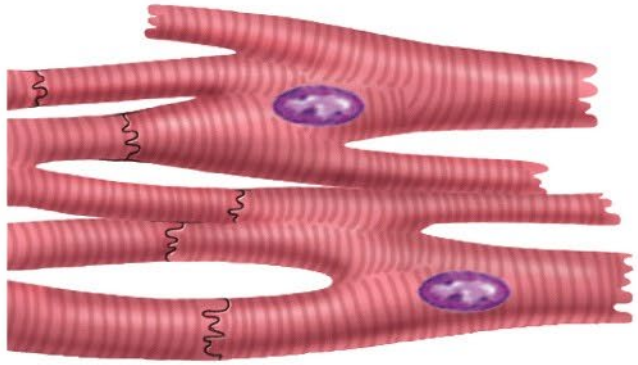
Chapter 11.5

Smooth & Cardiac Muscles

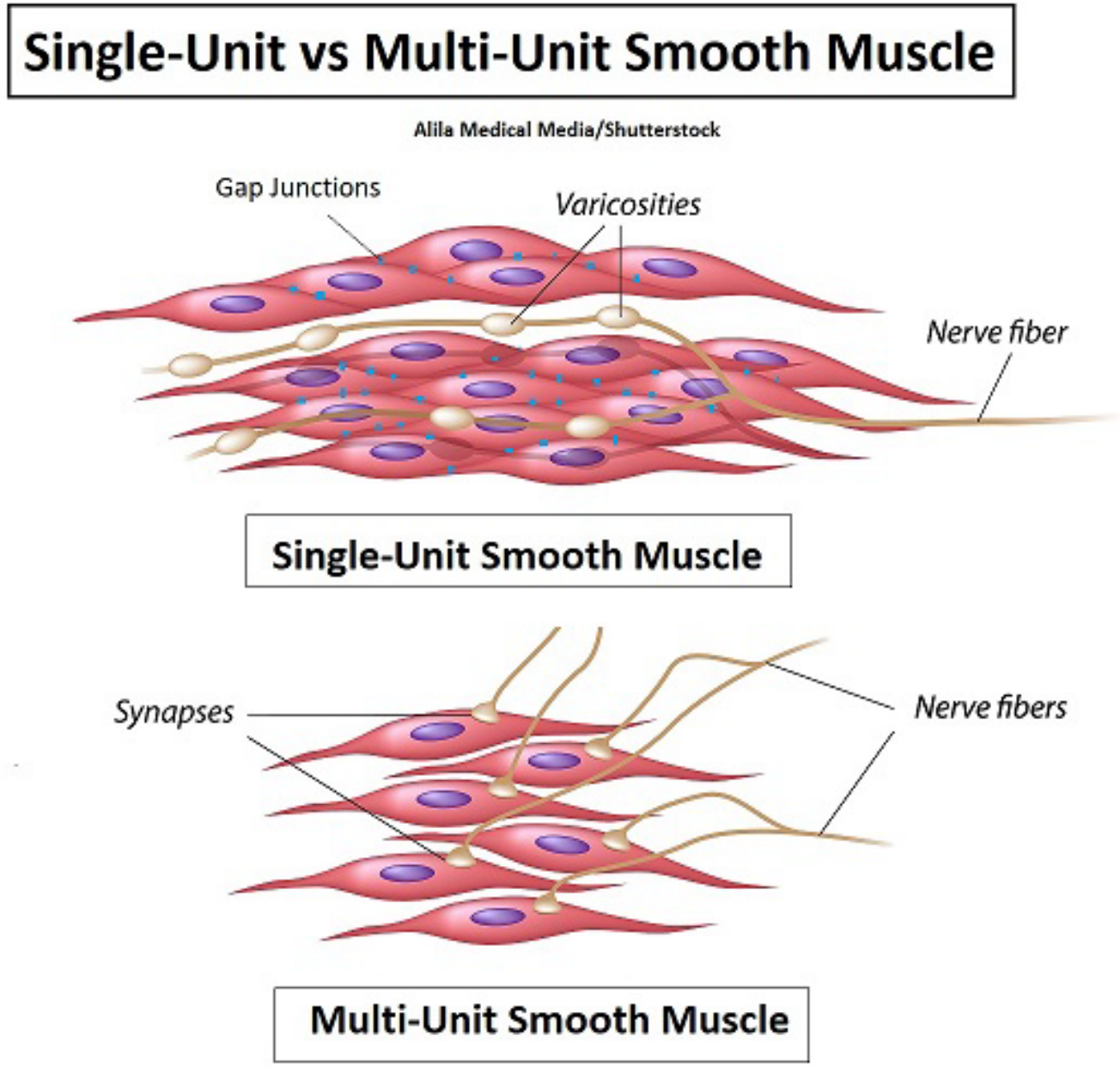
Cardiac muscle



Smooth muscle

Single-unit (or visceral) smooth muscle forms a functional syncytium, with gap junctions allowing cells to contract as a whole unit, common in hollow organs like the digestive tract.

Multi-unit smooth muscle, found in structures like the iris of the eye and the airways, consists of individual cells that are independently innervated, enabling finer, more precise control over contractions



Smooth Muscle

Some smooth muscle cells contract without direct innervation // in response to stretch

Some smooth muscle cells receive nerve stimulation from autonomic nervous system (Note: not somatic motor fibers as in skeletal muscle)

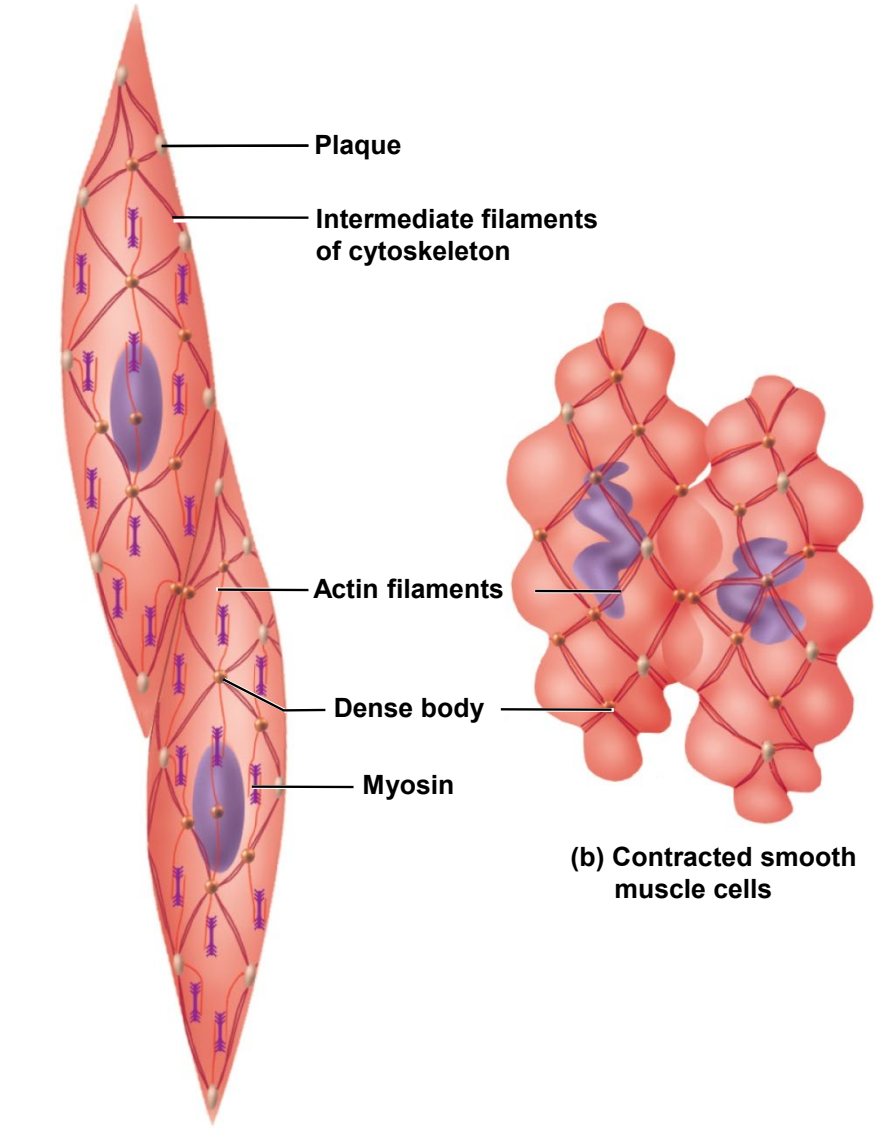
Hormones may cause smooth muscle to contract // stimulate smooth muscle contraction with either acetylcholine or norepinephrine // different receptors allow for contrasting effects with similar hormone /// e.g. histamine circulating in blood relax the smooth muscle of arteries while contract smooth muscles of the bronchioles

- SM capable of mitosis and hyperplasia // Injured smooth muscle regenerates

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 to form striations
- z discs are absent and replaced by dense bodies // well ordered array of protein masses in cytoplasm // contractile fibers anchored to 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

Contraction of Smooth Muscle



Contraction and Stretching

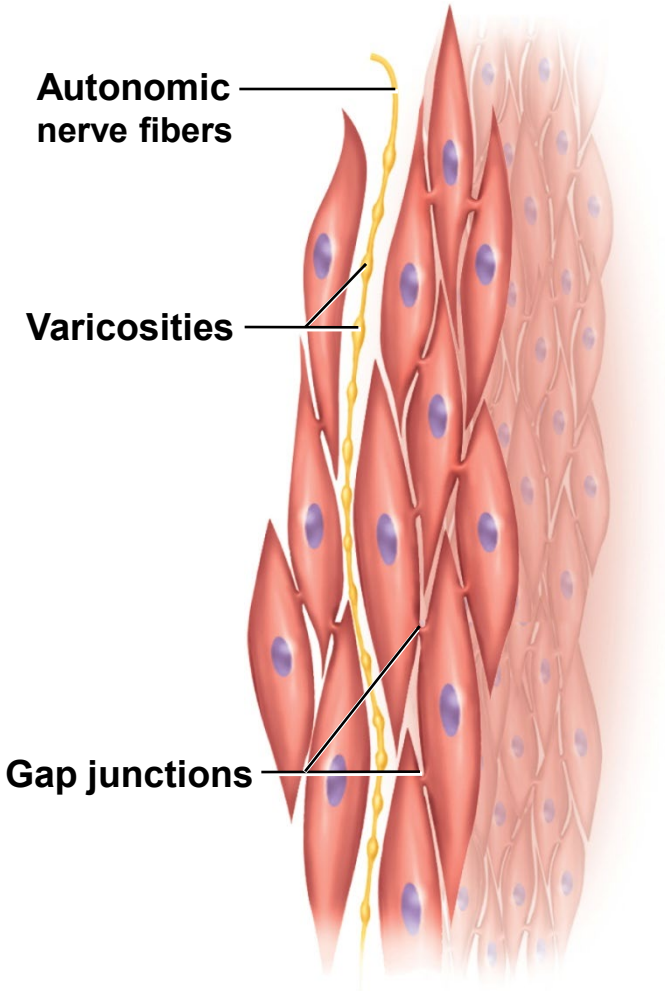
smooth muscle contracts forcefully even when greatly stretched

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

Single Unit SM



(b) Single-unit smooth muscle

more common

occurs in most blood vessels, in the digestive, respiratory, urinary, and reproductive tracts

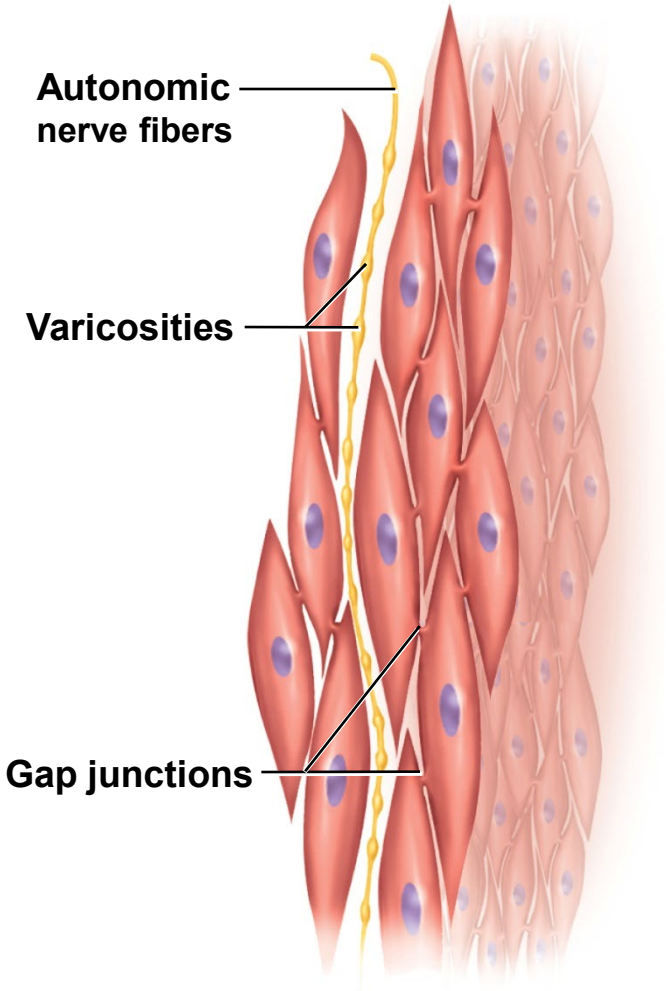
also called visceral muscle // often in two layers // e.g. digestive tract

- 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

Single Unit SM



(b) Single-unit smooth muscle

- in single unit smooth, each autonomic nerve fibers has up to 20,000 beadlike swelling called varicosities

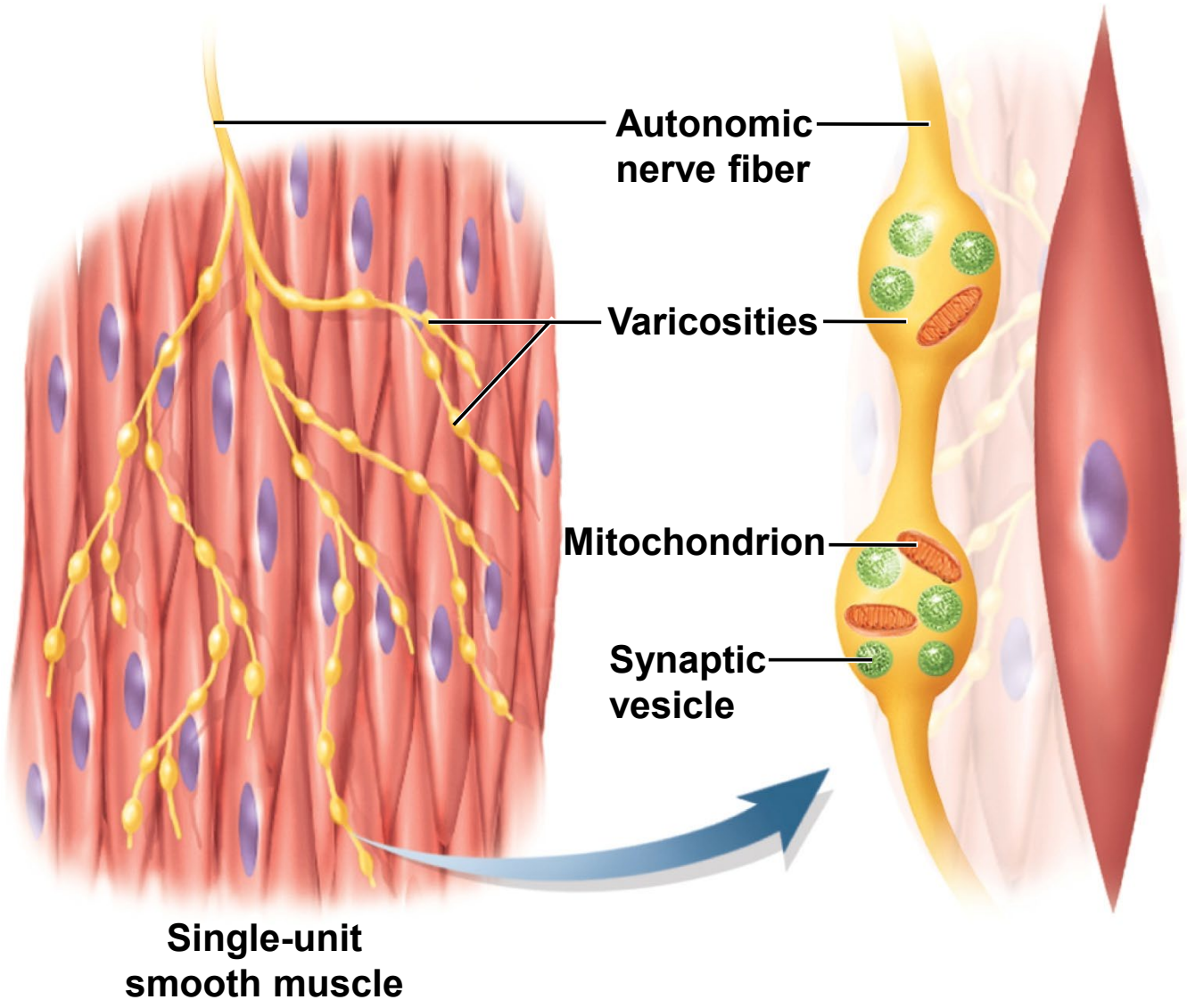
–each contains synaptic vesicles and a few mitochondria

–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

Single-Unit Smooth Muscle



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

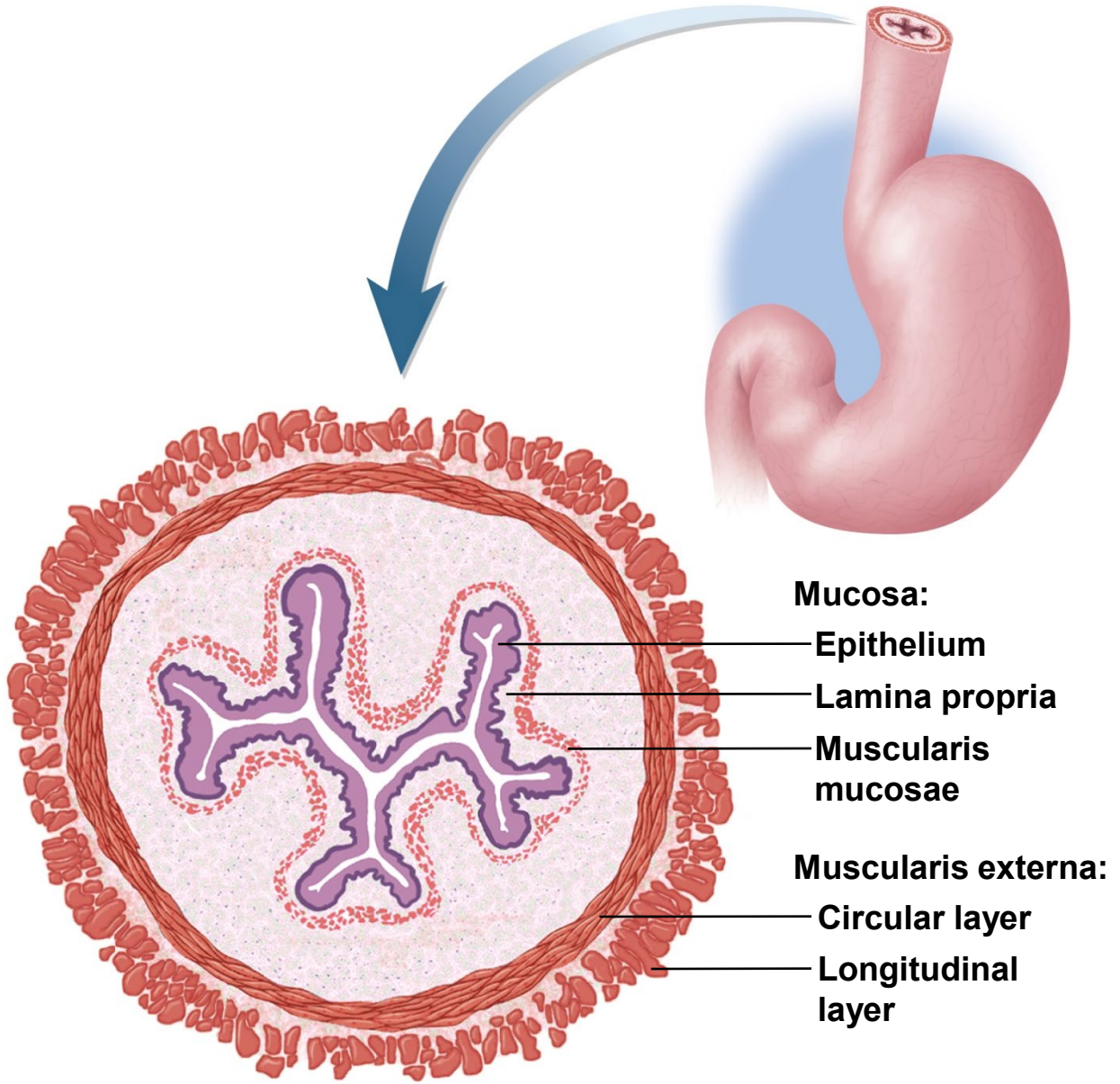
–voltage, ligand, and mechanically-gated (stretching)

- 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

–single unit smooth muscle in stomach and intestines has **pacemaker cells** that set off waves of contraction throughout the entire layer of muscle

Layers of Visceral Muscle



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

–<u>smooth muscle makes most of its ATP aerobically</u>

Contraction and Relaxation

smooth muscle resistant to fatigue

latch-bridge mechanism - heads of myosin molecules do not detach from actin immediately

maintains tetanus tonic contraction (smooth muscle tone)

- arteries – vasomotor tone
- intestinal tone

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

why there are no striations in smooth muscle:

here are no z discs, so thick filaments cannot butt against them and stop contraction

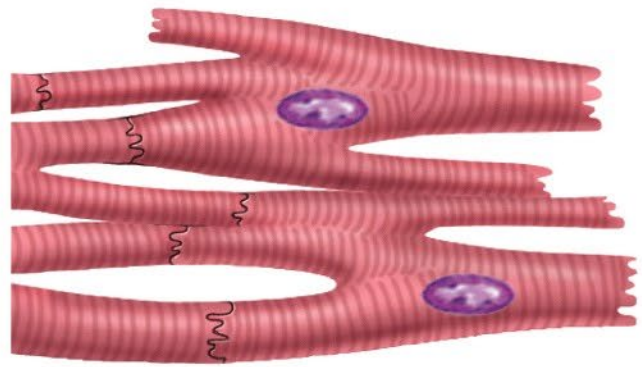
since the thick and thin filaments are not arranged in orderly sarcomeres, stretching does not cause a situation where there is too little overlap for cross-bridges to form

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



Cardiac Muscle

- heart muscle 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
  - –contracts while sleeping or wakefulness, and without voluntary control
  - –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 /// mechanical junctions that keep the myocytes from pulling apart

–electrical gap junctions allow each myocyte to directly stimulate its neighbors

–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 maybe 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

Cardiac Muscle

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