Smooth Muscle

- Found in walls of hollow organs and tubes
- No striations
  - Filaments do not form myofibrils
  - Not arranged in sarcomere pattern found in skeletal muscle
- Spindle-shaped cells with single nucleus
- Cells usually arranged in sheets within muscle
- Have dense bodies containing same protein found in Z lines
Smooth Muscle

• Cell has 3 types of filaments
  – Thick myosin filaments
    • Longer than those in skeletal muscle
  – Thin actin filaments
    • Contain tropomyosin but lack troponin
  – Filaments of intermediate size = Intermediate Filaments
    • Do not directly participate in contraction
    • Form part of cytoskeletal framework that supports cell shape

Structure of Smooth Muscle

• Each smooth muscle cell is spindle-shaped, with a diameter between 2 and 10 µm, and length ranging from 50 to 400 µm.

• They are much smaller than skeletal muscle fibers, which are 10 to 100 µm wide and can be tens of centimeters long.

• Smooth muscle cells (SMC) have a single nucleus and have the capacity to divide throughout the life of an individual.

• SMCs have thick myosin-containing filaments and thin actin-containing filaments, and tropomyosin but NO troponin.

• The thin filaments are anchored either to the plasma membrane or to cytoplasmic structures known as dense bodies.
Structure of Smooth Muscle

- The thick and thin filaments are not organized into myofibrils, and there are NO sarcomeres, which accounts for the absence of a banding pattern.

- Smooth muscle contraction occurs by a sliding-filament mechanism.

- Smooth muscles surround hollow structures and organs that undergo changes in volume with accompanying changes in the lengths of the smooth muscle fibers in their walls.
Smooth Muscle Contraction and its Control

• Cross-Bridge Activation:

  – Cross-bridge cycling in smooth muscle is controlled by a Ca\(^{2+}\)-regulated enzyme that phosphorylates myosin. Only the phosphorylated form of smooth muscle myosin can bind to actin and undergo cross-bridge cycling.

  – This is done by myosin light chain kinase (MLCK).

  – To relax a contracted smooth muscle, myosin must be dephosphorylated because dephosphorylated myosin is unable to bind to actin. This dephosphorylation is mediated by the enzyme myosin light-chain phosphatase (MLCP).
Thick filament
Thin filament
Plasma membrane

(a) Relaxed smooth muscle cell
(b) Contracted smooth muscle cell

Dense body
Bundle of thick and thin filaments
One relaxed contractile unit extending from side to side

One contracted contractile unit

Fig. 8-22, p. 221

Myosin light chain
Part of cross-bridge energy cycle
Permits binding with actin

ADP
Myosin light chain

Fig. 8-23, p. 221
Smooth Muscle Contraction and its Control

Fig. 9-34
Sources of Cytosolic Ca\textsuperscript{2+}

- Two sources of Ca\textsuperscript{2+} contribute to the rise in cytosolic Ca\textsuperscript{2+} that initiates smooth muscle contraction:
  1. The sarcoplasmic reticulum
  2. Extracellular Ca\textsuperscript{2+} entering the cell through plasma-membrane Ca\textsuperscript{2+} channels.

- To relax, the Ca\textsuperscript{2+} has to be removed either to the SR or back to the extra cellular fluid.
Sources of Cytosolic Calcium

- Calcium that initiates smooth muscle contraction comes from both the sarcoplasmic reticulum and from the extracellular fluid entering through plasma-membrane channels.

Membrane Activation

- Smooth muscle responses can be graded.

- Input to smooth muscle can be either excitatory or inhibitory.
Nerves and Hormones

- The contractile activity of smooth muscles is influenced by neurotransmitters released by autonomic neuron endings.
- Unlike skeletal muscle fibers, smooth muscle cells do not have a specialized motor end-plate region. They have swollen regions known as varicosities.
- Each varicosity contains many vesicles filled with neurotransmitter, some of which are released when an action potential passes the varicosity.
- Varicosities from a single axon may be located along several muscle cells, and a single muscle cell may be located near varicosities belonging to postganglionic fibers of both sympathetic and parasympathetic neurons.
- Therefore, a number of smooth muscle cells are influenced by the neurotransmitters released by a single neuron, and a single smooth muscle cell may be influenced by neurotransmitters from more than one neuron.
Nerves and Hormones

• Whereas some neurotransmitters enhance contractile activity, others decrease contractile activity.

• A given neurotransmitter may produce opposite effects in different smooth muscle tissues. For example, norepinephrine, the neurotransmitter released from most postganglionic sympathetic neurons, enhances contraction of most vascular smooth muscle by acting on alpha-adrenergic receptors, but produces relaxation of airway (bronchiolar) smooth muscle by acting on beta-2 adrenergic receptors.

• Thus, the type of response (excitatory or inhibitory) depends not on the chemical messenger per se, but on the receptors the chemical messenger binds to in the membrane and on the intracellular signaling mechanisms those receptors activate.
Membrane Activation

Local Factors

- Local factors, including paracrine signals, acidity, O$_2$ and CO$_2$ levels, osmolarity, and the ion composition of the extracellular fluid, can also alter smooth muscle tension.

- Responses to local factors provide a means for altering smooth muscle contraction in response to changes in the muscle’s immediate internal environment, independent of long-distance signals from nerves and hormones.

- Many of these local factors induce smooth muscle relaxation. Nitric oxide (NO) which produces smooth muscle relaxation. NO in a paracrine manner.

- Some smooth muscles can also respond by contracting when they are stretched. Stretching opens mechanosensitive ion channels, leading to membrane depolarization. The resulting contraction opposes the forces acting to stretch the muscle.
Spontaneous Electrical Activity

- Some types of smooth muscle cells generate action potentials spontaneously in the absence of any neural or hormonal input.

- The membrane potential change occurring during the spontaneous depolarization to threshold is known as a pacemaker potential.

- Other smooth muscle pacemaker cells have a slightly different pattern of activity. The membrane potential drifts up and down due to regular variation in ion flux across the membrane. These periodic fluctuations are called slow waves.

- Pacemaker cells are found throughout the gastrointestinal tract, and thus gut smooth muscle tends to contract rhythmically even in the absence of neural input.

- Some cardiac muscle fibers and a few neurons in the central nervous system also have pacemaker potentials and can spontaneously generate action potentials in the absence of external stimuli.

Factors influencing activity in Smooth Muscle - Summary

1. Spontaneous electrical activity in the plasma membrane of the muscle cell
2. Neurotransmitters released by autonomic neurons
3. Hormones
4. Locally induced changes in the chemical composition (paracrine agents, acidity, oxygen, osmolarity, and ion concentrations) of the extracellular fluid surrounding the cell
5. Stretch