

TOPIC 13: SMOOTH AND CARDIAC MUSCLE**I. Broad Comparisons of Smooth, Cardiac, and Skeletal Muscle**

- A. All have contractile system apparatus composed of thin actin filaments that slide past stationary thick myosin filaments in response to increase in Ca^{++}
- B. All use ATP directly as energy source for cross-bridge cycling
- C. But structure and organization of the 3 muscle fibers are different
- D. But mechanisms of excitation different
- E. But coupling of excitation and contraction different
- F. But contraction responses different

II. Smooth Muscle Structure

- A. Structure of smooth muscle cells (Fig 12.33)
 - 1. Found mostly in walls of hollow organs and tubes
 - a) contraction causes forward movement of contents of tube
 - b) digestive tract & blood vessels
 - 2. Spindle shaped, have a single nucleus (recall that skeletal muscle cells are multi-nucleated)
 - 3. Smaller than skeletal muscle cells
 - 4. Do not extend full length of muscle as do skeletal muscle cells
 - 5. Groups of smooth muscle cells are typically arranged in sheets
- B. Subcellular structure of smooth muscle
 - 1. Three types of smooth muscle cell filaments
 - a) Thick myosin filaments
 - (1) longer than in skeletal muscle
 - b) Thin filaments composed of
 - (1) actin
 - (2) tropomyosin
 - (3) **No troponin**
 - (4) 10 to 15 thin filaments/thick filament
 - c) Intermediate filaments only support cell shape
 - 2. Myofibrils are not formed, and there is no sarcomere arrangement
 - 3. **No Z lines**
 - a) smooth muscle does have **dense bodies** made of the same protein that make up Z lines
 - b) Dense bodies are found throughout cell and are anchored to the cell membrane
 - c) **actin filaments are anchored to dense bodies.**
 - 4. No T tubules
 - 5. Underdeveloped SR

III. Molecular basis of smooth muscle contraction (Fig 12.34)

- A. Ca^{++} channels on smooth muscle membrane open, and Ca^{++} from the ECF diffuses into cell (concentration gradient of Ca^{++} is from ECF into ICF)
- B. Entering Ca^{++} causes SR to release small amounts of Ca^{++} , functionally not very important
 - 1. Because smooth muscle cells are so much smaller in diameter than skeletal muscle cells SR & T-tubules are not needed to deliver Ca^{++} deep into the muscle
- C. Ca^{++} activates enzyme called calmodulin
- D. Activated calmodulin activates enzyme myosin light chain kinase

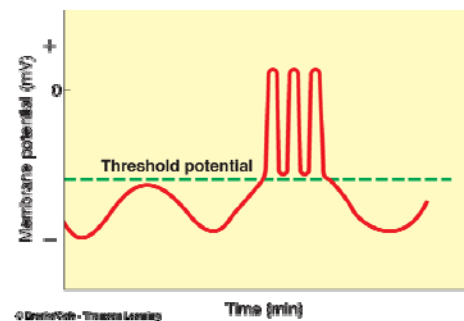
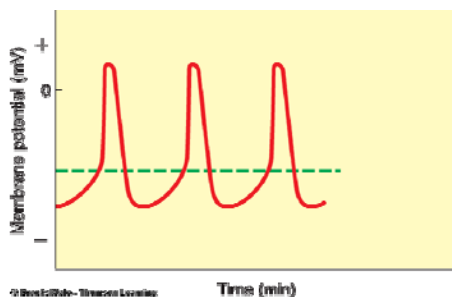
- E. Activated myosin light chain kinase phosphorylates myosin by splitting a phosphate off of ATP
- F. Phosphorylated myosin binds with actin and cross bridge cycling begins.
- G. When Ca^{++} removed by active transport out of smooth muscle cell, calmodulin and in turn myosin kinase return to inactive form, and an enzyme called phosphatase removes phosphate from myosin. Hence myosin becomes unphosphorylated and no longer binds to actin, and the muscle cell relaxes
- H. Mechanism of stimulation of smooth muscle depends on whether it is multiunit or single unit smooth muscle

IV. Multiunit Smooth Muscle (rare) (Fig 12.35)

- A. Organization
 1. Smooth muscle cells within a smooth muscle are organized into different functional units
 2. Each unit (i.e., group of smooth muscle cells) separately stimulated by nerves of autonomic nervous system
 - a) such contractions are called neurogenic (nerve produced)
 3. Each unit functions independently of other units
 - a) similar to skeletal muscle
 4. Rare; found in
 - a) walls of large blood vessels
 - b) large airways to lungs
 - c) eye muscles related to distance vision
 - d) iris of eye
 - e) base of hair follicles (goose bumps)

V. Single-Unit Smooth Muscle (common) (Fig 12.35)

- A. Muscle fibers in muscle make up a single unit and contract together
- B. Fibers are linked by gap junctions; an AP anywhere in the muscle propagates via gap junctions to all fibers, so whole muscle contracts together
 1. Example: uterine walls need to contract together to expel baby from uterus
- C. Stimulated by
 1. Autonomic nervous system
 2. Myogenic activity (muscle produced)
 - a) pacemaker activity (e.g., lymph vessels) left figure
 - (1) in a pacemaker cell, the membrane depolarizes on its own because of automatic changes in channel permeability
 - (2) once AP fired in pacemaker, it spreads to rest of smooth muscle cells via gap junctions
 - b) slow wave potential (e.g., intestine) right figure
 - (1) gradual alternating hyperpolarizing and depolarizing swings in potential caused by cyclical changes in the rate at which Na^+ is actively transported across membrane
 - (2) Threshold not always reached, but when it is, a burst of AP's follow



VI. Smooth Muscle Mechanics

- A. Modification of contraction strength **in single unit smooth muscle**
 - 1. Fiber tension modified by varying cytosolic Ca^{++} concentration
 - 2. As cytosolic Ca^{++} increases, so does number of cycling cross bridges
 - 3. Many single unit smooth muscles maintain low levels of cytosolic Ca^{++} , which means low level of contraction always occurring; this is called muscle tone
- B. Modification of contraction strength **in multiunit smooth muscle**
 - 1. Functional unit recruitment (= motor unit recruitment of skeletal muscle)
 - 2. Varying cytosolic Ca^{++} concentration within a cell
- C. Factors that modify cytosolic Ca^{++} and hence contraction strength for **both single and multiunit smooth muscle**
 - 1. both branches of autonomic nervous system
 - 2. hormones
 - 3. metabolites
 - 4. mechanical stretch
 - 5. drugs
- D. Considerably stretched smooth muscle can still develop tension
 - 1. urinary bladder: when full, it is stretched, but you need to develop more tension because you have to contract bladder to empty it
- E. Can relax even when stretched
 - 1. probably caused by re-arrangement of cross bridges after stretching
- F. Is slow and economical
 - 1. slow rate of ATP use
 - 2. cross bridges latch onto thin filaments longer
- G. Bottom line: Smooth muscle is highly specialized to economically maintain tension for long periods without fatigue, and can accommodate variation in contents volume with little change in muscle tension

VII. Cardiac Muscle

- A. Structure
 - 1. Striated: Thick and thin filaments highly organized
 - 2. Contains troponin and tropomyosin
 - 3. Clear cut length-tension relationship like skeletal muscle
 - 4. Have T tubules and pretty good SR
 - 5. Lots of mitochondria like oxidative skeletal muscle fibers
 - 6. cells are connected by gap junctions
 - 7. Innervated by autonomic nervous system
 - 8. Fibers are joined in branching network
- B. Function
 - 1. Ca^{++} enters cytosol from ECF and SR
 - 2. Some cardiac cells have pacemaker activity like smooth muscle
 - 3. APs have long duration