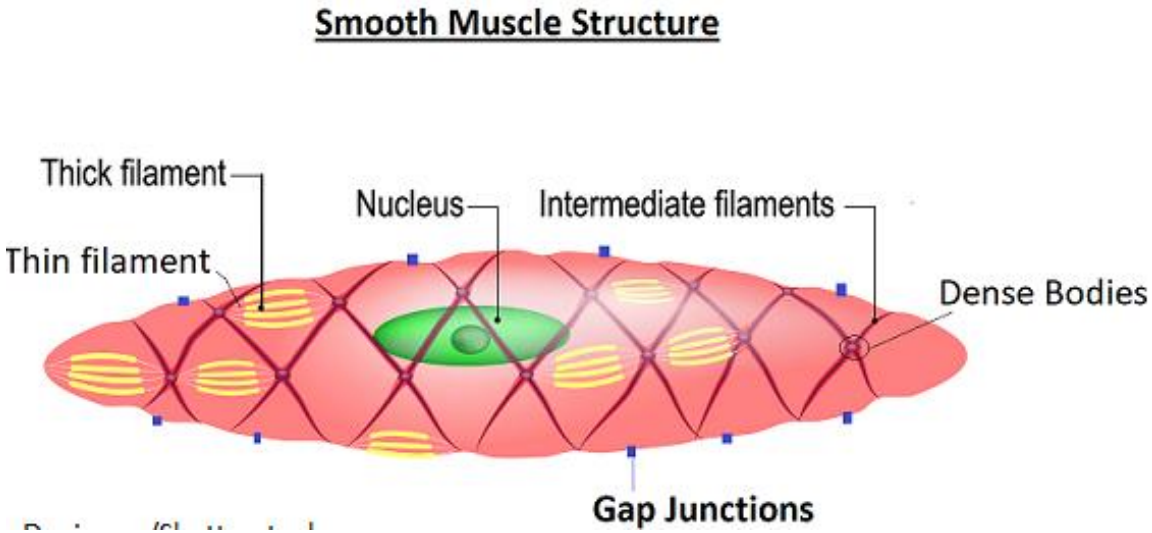
5-Describe the relation between changing length and tension.

Morphology:

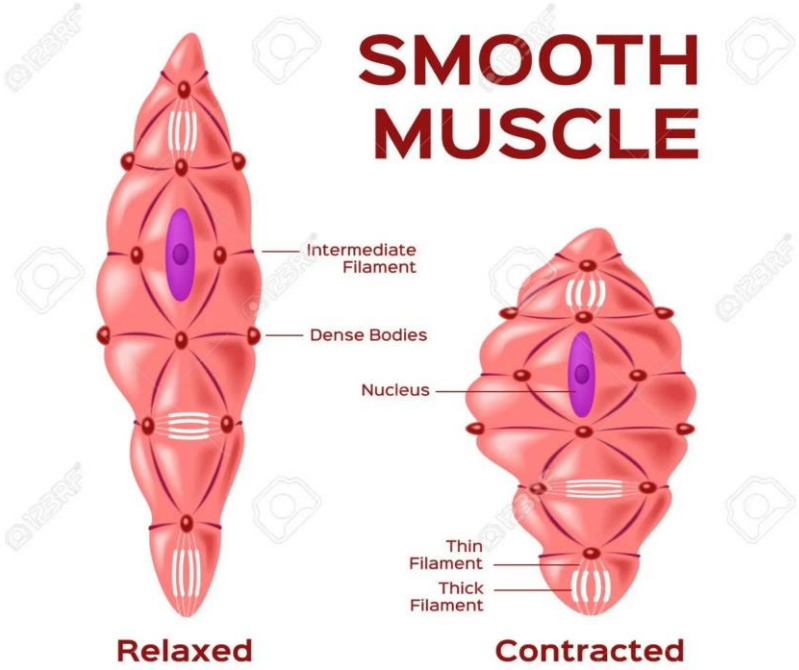
- Smooth muscle is distinguished from skeletal and cardiac muscle because it **lacks visible cross-striations**.
- **Involuntary**, **non-striated muscle**.
- Smooth muscle cells are typically **spindle-shape**.
- **Actin and myosin-II are present**, and they slide on each other to produce contraction. However, they are not arranged in regular arrays, as in skeletal and cardiac muscle, and so the **striations are absent**.

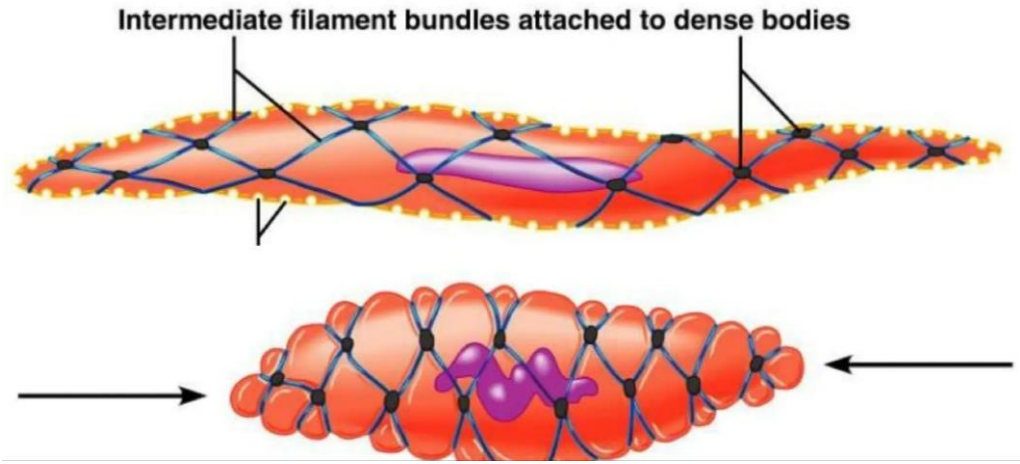


Smooth Muscle

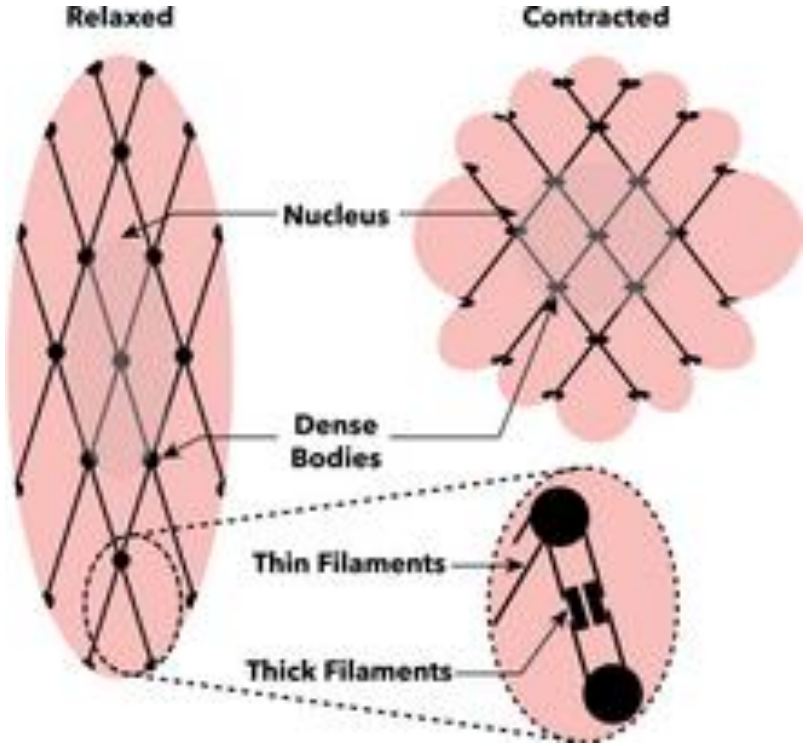


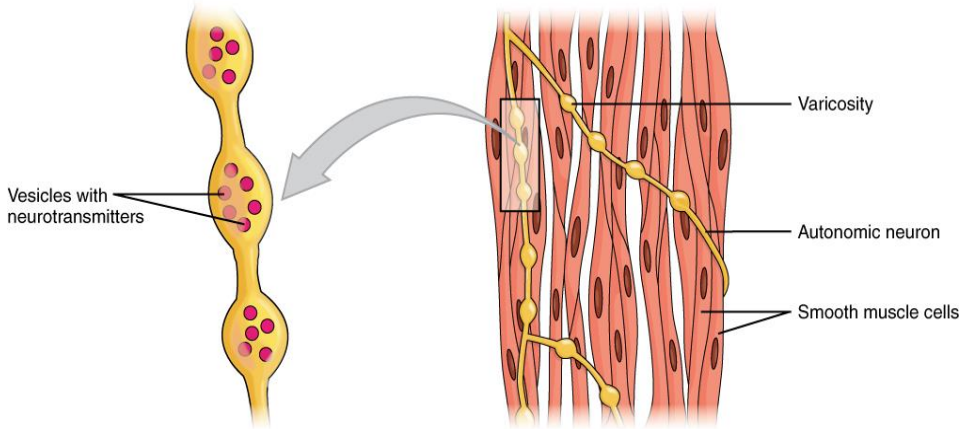
- **Instead of Z-lines**, there are **dense bodies** in the cytoplasm and attached to the cell membrane, and these are bound by α-actinin to actin filaments
- Smooth muscle also **contains tropomyosin**, but **troponin appears to be absent**.
- A sarcoplasmic reticulum is present, but **poorly developed sarcoplasmic reticulum**.
- In general, smooth muscles contain **few mitochondria** and **depend, to a large extent, on glycolysis** for their metabolic needs.





- **T-tubules are not required to reach the interior of the cell and therefore not necessary to transmit an action potential deep into the fiber**. Smooth muscle fibers have a limited calcium-storing sarcoplasmic reticulum, but **have calcium channels in the sarcolemma**, that open during the action potential.
- **Axons of neurons in the Autonomic Nervous System (ANS)** 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.



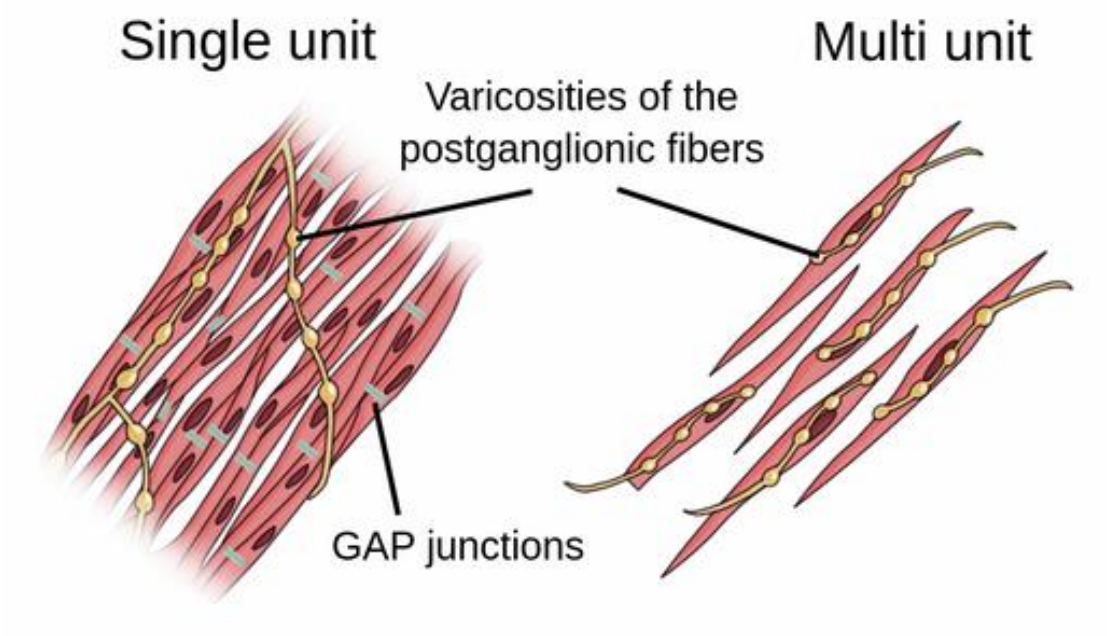


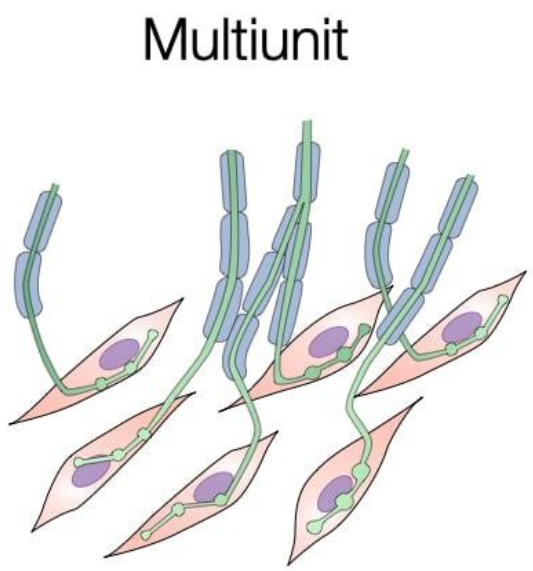
Types of smooth muscles

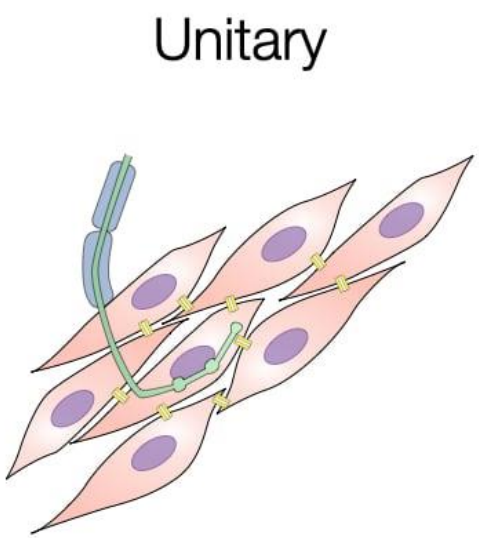
2 Types:

1-Unitary (or visceral) smooth muscle.

2-Multiunit smooth muscle.



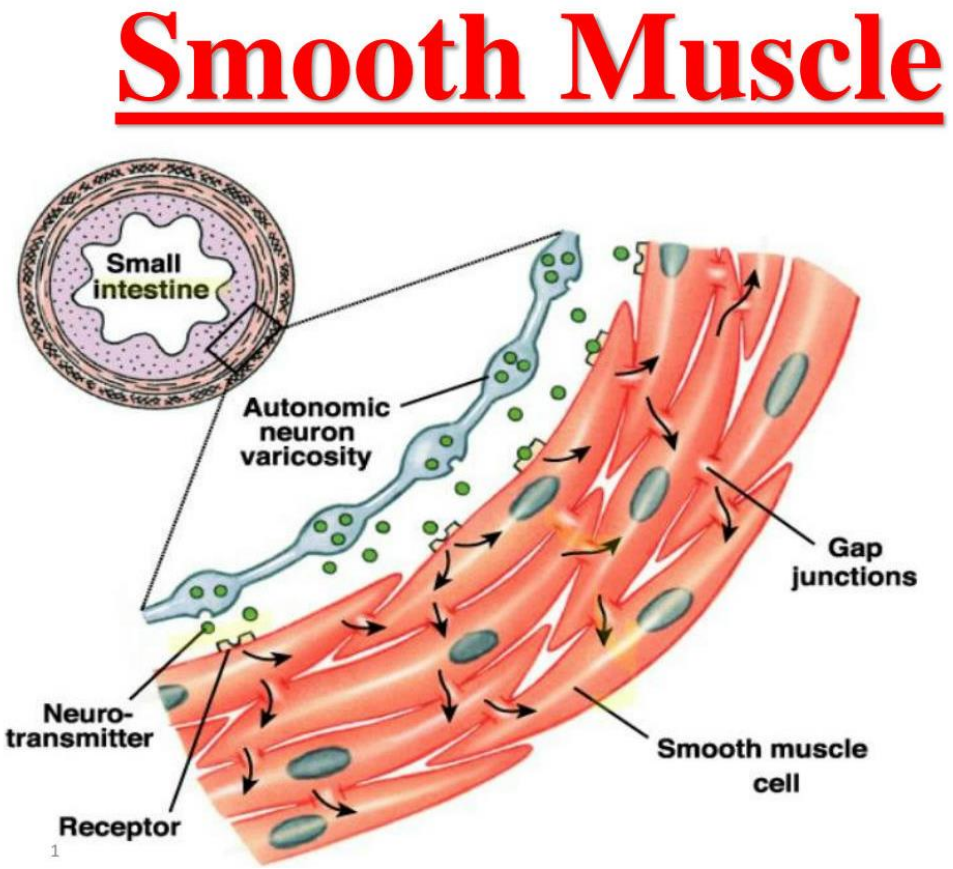




Unitary or visceral smooth muscles (or syncytial smooth muscles):

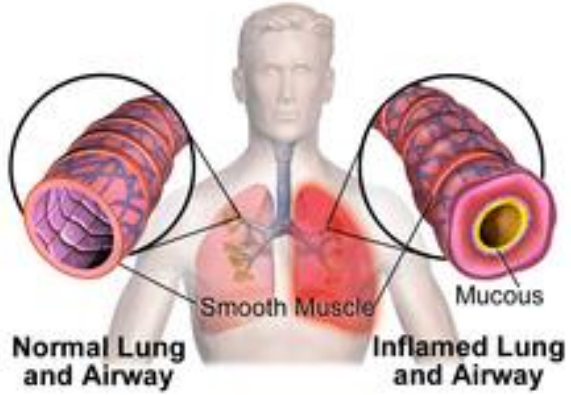
- It is found on the **walls of hollow organs** in the **digestive tract**, **urinary tract**, and **reproductive system**.
- It occurs in large sheets, has low-resistance bridges between individual muscle cells, and **functions in a syncytial fashion**, they contract together as a **single unit**.
- **Gap junctions** through whom

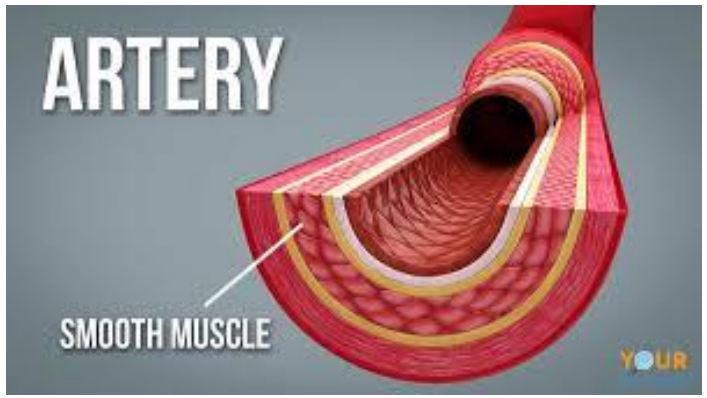
ions can flow freely.

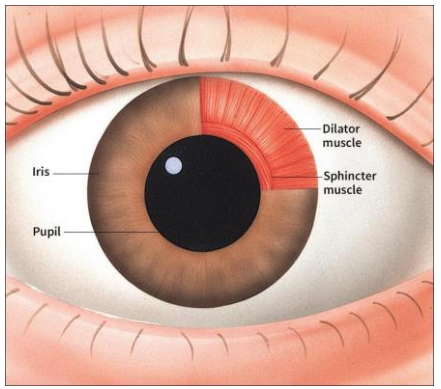


Multi-unit smooth muscle:

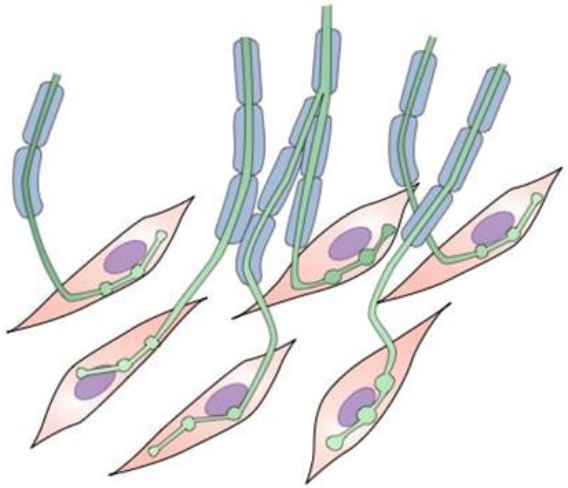
- **Multiunit smooth muscle** is made up of individual units with few (or no) gap junctional bridges.
- Multi-unit smooth muscle is found in the **airways of the lungs**, **large arteries**, and **ciliary muscles of the eye**.
- It is found in structures such as the **iris of the eye**, in which fine, graded contractions occur. It is not under voluntary control.
- **Blood vessels have both unitary and multiunit smooth muscle in their walls**.







Multiunit



CLASSIFICATION OF SMOOTH MUSCLES

- **AP**:

Action **p**otential

- **NT**:

Neuro-

Transmitter

UNITARY/ SINGLE UNIT/SYNCYTIAL/VISCERAL

1. Muscles of visceral organs .e.g. GIT, uterus, ureters & some of the smaller blood vessels.
2. Form a sheet or bundles of tissue.
3. Cell membranes show gap junctions that allows AP to pass rapidly from cell to cell.
4. AP spreads rapidly throughout the sheet of cells – ***cells contract as a single unit.***

MULTI-UNIT

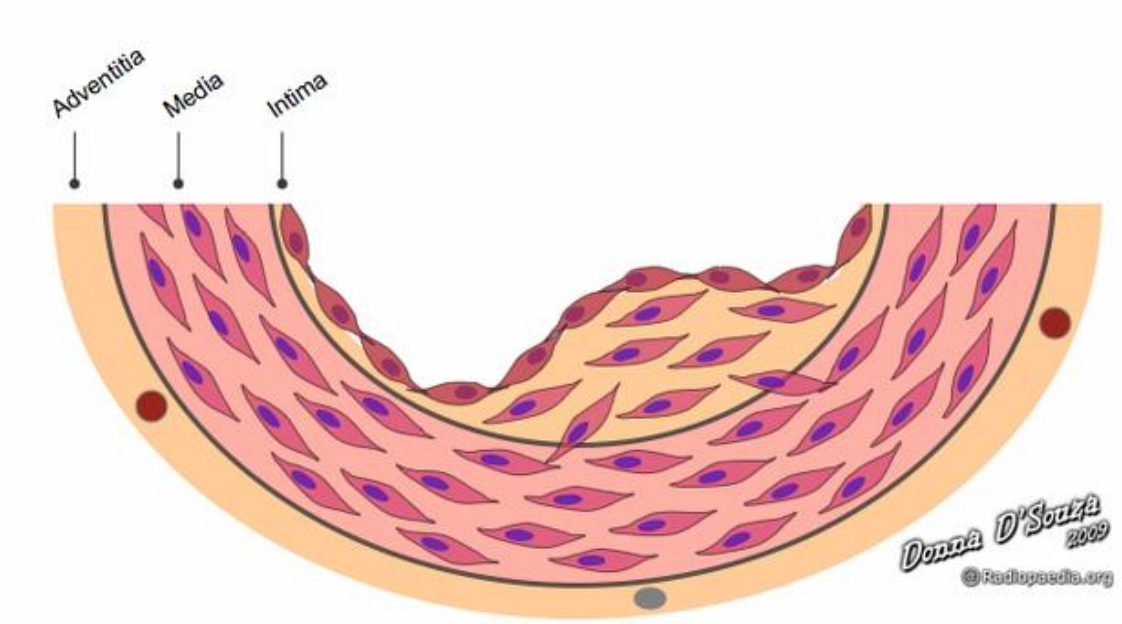
1. Iris & Ciliary body of the eye, large arteries, Piloerector muscles
2. Showing discrete, individual smooth muscle fibers.
3. Smooth muscle cells not electrically linked. Each muscle fiber innervated by a single nerve ending. NT itself can spread and lead to an AP.
4. Selective activation of each muscle fiber that can then contract independently of each other.

Hyperplasia in Smooth Muscle

- Similar to skeletal and cardiac muscle cells, **smooth muscle can undergo hypertrophy to increase in size.** Unlike other muscle, smooth muscle can **also divide to produce more cells, a process called hyperplasia**. This can most evidently be observed **in the uterus at puberty**, which responds to increased estrogen levels by producing more uterine smooth muscle fibers, and greatly increases the size of the myometrium.
- e.g **vascular smooth muscle cells**

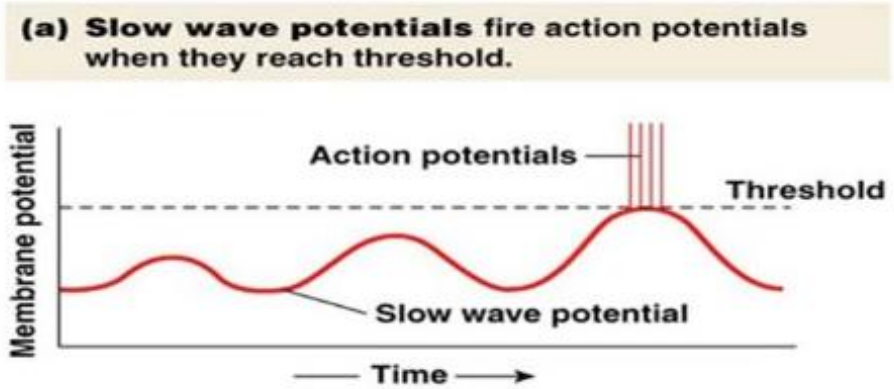
provoked by

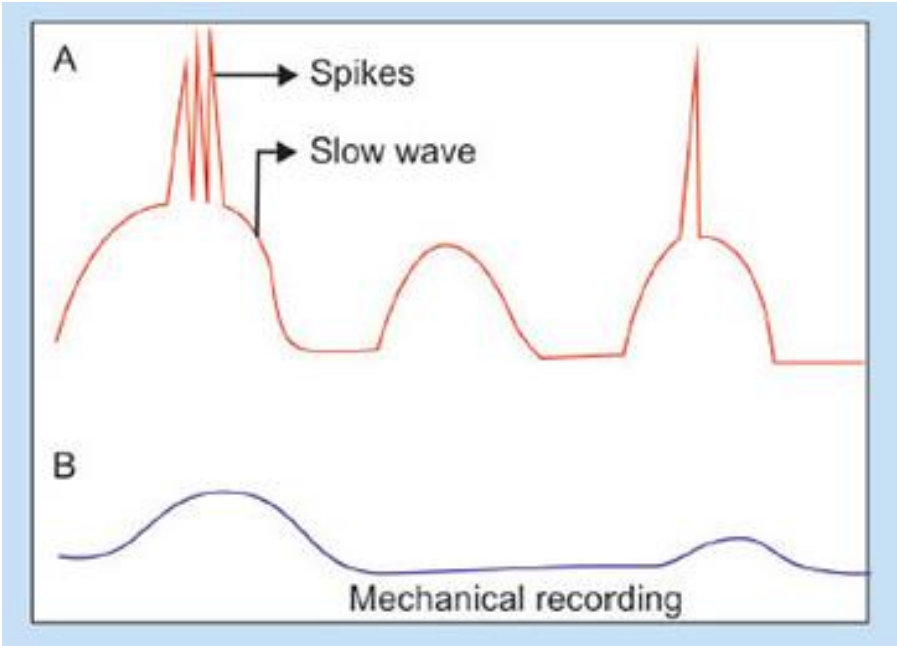
injury, inflammation, and stretch.



Electrical & Mechanical Activity:

- **Unitary smooth muscle** is characterized by the instability of its membrane potential and by the fact that it shows **continuous, irregular contractions** that are independent of its nerve supply. This maintained state of partial contraction is called **tonus**, or **tone**. The membrane potential has no true "resting" value, being relatively low (or less negative) when the tissue is active and higher (or more negative) when it is inhibited.
- **Smooth muscle cells can display divergent electrical activity** .**There are slow sine wave-like fluctuations** a few millivolts in magnitude and **spikes** that sometimes overshoot the zero potential line and sometimes do not.





Superimposed on the membrane potential are waves of various types:

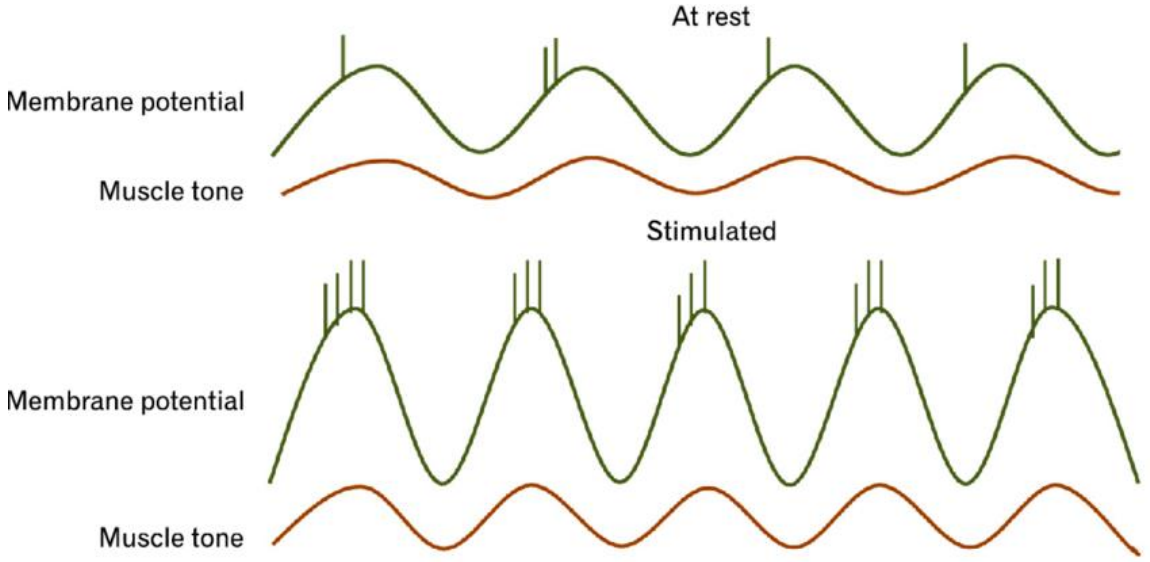
- **Slow sine wave-like**

The slow waves are, able to allow the smooth muscle to remain tonic without having to maintain continuous action potential firings.

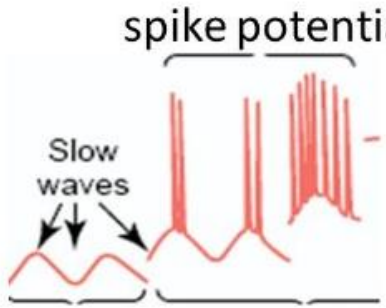
Slow wave are unique for GI muscles.

- **Sharp spikes**
- **Pacemaker potentials**

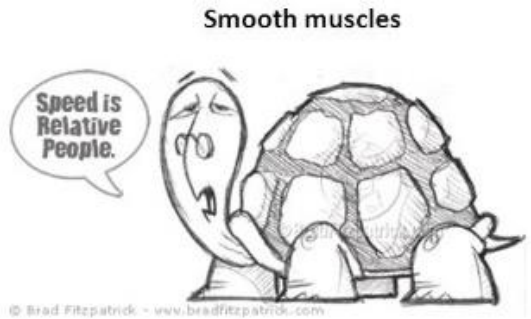
Thus, the **excitation-contraction coupling in visceral smooth muscle is a very slow process compared with that in skeletal and cardiac muscle**, in which the time from initial depolarization to initiation of contraction is less than 10 ms.



- Slow waves
- Spike potentials







Smooth muscle dysfunction

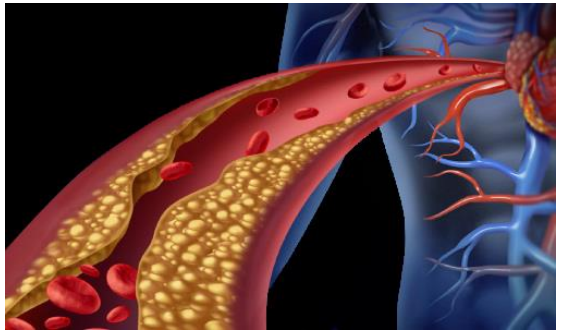
forms the molecular basis of many common diseases including

The cardiovascular system (systemic and pulmonary hypertension as well as heart failure),

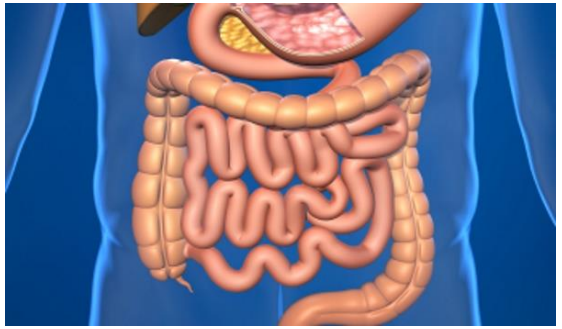
The respiratory system (asthma),

The gastrointestinal system (gastrointestinal dysmotility and inflammatory bowel diseases),

The genitourinary system (genito-urinary and bladder dysfunction as well as uterine dysfunction and the associated disorders of pregnancy)









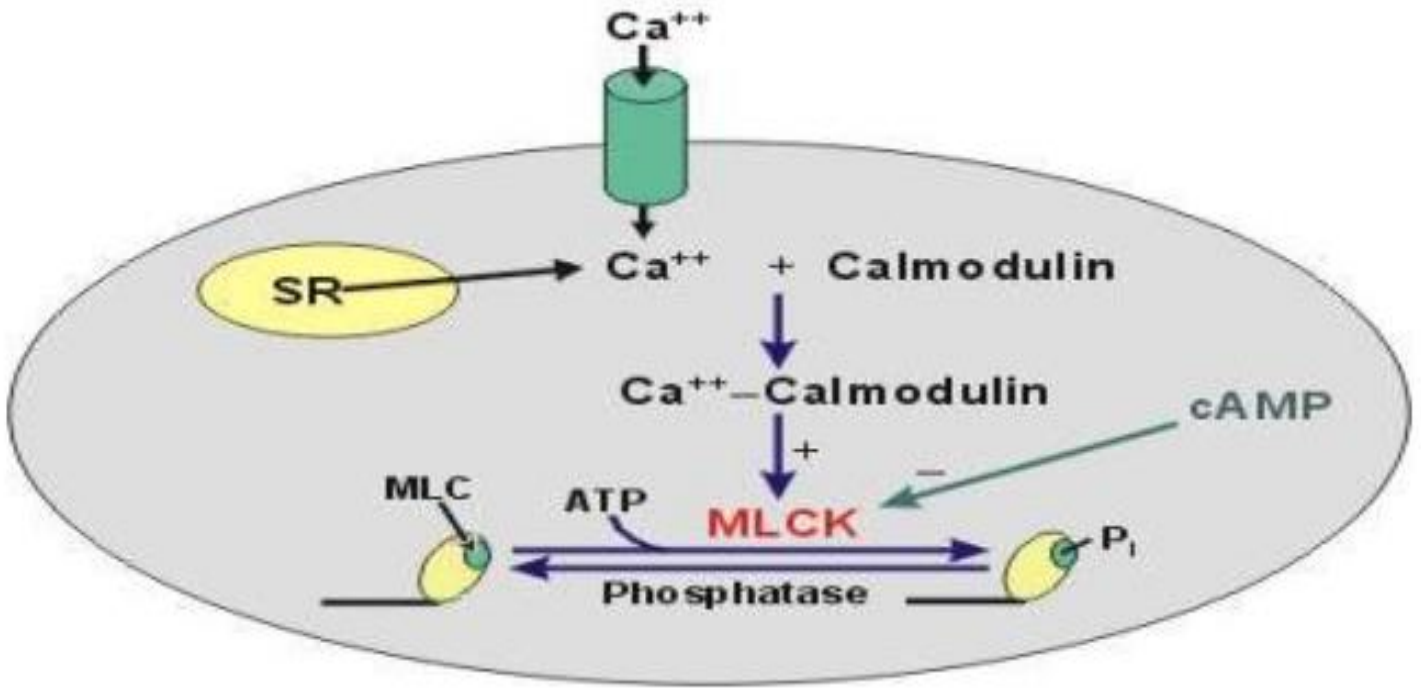
Molecular Basis of Contraction

1- Binding of Ach to Muscarinic receptors.

2- Ca2+ influx from the ECF (extracellular fluid) via Ca2+ channels.

3- Ca2+ binds to calmodulin, and the resulting complex activates calmodulin-dependent **Myosin Light Chain Kinase (MLCK)** .

This enzyme catalyzes the phosphorylation of the myosin light chain.



4- The phosphorylation allows the myosin ATPase to be activated, and actin slides on myosin, producing contraction.

5- Myosin is dephosphorylated by myosin light chain phosphatase in the cell.

6- Relaxation of the smooth muscle

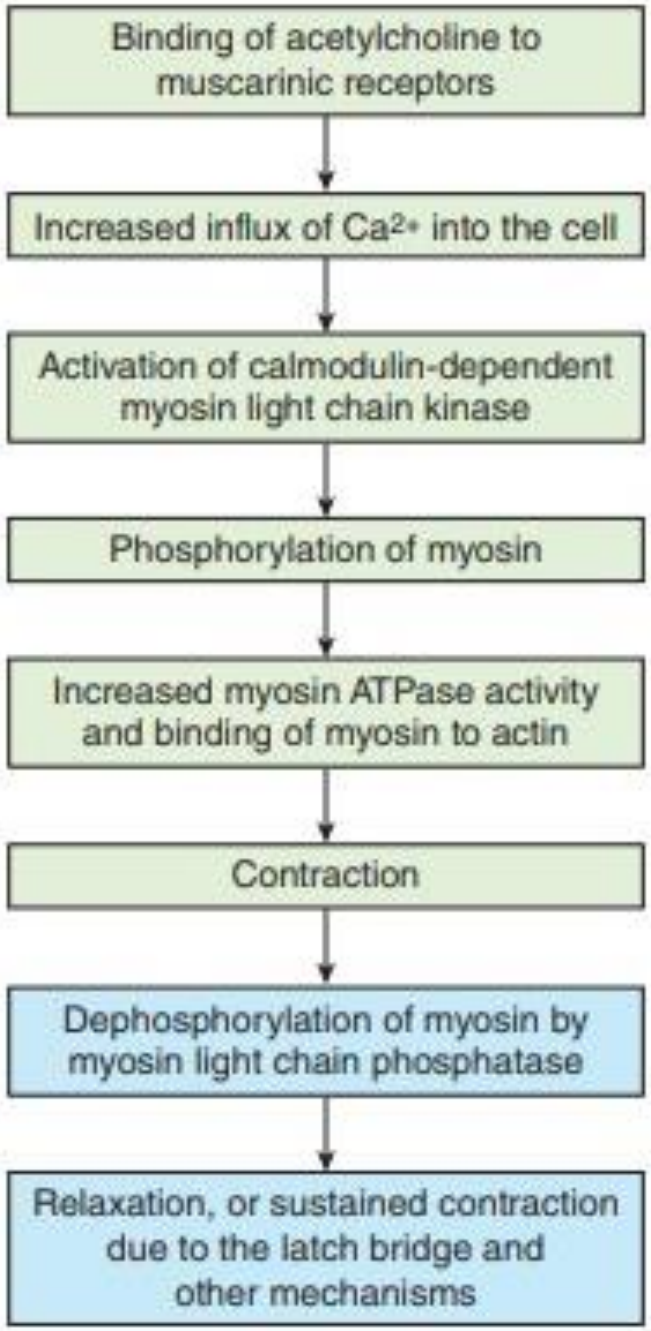


Figure : →

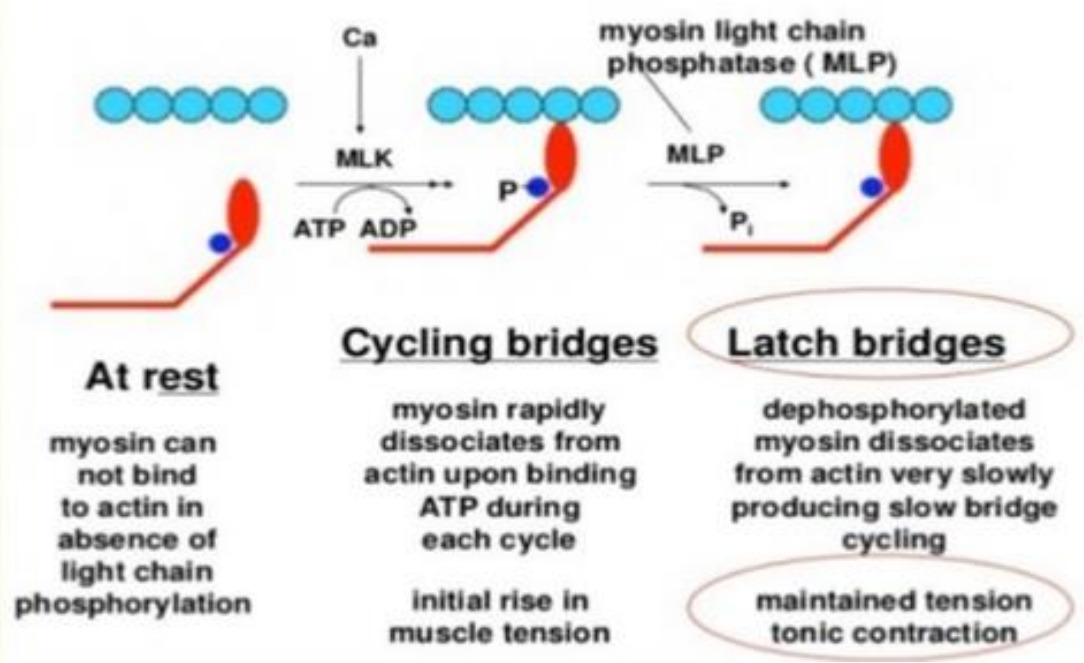
Sequence of events in contraction and relaxation of smooth muscle.

Latch bridge mechanism

- Dephosphorylation of myosin light chain kinase does not necessarily lead to relaxation of the smooth muscle. **a**

  latch bridge mechanism by which myosin cross-bridges remain attached to actin for some time after the cytoplasmic Ca2+ concentration falls. sustained contraction with little expenditure of energy, which is especially important in vascular smooth muscle.

- **Latch-bridges** are mechanisms within smooth muscle cells that enable sustained tension with minimal energy expenditure by maintaining a tight connection between actin and myosin filaments. **These bridges allow smooth muscles to remain contracted for extended periods without quick fatigue.**



Relaxation of SM

Contraction

↓

Dephosphorylation of myosin

↓

- Relaxation or
- sustained contraction due to latch bridge mechanism i.e. Prolonged tonic contraction for hours with little use of energy

Stimulation of the smooth muscles:

A- Stretch:

Stretch opens stretch-sensitive channels, depolarizes smooth muscle, and can initiate contraction.

Smooth muscle cell membrane receptors respond to a variety of ligands, and working through inositol-trisphosphate (IP_3), stimulate sarcoplasmic Ca^{++} release and smooth muscle contraction.

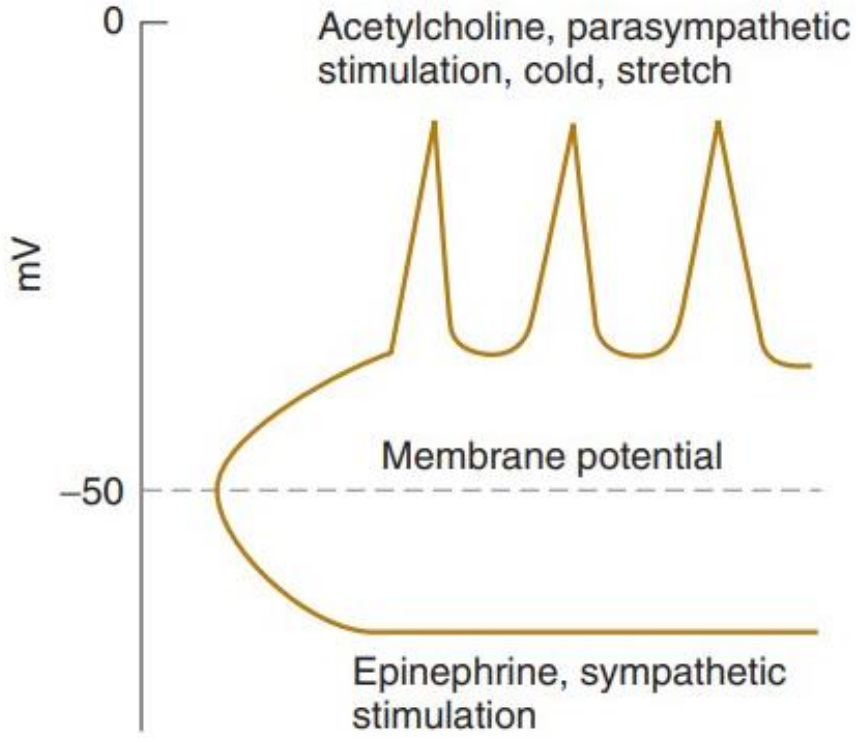


Figure : Effects of various agents on the membrane potential of intestinal smooth muscle. →

B-Chemical mediators:

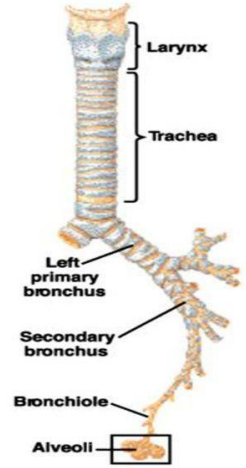
1-Epinephrine or norepinephrine :

norepinephrine or epinephrine causes smooth muscle relaxation through β2-Receptor Effects.

Smooths muscle relaxation, e.g., in bronchi (smooth muscle relaxation that helps to relieve bronchospasm)

and the GI tract (decreased motility). Lipolysis in adipose tissue.

Effects of epinephrine on airways

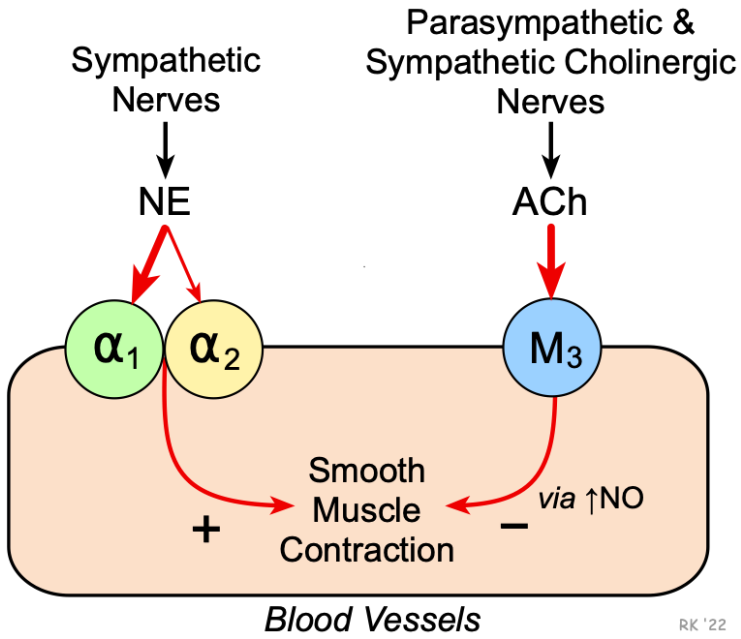


- Epi→β_2-adrenergic receptors on airway smooth muscle→ rapid, powerful relaxation→ bronchodilation

2- Acetylcholine (Ach)

Acetylcholine, the main neurotransmitter of the parasympathetic nervous system, depolarizes various smooth muscles and initiates their contraction via activating muscarinic cholinergic receptors.

Ach has an effect opposite to that of norepinephrine.



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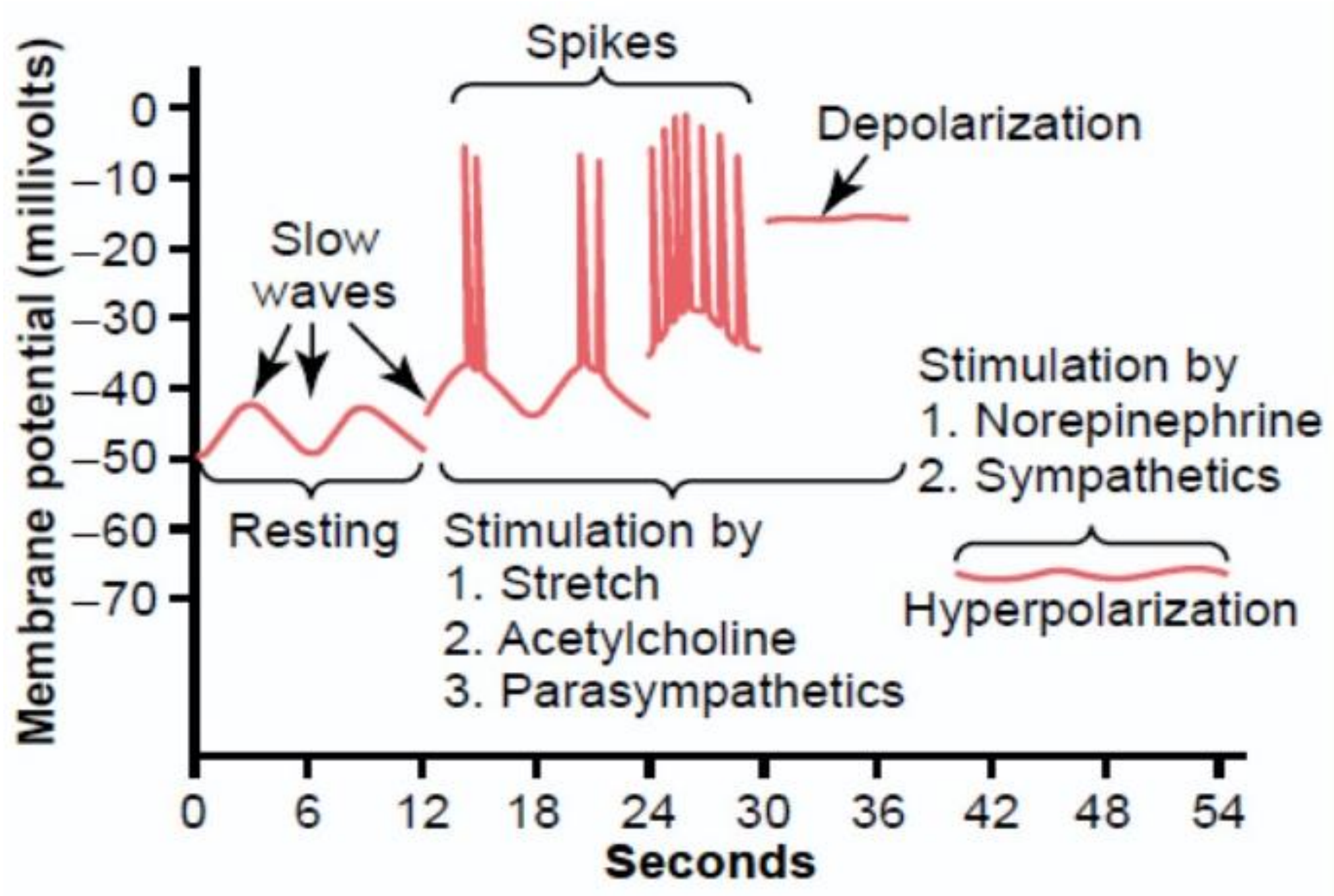
Spikes
Depolarization
Slow waves
Membrane potential (millivolts)
0
−10
−20
−30
−40
−50
−60
−70
Stimulation by
1. Norepinephrine
2. Sympathetics
Resting
Stimulation by
1. Stretch
2. Acetylcholine
3. Parasympathetics
Hyperpolarization
0
6
12
18
24
30
36
42
48
54
Seconds

3-Other chemicals: like progesterone which decreases the activity and estrogen which increase it (in uterine smooth muscles).

4-Thermal stimuli: like cold which causes spasm. increased body temperature can all cause local vasodilatation in the blood vesseles.

5-Some of the specific control factors are as follows:

- Lack of oxygen in the local tissues causes smooth muscle relaxation and, therefore, vasodilatation.
- Excess carbon dioxide causes vasodilatation.
- Increased hydrogen ion concentration causes vasodilatation.
- lactic acid, increased potassium ions, diminished calcium ion concentration .

Function of the Nerve Supply to Smooth Muscle:

It has **two** important properties:

(1) Its spontaneous activity in the absence of nervous stimulation, and

(2) Its sensitivity to chemical agents released from nerves locally or brought to it in the circulation.

The function of the nerve supply is not to initiate activity in the muscle but rather to modify it (control).

It has dual nerve supply from 2 divisions of the autonomic nervous system. Stimulation of one division usually increases smooth muscle activity, whereas stimulation of the other decreases it.

(i.e if noradrenergic increase ,the Acetylcholine decrease and visa versa).

Relation of Length to Tension; Plasticity:

It is the variability of the tension it exerts at any given length. If a piece of visceral smooth muscle is stretched, it first exerts increased tension, if the muscle is held at the greater length after stretching, the tension gradually decreases. It is consequently impossible to correlate length and developed tension accurately.

Stress relaxation and reverse stress-relaxation. Its importance is that its ability to return to nearly its original force of contraction seconds or minutes after it has been elongated or shortened.

Example: **Stress relaxation and reverse stress relaxation**: the phenomenon of accommodating extra blood by relaxation of arterial wall is known as stress relaxation, and the process of arterial contraction due to fall in blood volume is known as reverse stress relaxation.


Thank You