Chapter 10.6

Smooth & Cardiac Muscles

Cardiac muscle  Smooth muscle
Smooth Muscle

- Some smooth muscles lack nerve supply

- Other smooth muscle cells receive autonomic fibers
  - Note: not somatic motor fibers as in skeletal muscle

- Capable of mitosis and hyperplasia

- Injured smooth muscle regenerates well
Smooth Muscle

- composed of myocytes that have a **fusiform shape**

- **one nucleus**, located near the middle of the cell

- **no visible striations**
  - reason for the name ‘smooth muscle’
  - thick and thin filaments are present, but not aligned with each other

- z discs are absent and replaced by **dense bodies**
  - well ordered array of protein masses in cytoplasm
  - **protein plaques** on the inner face of the plasma membrane

- cytoplasm contains extensive cytoskeleton of intermediate filament
  - attach to the membrane plaques and dense bodies
  - provide mechanical linkages between the thin myofilaments and the plasma membrane

- sarcoplasmic reticulum is scanty and there are no T tubules

- Ca\(^2+\) needed for muscle contraction comes from the ECF by way of Ca\(^2+\) channels in the sarcolemma
Stimulation of Smooth Muscle

- smooth muscle is **involuntary**

- can may contract without nervous stimulation
  - can contract in response to chemical stimuli
    - hormones, carbon dioxide, low pH, and oxygen deficiency
    - in response to stretch
    - single unit smooth muscle in stomach and intestines has **pacemaker cells** that set off waves of contraction throughout the entire layer of muscle

- most smooth muscle is innervated by **autonomic nerve fibers**
  - can trigger and modify contractions
  - **stimulate smooth muscle with either acetylcholine or norepinephrine**
  - can have **contrasting effects**
    - relax the smooth muscle of arteries
    - contract smooth muscles of the bronchioles
2 Types of Smooth Muscle – 1 of 3

- **multiunit smooth muscle**
  - occurs in some of the largest arteries and pulmonary air passages, in piloerector muscles of hair follicle, and in the iris of the eye
  - ANS (autonomic nervous system) innervation similar to skeletal muscle
    - terminal branches of a nerve fiber synapse with individual myocytes and form a motor unit
    - each motor unit contracts independently of the others
2 Types of Smooth Muscle – 2 of 3

- single-unit smooth muscle
  - more widespread
  - occurs in most blood vessels, in the digestive, respiratory, urinary, and reproductive tracts
  - also called visceral muscle
    - often in two layers
    - inner circular
    - outer longitudinal
  - myocytes of this cell type are electrically coupled to each other by gap junctions
  - they directly stimulate each other and a large number of cells contract as a single unit

(b) Single-unit smooth muscle
2 Types of Smooth Muscle – 3 of 3

- in single unit smooth, each autonomic nerve fibers has up to 20,000 beadlike swelling called varicosities
  - each contains synaptic vesicles and a few mitochondria
  - nerve fiber passes amid several myocytes and stimulates all of them at once when it releases its neurotransmitter

- no motor end plates, but receptors scattered throughout the surface

- diffuse junctions – no one-to-one relationship between nerve fiber and myocyte
Stimulation of Smooth Muscle

- Autonomic nerve fiber
- Varicosities
- Mitochondrion
- Synaptic vesicle
- Single-unit smooth muscle
Layers of Visceral Muscle

Mucosa:
- Epithelium
- Lamina propria
- Muscularis mucosae

Muscularis externa:
- Circular layer
- Longitudinal layer
Smooth Muscle Contraction and Relaxation

- contraction is triggered by Ca\(^{+2}\), energized by ATP, and achieved by sliding thin past thick filaments

- contraction begins in response to Ca\(^{+2}\) that enters the cell from ECF, a little internally from sarcoplasmic reticulum
  - Ca\(^{+2}\) channels open to allow Ca\(^{+2}\) to enter cell
  - voltage, ligand, and mechanically-gated (stretching)

- calcium binds to calmodulin on thick filaments
  - activates myosin light-chain kinase – adds phosphate to regulatory protein on myosin head
  - myosin ATPase
    - hydrolyzing ATP
    - enables myosin *similar power and recovery strokes like skeletal muscle*

  - thick filaments pull on thin ones - thin ones pull on dense bodies and membrane plaques
    - force is transferred to plasma membrane and entire cell shortens
    - puckers and twists like someone wringing out a wet towel
Contraction and Relaxation

- very slow in comparison to skeletal muscle
  - latent period in skeletal 2 msec, smooth muscle 50 - 100 msec
  - tension peaks at about 500 msec (0.5 sec)
  - declines over a period of 1 – 2 seconds
  - slows myosin ATPase enzyme and slow pumps that remove Ca\(^{+2}\)
  - Ca\(^{+2}\) binds to calmodulin instead of troponin // activates kinases and ATPases that hydrolyze ATP
  - smooth muscle makes most of its ATP aerobically
Contraction and Relaxation

• smooth muscle resistant to fatigue
  – latch-bridge mechanism - heads of myosin molecules do not detach from actin immediately
  – do not consume more ATP immediately
  – maintains tetanus tonic contraction (smooth muscle tone)

• arteries – vasomotor tone
• intestinal tone
Contraction of Smooth Muscle

(a) Relaxed smooth muscle cells

(b) Contracted smooth muscle cells

- Plaque
- Intermediate filaments of cytoskeleton
- Actin filaments
- Dense body
- Myosin
Stretching Smooth Muscle

• **stretch** can open **mechanically-gated calcium** channels in the sarcolemma causing contraction
  
  – **peristalsis** – waves of contraction brought about by food distending the esophagus or feces distending the colon // propels contents along the organ

• **stress-relaxation response** (receptive relaxation)
  
  – helps **hollow organs gradually fill** (urinary bladder)
  
  – when stretched, tissue briefly contracts then relaxes – helps prevent emptying while filling
Contraction and Stretching

- smooth muscle contracts forcefully even when greatly stretched
  - allows hollow organs such as the stomach and bladder to fill and then expel their contents efficiently
  - smooth muscle can be anywhere from half to twice its resting length and still contract powerfully
  - skeletal muscle cannot contract forcefully if overstretched
Contraction and Stretching

• three reasons why
  
  – there are no z discs, so thick filaments cannot butt against them and stop contraction

  – since the thick and thin filaments are not arranged in orderly sarcomeres, stretching does not cause a situation where there is too little overlap for cross-bridges to form

  – the thick filaments of smooth muscle have myosin heads along their entire length, so cross-bridges can form anywhere

• plasticity – the ability to adjust its tension to the degree of stretch // a hollow organ such as the bladder can be greatly stretched yet not become flabby when it is empty
Cardiac Muscle
Cardiac Muscle

- limited to the heart where it functions to pump blood

- required properties of cardiac muscle
  - contraction with regular rhythm
  - muscle cells of each chamber must contract in unison
  - contractions must last long enough to expel blood
  - must work in sleep or wakefulness, without fail, and without conscious attention
  - must be highly resistant to fatigue
Cardiac Muscle

• characteristics of cardiac muscle cells
  – striated like skeletal muscle, but myocytes (cardiocytes) are
    shorter and thicker

  – each myocyte is joined to several others at the uneven, notched
    linkages – intercalated discs
      • appear as thick dark lines in stained tissue sections
      • electrical gap junctions allow each myocyte to directly stimulate
        its neighbors
      • mechanical junctions that keep the myocytes from pulling apart

  – sarcoplasmic reticulum less developed, but T tubules are larger
    and admit supplemental Ca^{2+} from the extracellular fluid

  – damaged cardiac muscle cells repair by fibrosis
    • a little mitosis observed following heart attacks
    • not in significant amounts to regenerate functional muscle
Cardiac Muscle

- can contract without need for nervous stimulation
  - contains a built-in pacemaker that rhythmically sets off a wave of electrical excitation
  - wave travels through the muscle and triggers contraction of heart chambers
  - autorhythmic – because of its ability to contract rhythmically and independently

- autonomic nervous system does send nerve fibers to the heart
  - can increase or decrease heart rate and contraction strength

- very slow twitches - does not exhibit quick twitches like skeletal muscle
  - maintains tension for about 200 to 250 msec
  - gives the heart time to expel blood

- uses aerobic respiration almost exclusively
  - rich in myoglobin and glycogen
  - has especially large mitochondria
    - 25% of volume of cardiac muscle cell
    - 2% of skeletal muscle cell with smaller mitochondria

- very adaptable with respect to fuel used

- very vulnerable to interruptions of oxygen supply

- highly fatigue resistant