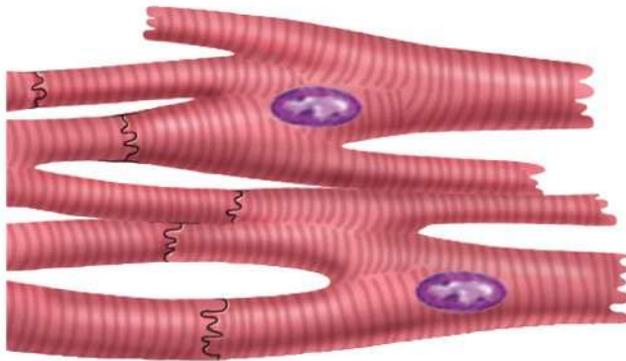


Chapter 11.5

Smooth & Cardiac Muscles

Cardiac muscle



Smooth muscle



Smooth Muscle

- Some smooth muscles may contract without direct innervation
- Other smooth muscle cells receive nerve stimulation from autonomic nervous system (Note: not somatic motor fibers as in skeletal muscle)
- SM 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**
- may contract without nervous stimulation // can contract in response to chemical stimuli (hormones) or physical “stretch”
 - 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

Stimulation of Smooth Muscle

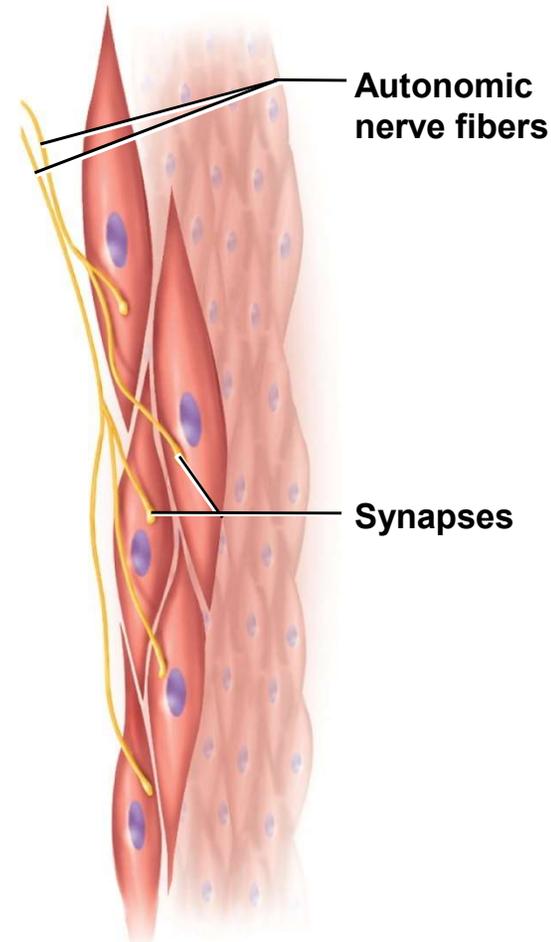
- However, most smooth muscle is innervated by **autonomic nerve fibers**
 - can trigger and modify contractions
 - stimulate smooth muscle with either acetylcholine or norepinephrine
 - can have contrasting effects /// hormone circulating in blood at same time will relax the smooth muscle of arteries while contract smooth muscles of the bronchioles

2 Types of Smooth Muscle



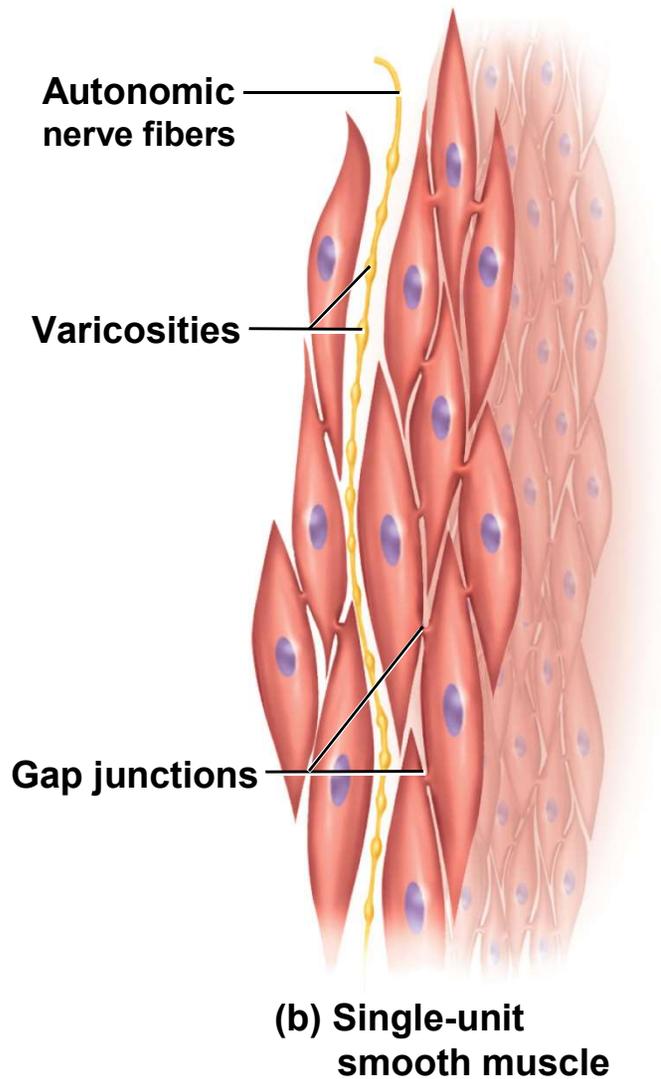
- **Multiunit smooth muscle**

- 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



(a) Multiunit smooth muscle

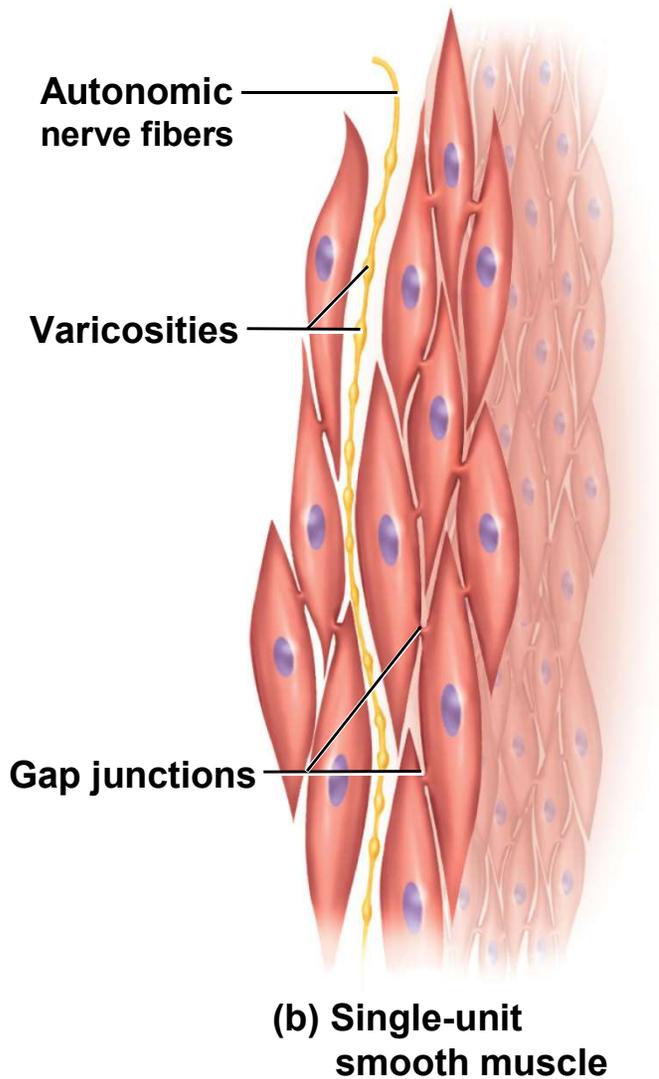
Single Unit SM



- 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

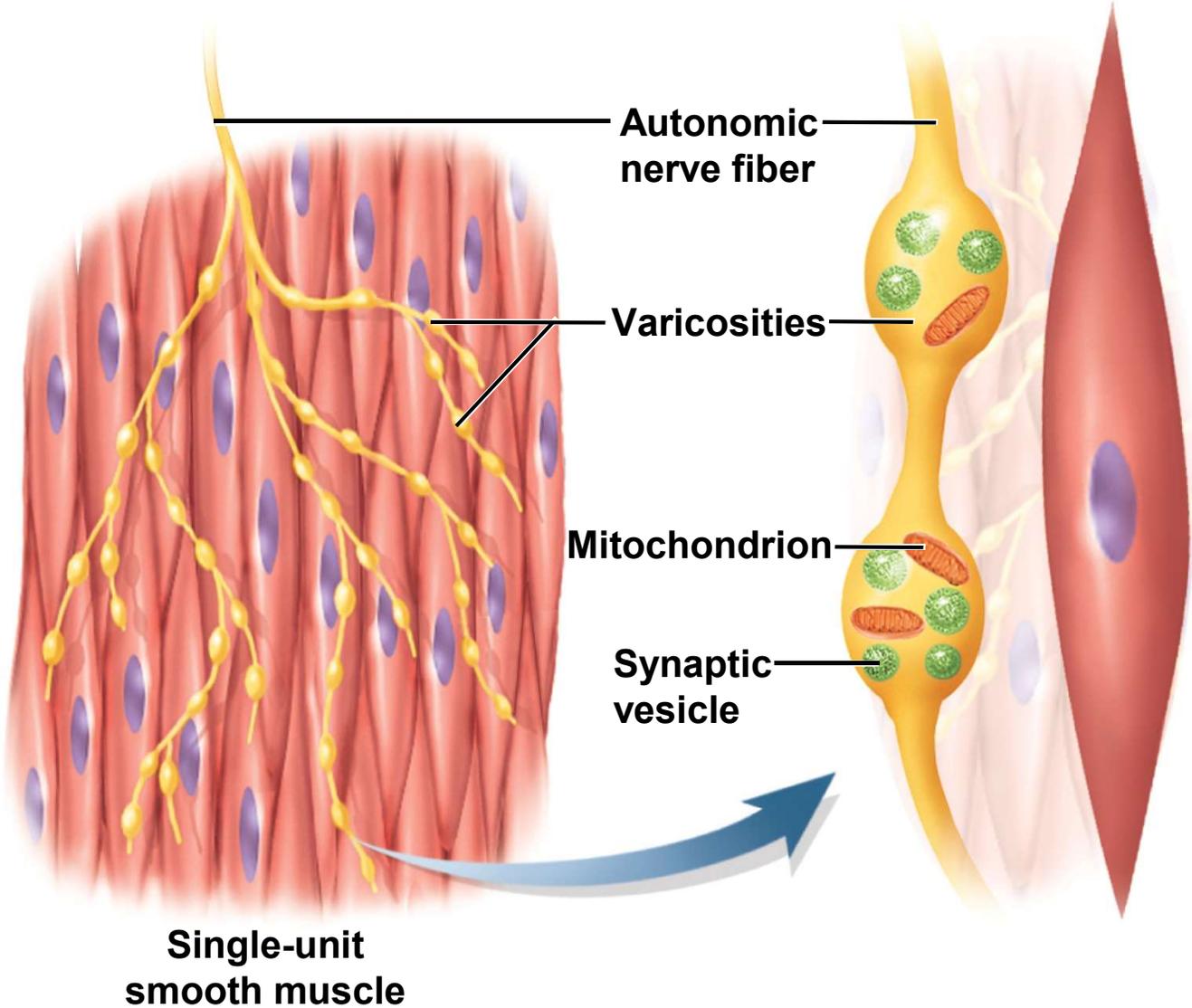


Single Unit SM

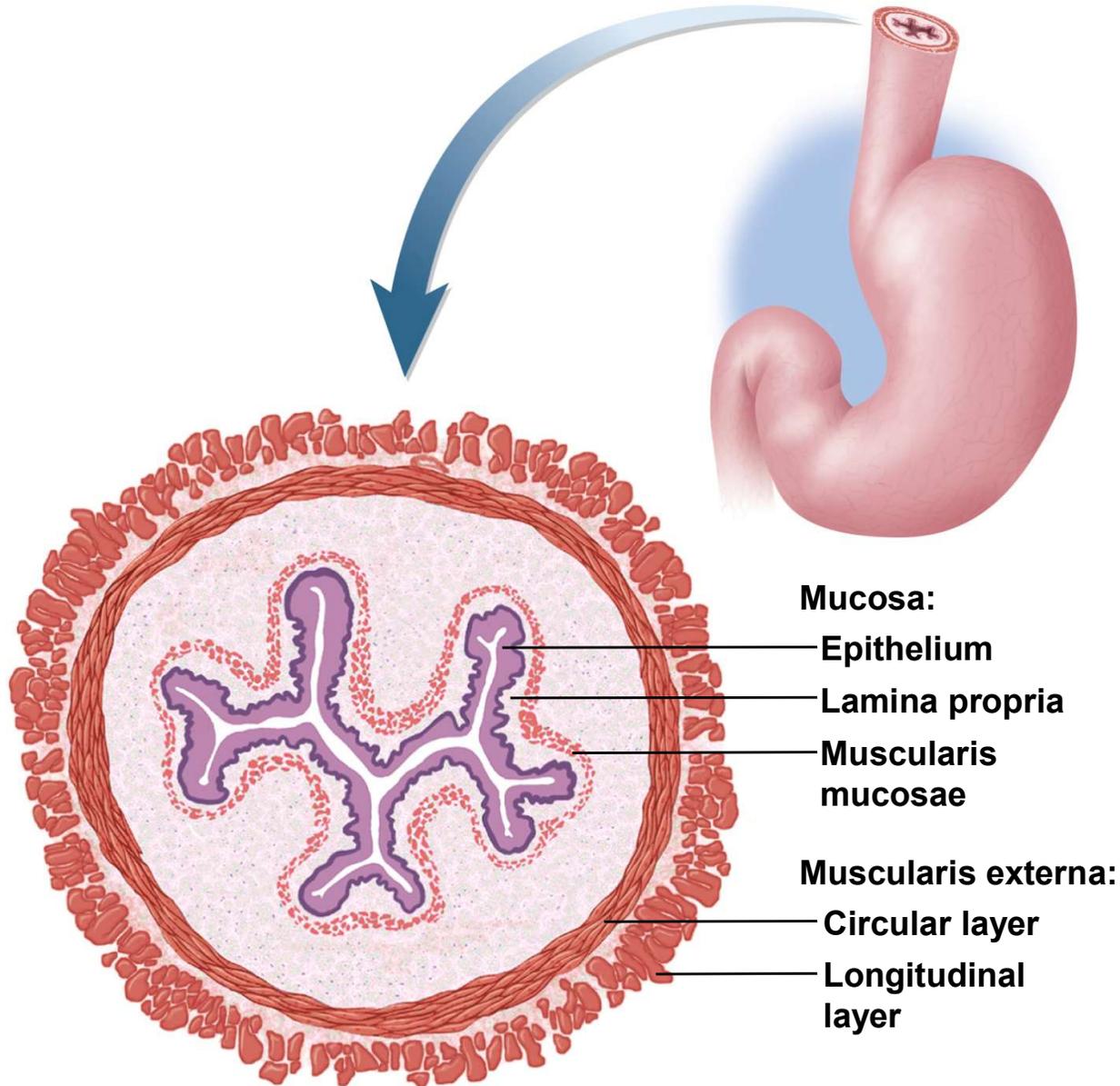


- in single unit smooth, each autonomic nerve fibers has up to 20,000 beadlike swelling called **varicosities**
 - each contains synaptic vesicles and a few mitochondria
 - nerve fiber passes amid several myocytes and stimulates all of them at once when it releases its neurotransmitter
- no motor end plates, but receptors scattered throughout the surface
- diffuse junctions – no one-to-one relationship between nerve fiber and myocyte

Stimulation of Smooth Muscle



Layers of Visceral 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

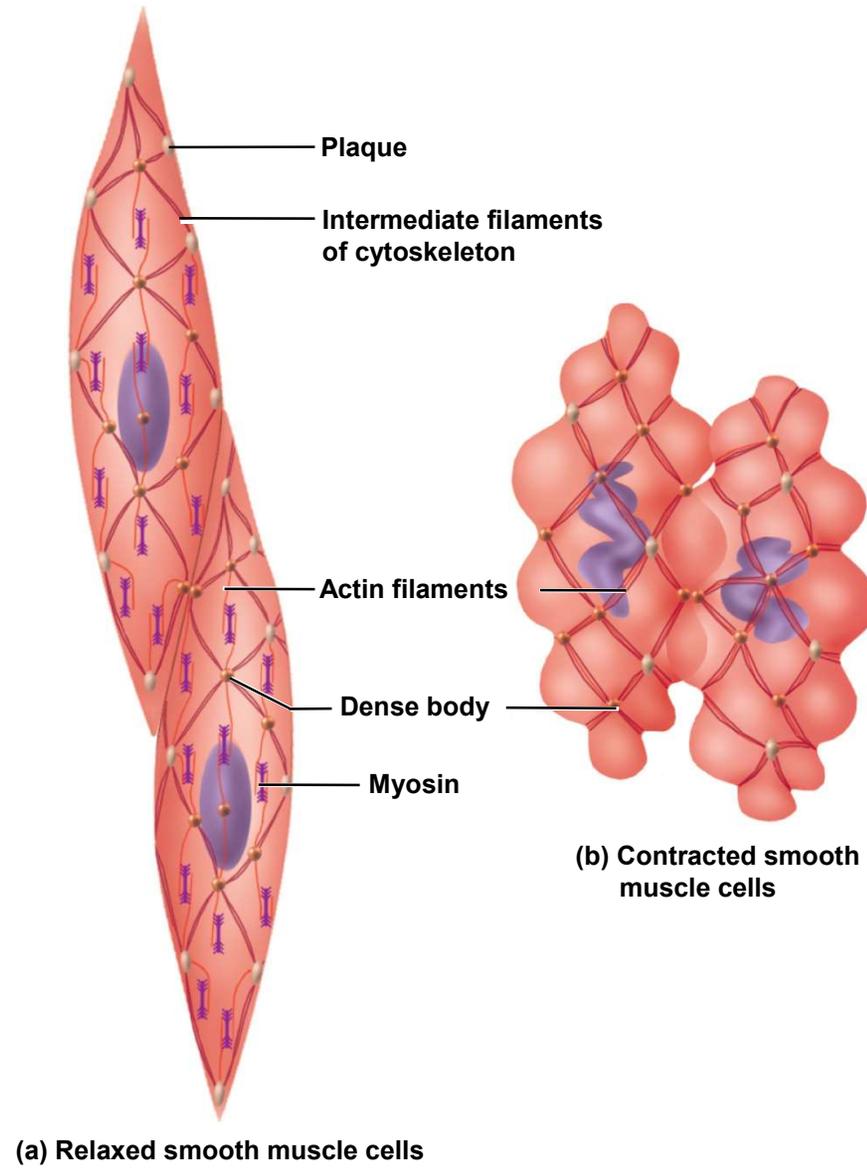
Contraction and Relaxation

- 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



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

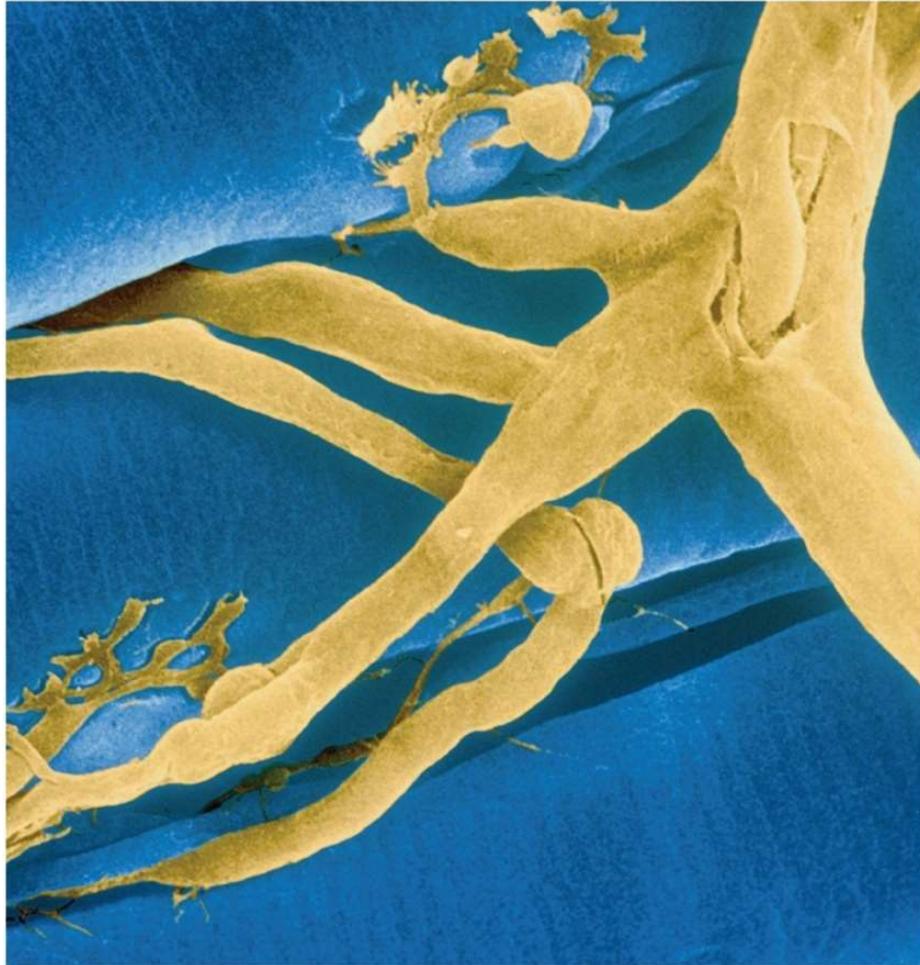
Contraction and Stretching

- 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

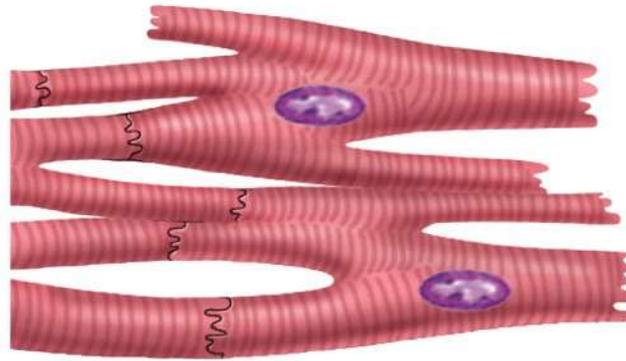
Cardiac Muscle



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, with out fail, and without conscious attention
 - must be highly resistant to fatigue

Cardiac muscle



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**