Muscular System

Part II

Diving In Deeper...

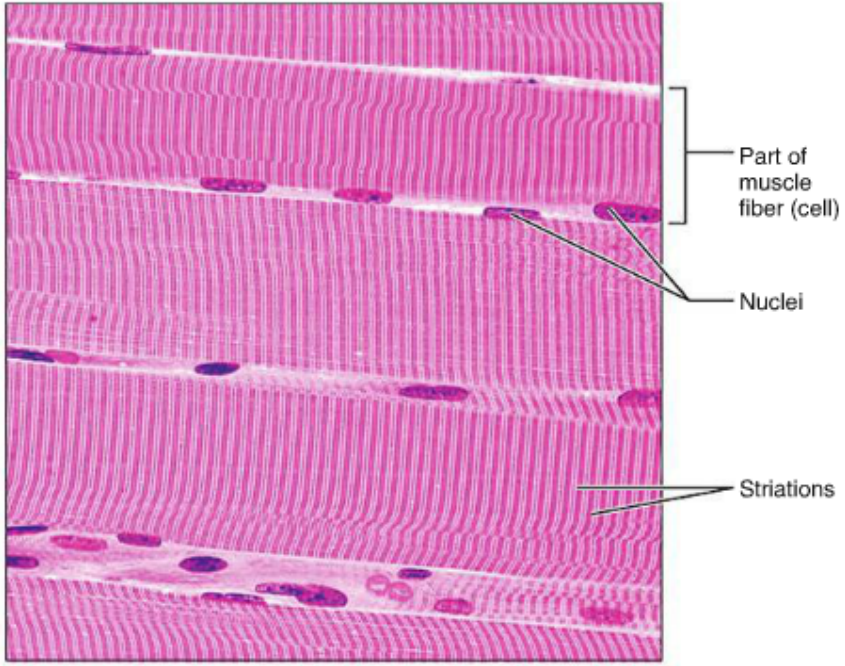
- Skeletal, cardiac, & smooth muscle
  - Only skeletal & smooth muscles have fibers
    - Skeletal fibers (cells) are the longest
    - Skeletal and cardiac are striated (pattern of sarcomeres)
- Myofilaments → Sarcomere → Myofibril → Muscle Fiber (Cell) → Fascicles → Muscle

(a) Skeletal muscle

Description: Long, cylindrical, multinucleate cells; obvious striations.

Function: Voluntary movement; locomotion; manipulation of the environment; facial expression; voluntary control.

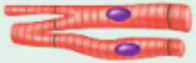
Location: In skeletal muscles attached to bones or occasionally to skin.



Photomicrograph: Skeletal muscle (approx. 440×). Notice the obvious banding pattern and the fact that these large cells are multinucleate.

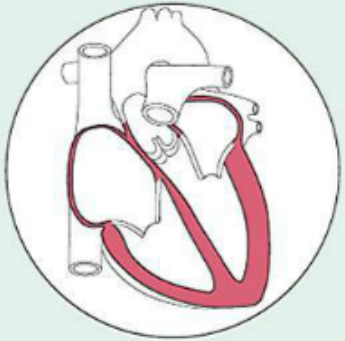
(b) Cardiac muscle

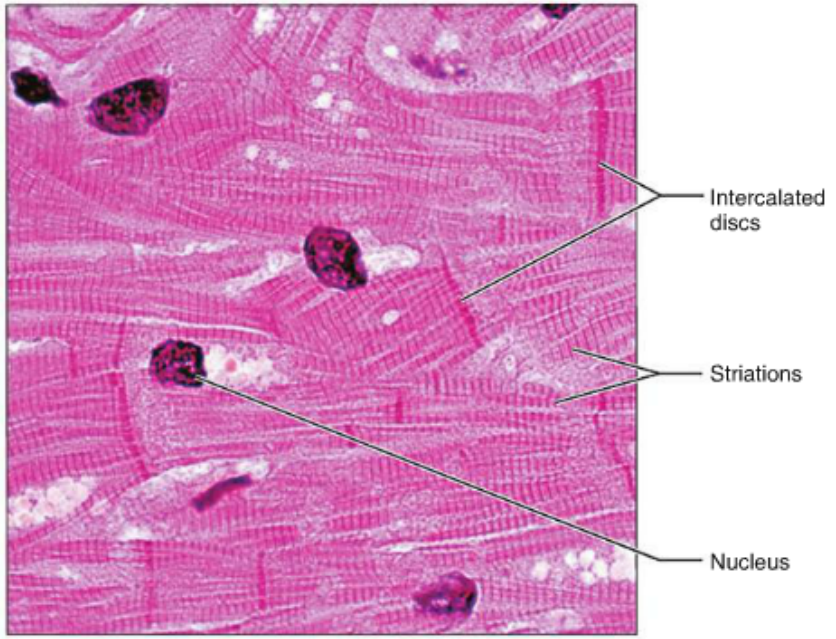
Description: Branching, striated, generally uninucleate cells that interdigitate at specialized junctions (intercalated discs).



Function: As it contracts, it propels blood into the circulation; involuntary control.

Location: The walls of the heart.

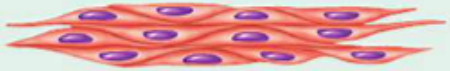




Photomicrograph: Cardiac muscle (900×); notice the striations, branching of cells, and the intercalated discs.

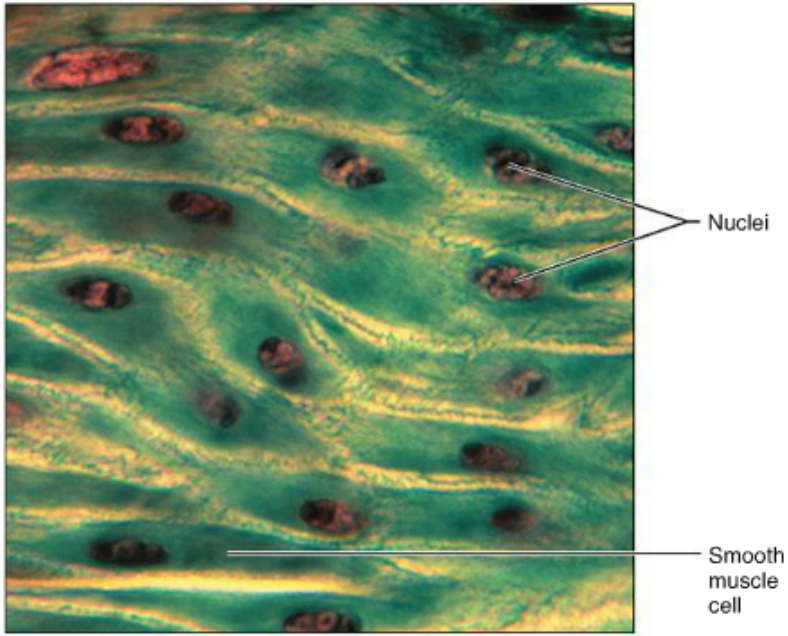
(c) Smooth muscle

Description: Spindle-shaped cells with central nuclei; no striations; cells arranged closely to form sheets.



Function: Propels substances or objects (foodstuffs, urine, a baby) along internal passageways; involuntary control.

Location: Mostly in the walls of hollow organs.



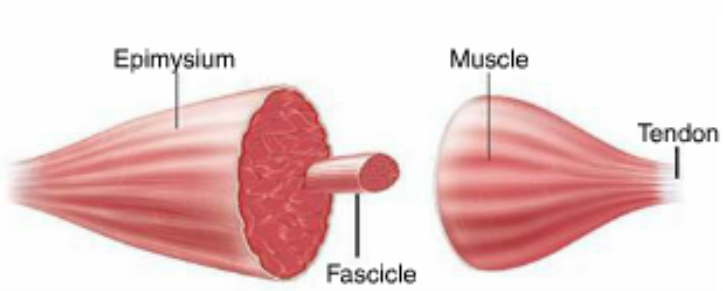
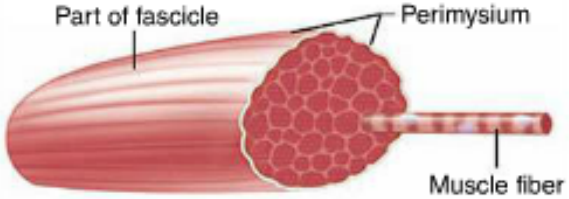
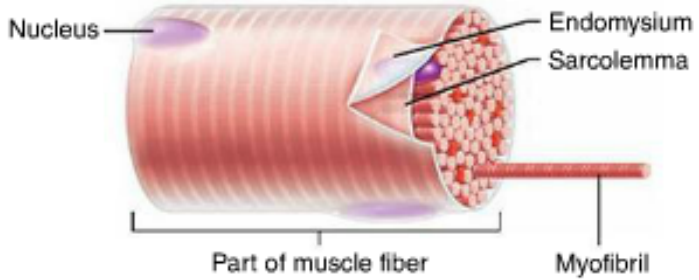
Photomicrograph: Sheet of smooth muscle (720×).

Muscle Tissues are Special Because...

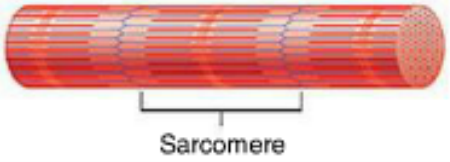
- **Excitability** (responsiveness): ability to receive and respond to a stimulus
  - usually chemical in muscles; neurotransmitter or pH change generates an electrical impulse that travels along the plasma membrane of the muscle cell causing contraction
- **Contractility**: ability to shorten forcible when adequately stimulated
- **Extensibility:** ability to extend or stretch cells shorten when contracting but they can stretch, even beyond their resting length
- **Elasticity:** ability of a muscle cell to recoil and resume its resting length after stretching

Skeletal Muscle

- Contains one nerve, one artery, & one or more veins.
- Connective tissue layers attach muscle to bone, allowing entry for blood vessels and nerves.
  - Endomysium, perimysium, epimysium
- Muscle Attachments:
  - **Direct**, or fleshy, attachments = epimysium of the muscle is fused to the periosteum of a bone or perichondrium of a cartilage.
  - **Indirect** attachments = muscle's connective tissue wrappings extend beyond the muscle as either a ropelike tendon or as a sheetlike aponeurosis
    - tendon or aponeurosis **anchors** the muscle to the connective tissue covering a skeletal element or to the fascia of other muscles
    - more common because of their durability and small size

STRUCTURE AND ORGANIZATIONAL LEVEL	DESCRIPTION	CONNECTIVE TISSUE WRAPPINGS
Muscle (organ) 	A muscle consists of hundreds to thousands of muscle cells, plus connective tissue wrappings, blood vessels, and nerve fibers.	Covered externally by the epimysium
Fascicle (a portion of the muscle) 	A fascicle is a discrete bundle of muscle cells, segregated from the rest of the muscle by a connective tissue sheath.	Surrounded by perimysium
Muscle Fiber (cell) 	A muscle fiber is an elongated multinucleate cell; it has a banded (striated) appearance.	Surrounded by endomysium

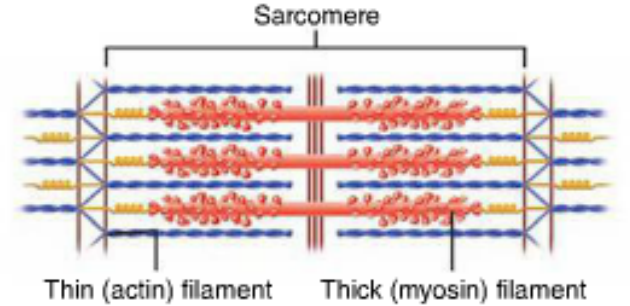
Myofibril or Fibril (complex organelle composed of bundles of myofilaments)



Myofibrils are rodlike contractile elements that occupy most of the muscle cell volume. Composed of sarcomeres arranged end to end, they appear banded, and bands of adjacent myofibrils are aligned.

—

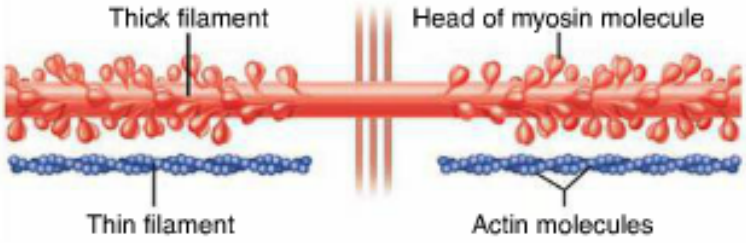
Sarcomere (a segment of a myofibril)



A sarcomere is the contractile unit, composed of myofilaments made up of contractile proteins.

—

Myofilament or Filament (extended macromolecular structure)

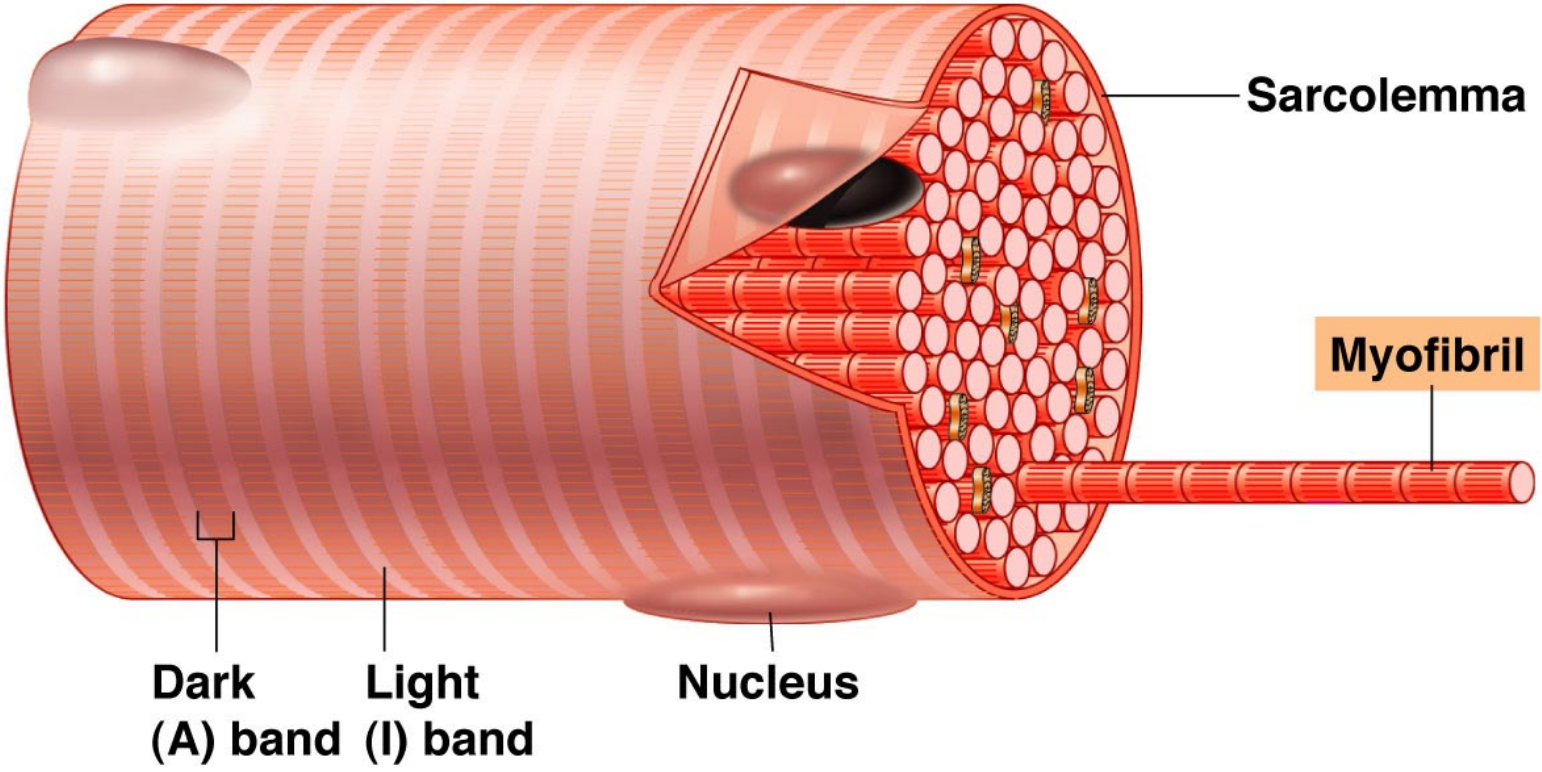


Contractile myofilaments are of two types—thick and thin. Thick filaments contain bundled myosin molecules; thin filaments contain actin molecules (plus other proteins). The sliding of the thin filaments past the thick filaments produces muscle shortening. Elastic filaments (not shown here) maintain the organization of the A band and provide elastic recoil when muscle contraction ends.

—

Skeletal Muscle Fiber

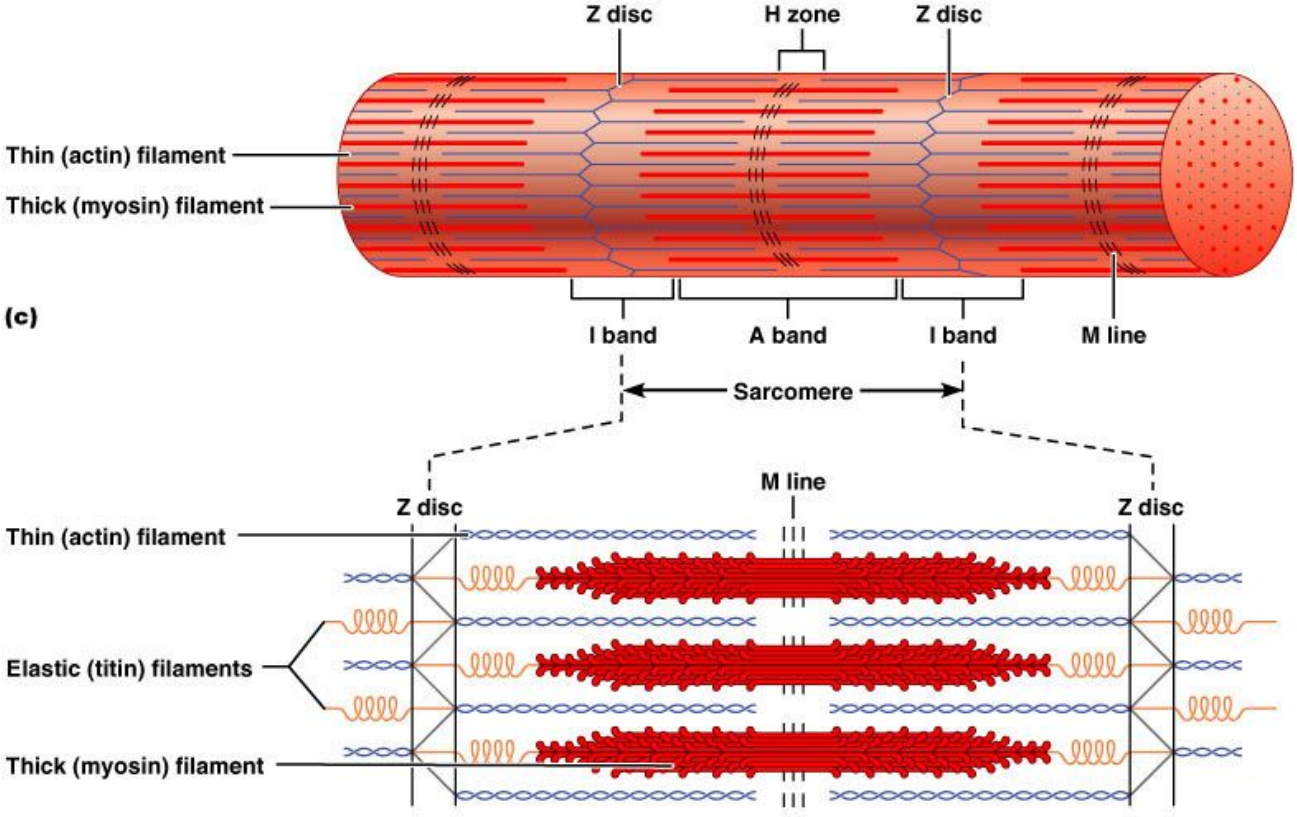
- Long cylindrical cell with multiple nuclei right beneath the sarcolemma
- Contain sarcoplasm, glycosomes, & myoglobin
  - glycosomes - stored glycogen granules; provide glucose during muscle activity
  - myoglobin - red pigment in muscle that stores oxygen



(a) Segment of a muscle fiber (cell)

Myofibrils

- Bundles of myofilaments within the muscle fiber
  - thick & thin filaments
  - repeating sarcomeres
- Packed tight with mitochondria in between
- Take up most of the cellular space (80%)



A Band: overlapping of thick & thin; length of thick

H Zone: middle of A Band; thick only

M Line: myomesin

I Band: thin only

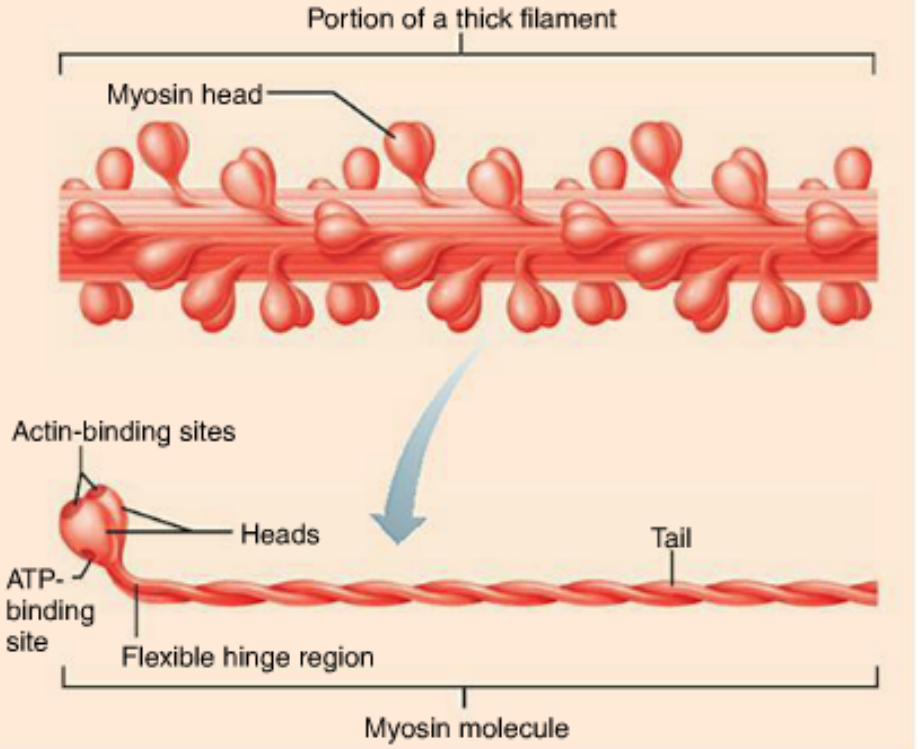
Z Disc: interruption of thin

Thick Filaments

- Connected at M-Line
- Contain myosin
  - one of the principal proteins found in muscle
  - rodlike tail attached by a flexible hinge to two globular heads
    - during contraction, the heads link the thick and thin filaments together forming **cross bridges**
      - act as motors to generate force
        - “flicking”

Thick filament

Each thick filament consists of many myosin molecules whose heads protrude at opposite ends of the filament.



Thin Filaments

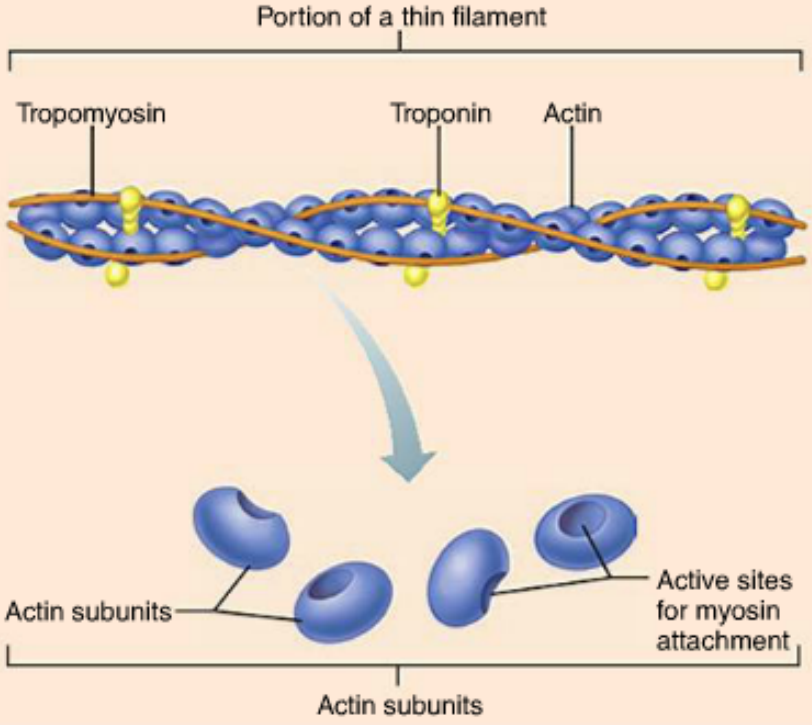
- Anchored at Z-Disc
- Contain Actin
- A contractile protein of muscle
  - **Globular actin or G actin:** bear the active sites to which the myosin heads attach during contraction
    - polymerized into long actin filaments called filamentous, or F actin

Thin Filament Regulators

- **Tropomyosin:** rod-shaped protein
  - spirals about the actin core to stiffen and stabilize it
  - block myosin-binding sites on actin to prevent myosin heads on thick filaments from binding to thin filaments in relaxed state
- **Troponin:** globular three-polypeptide complex
  - inhibitory subunit
  - helps position Tropomyosin on actin
  - binds calcium ions

Thin filament

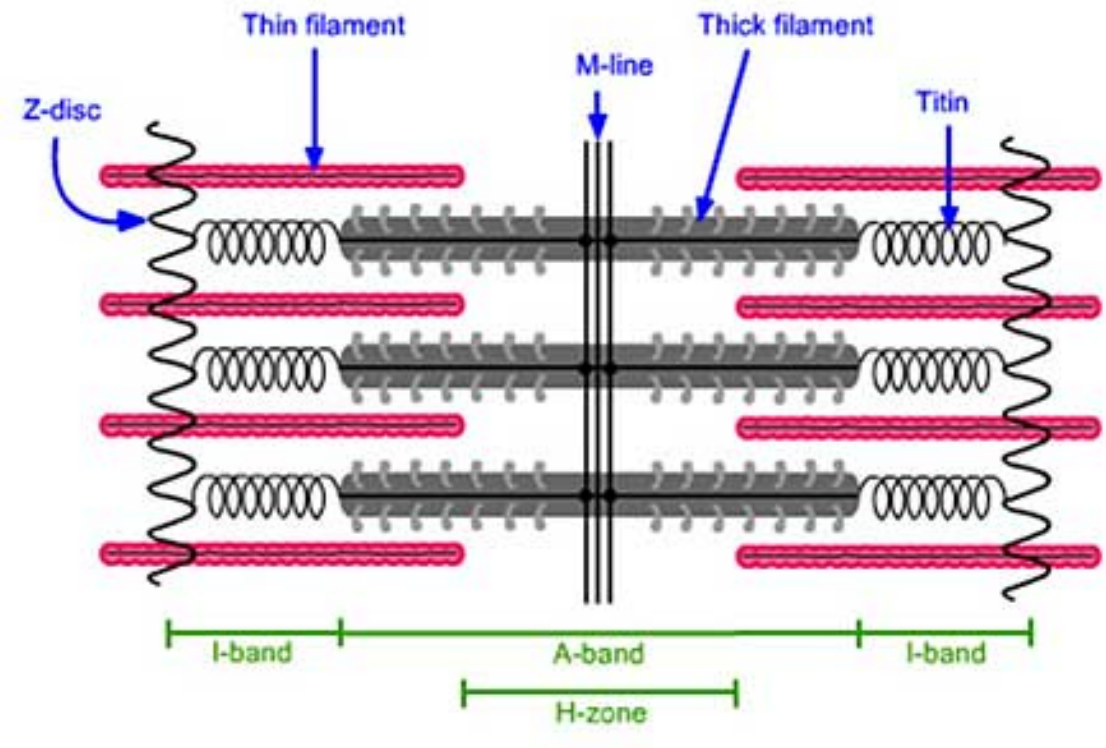
A thin filament consists of two strands of actin subunits twisted into a helix plus two types of regulatory proteins (troponin and tropomyosin).

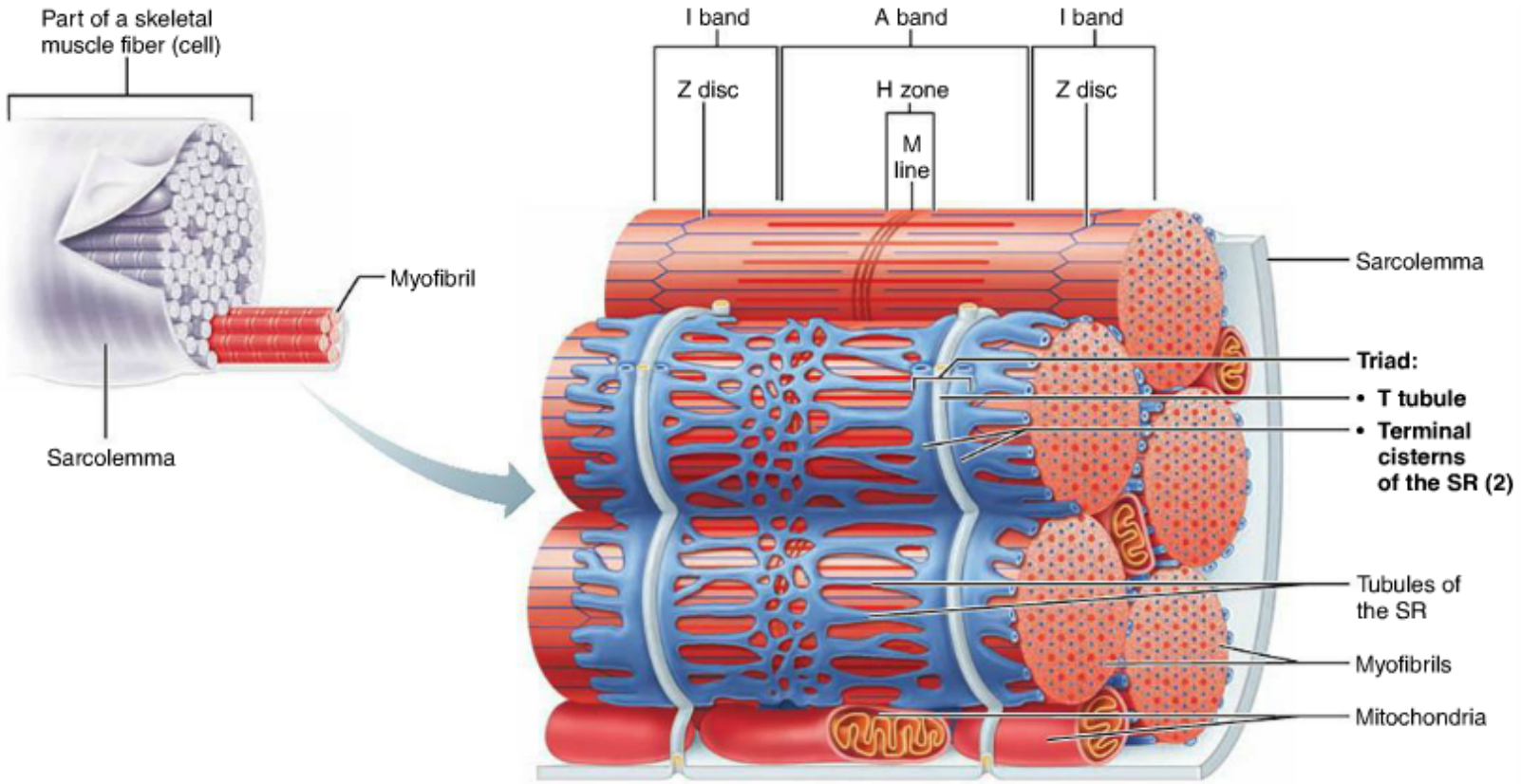


Additional Myofibril Proteins

- **Elastic filament:** composed of the giant protein **titin**
  - extends from the Z disc to the thick filament and runs within the thick filament to attach to the M line
  - holds thick filaments in place
  - helps resist excessive stretching
- **Dystrophin**: links the thin filaments to integral proteins of the sarcolemma
- **Nebulin, Myomesin, and C proteins:** bind filaments or sarcomeres together and maintain their alignment

Sarcomere

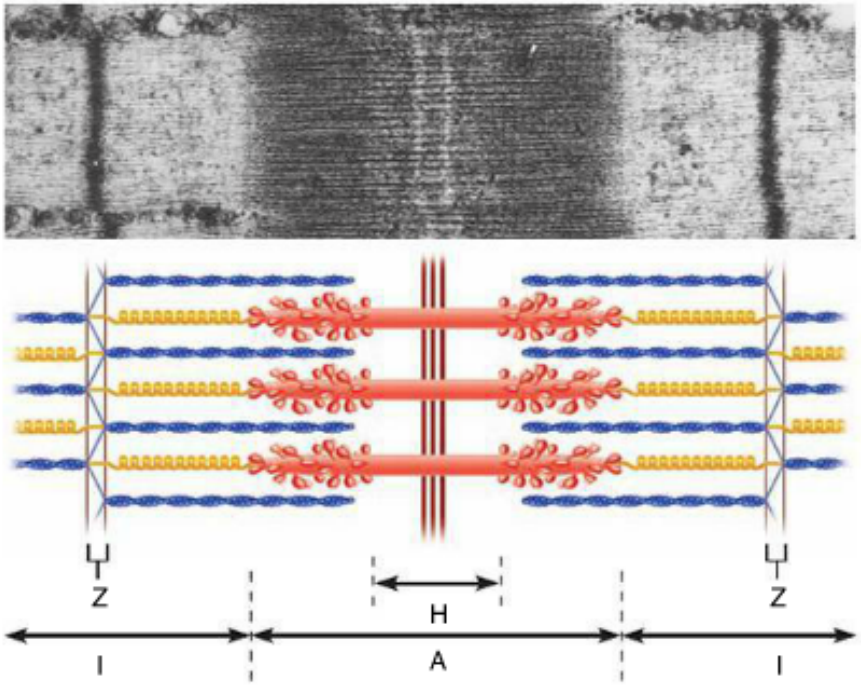

Thin filament
Thick filament
M-line
Z-disc
Titin
I-band
A-band
I-band
H-zone


Part of a skeletal muscle fiber (cell)
Myofibril
Sarcolemma
I band
A band
I band
Z disc
H zone
Z disc
M line
Sarcolemma
Triad:
• T tubule
• Terminal cisterns of the SR (2)
Tubules of the SR
Myofibrils
Mitochondria

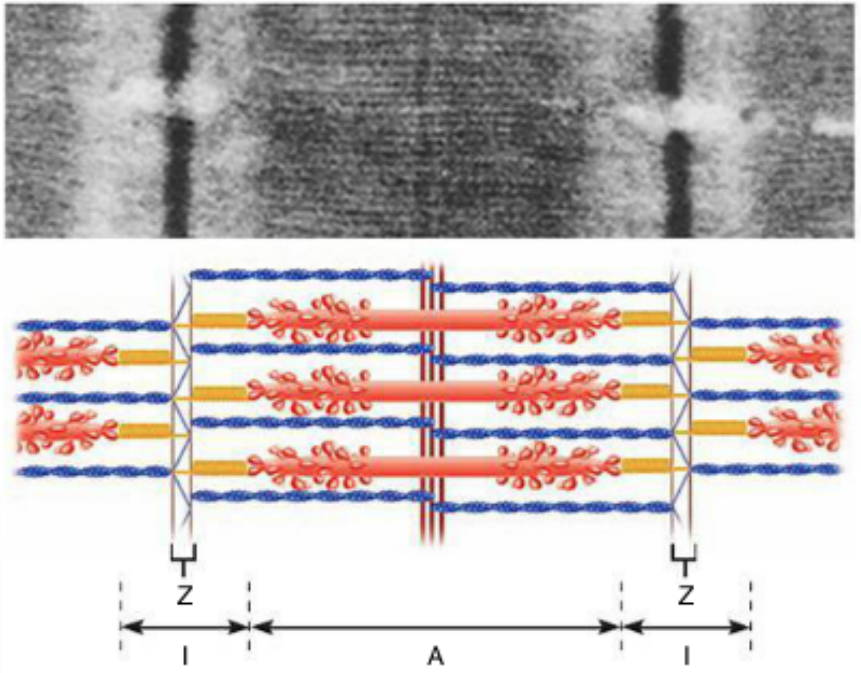
Muscle Contraction

- To shorten or develop tension, an ability highly developed in muscle cells
- Occurs if and when the cross bridges generate enough tension on the thin filaments to exceed the forces (“flicking”)
- Ends when the cross bridges become inactive, the tension declines, and then the muscle fiber relaxes

① Fully relaxed sarcomere of a muscle fiber



② Fully contracted sarcomere of a muscle fiber



Sliding Filament Theory

During contraction the thin filaments slide past the thick ones so that the actin and myosin filaments overlap to a greater degree.

- Nervous system stimulates fibers
  - myosin heads on thick filaments latch onto myosin-binding sites on actin in the thin filaments→ sliding begins
- Cross bridge attachments form and break several time in a contraction, generating tension and propelling thin filaments toward the center of the sarcomere → muscle cell shortens
- Thin filaments slide centrally, the Z discs to which they attach are pulled toward the M line

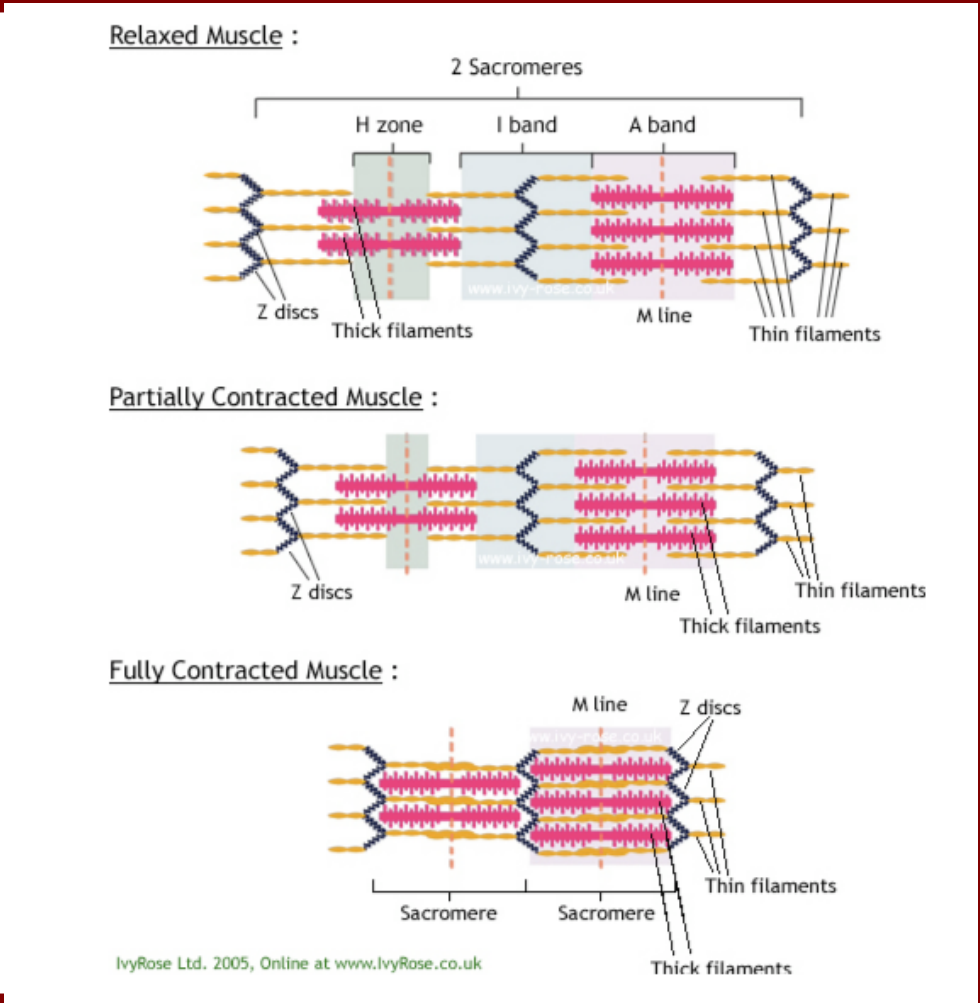
I Band decreases

H Band decreases and then disappears

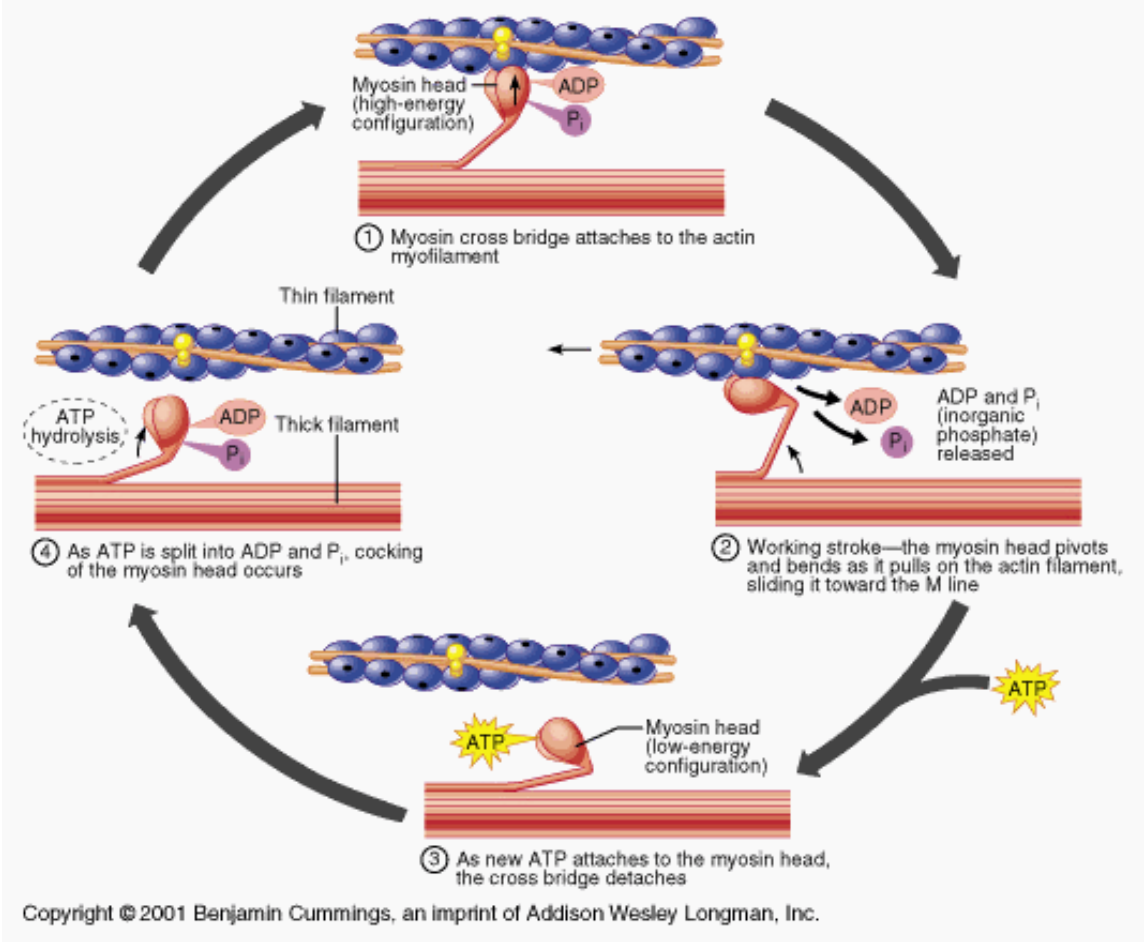
Zone of overlap increases

Z Discs move closer to one another

A Band doesn't change (just closer together now)



- A fiber must be stimulated by a nerve ending so that a change in membrane potential occurs.
- It must generate an electrical current (**action potential**) in its sarcolemma
- Action potential is automatically transmitted along the **sarcolemma**
- Intracellular **calcium** ion levels must rise briefly, providing final trigger

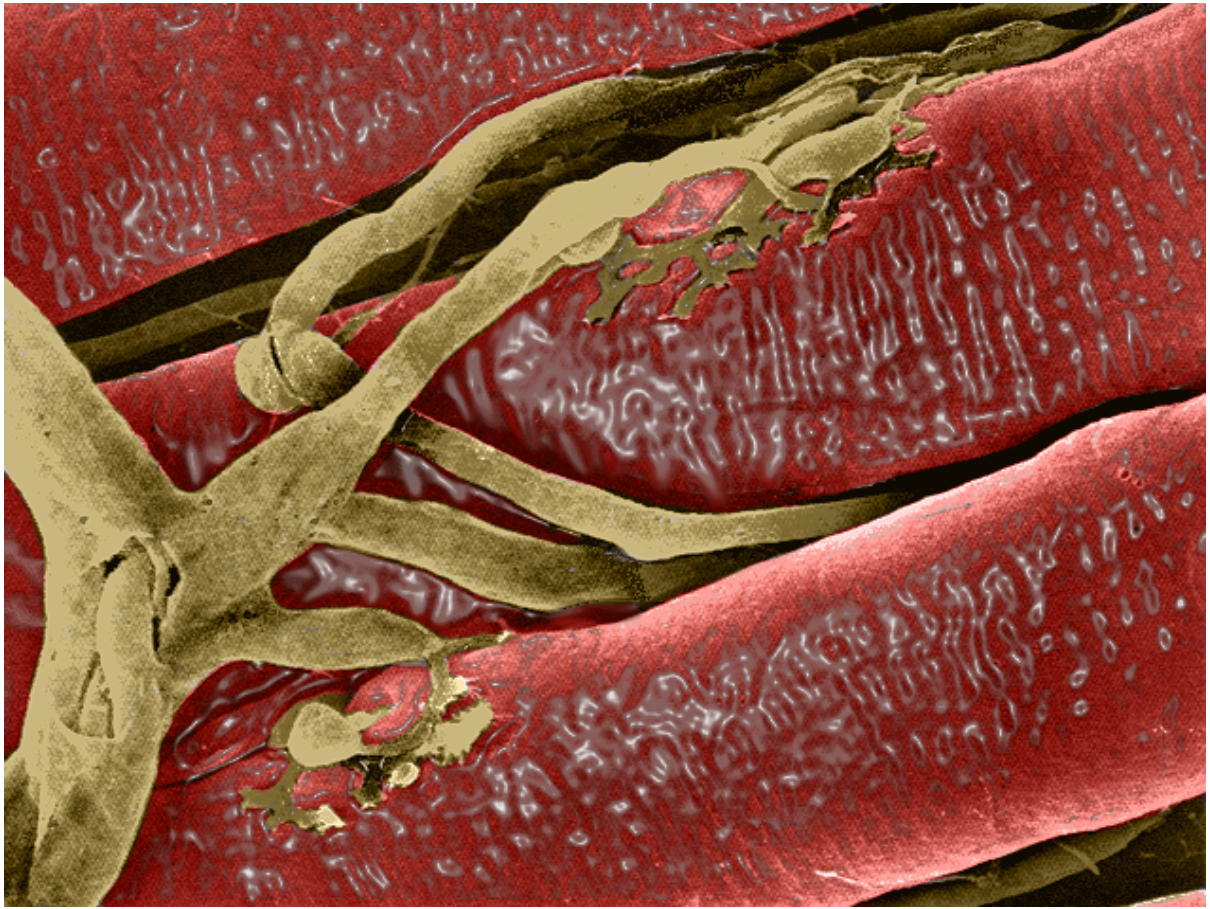


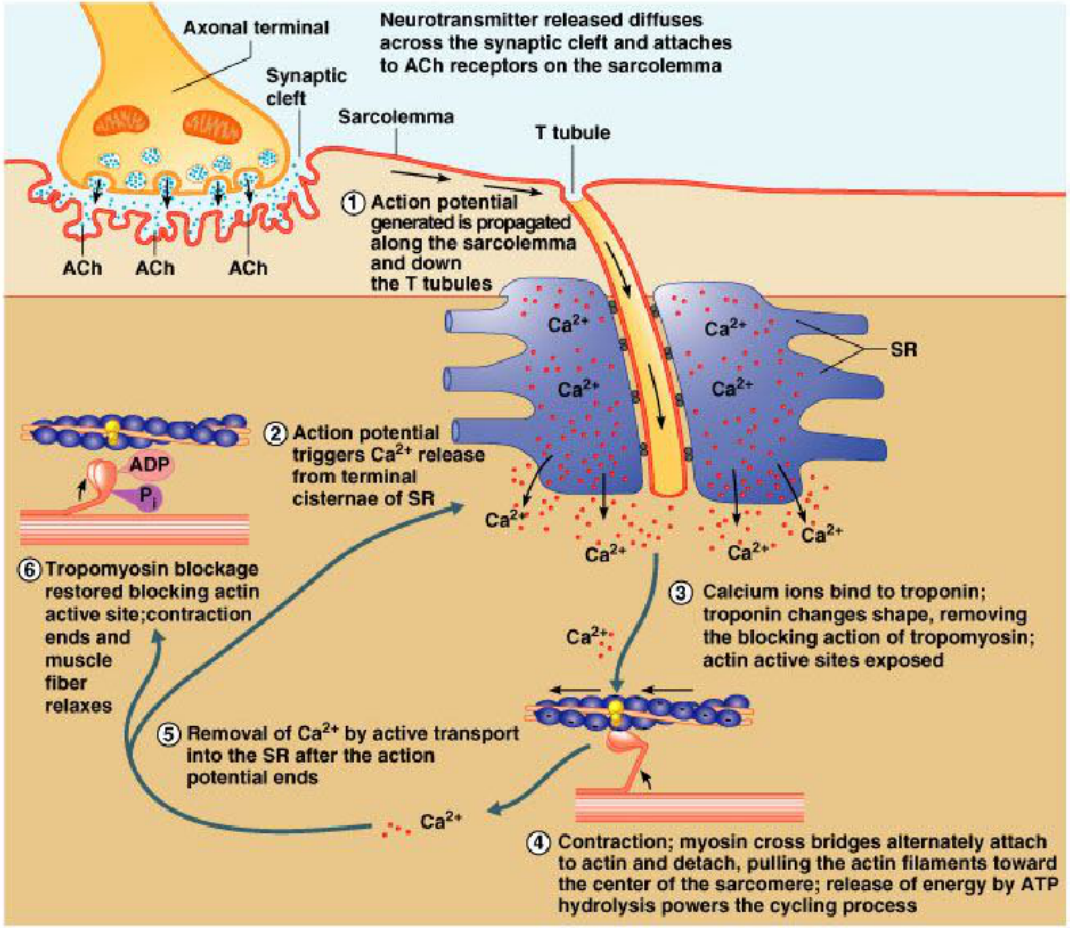
Neuromuscular Junction

- Region where a motor neuron comes into close contact with skeletal muscle cell
  - Motor Neuron - nerve that resides in the brain/spinal cord and its axon activates skeletal muscle

Participants of the NMJ

- **Synaptic Cleft:** Fluid filled space at a synapse
  - Separate axon terminal and muscle fiber
- **Synaptic Vesicles:** small membranous sacs containing the neurotransmitter
- **Acetylcholine** (ACh): chemical neurotransmitter released by some nerve endings
- **Junctional folds**: trough-like part of the muscle fibers sarcolemma that provide a large surface area for ACh receptors located there
- **Acetylcholinesterase** (AChE): enzyme present at the neuromuscular junction and synapses that degrades acetylcholine and terminates it actions




Axonal terminal
Synaptic cleft
Neurotransmitter released diffuses across the synaptic cleft and attaches to ACh receptors on the sarcolemma
Sarcolemma
T tubule
ACh
ACh
ACh
1 Action potential generated is propagated along the sarcolemma and down the T tubules
SR
Ca2+
2 Action potential triggers Ca2+ release from terminal cisternae of SR
ADP
Pi
3 Calcium ions bind to troponin; troponin changes shape, removing the blocking action of tropomyosin; actin active sites exposed
4 Contraction; myosin cross bridges alternately attach to actin and detach, pulling the actin filaments toward the center of the sarcomere; release of energy by ATP hydrolysis powers the cycling process
5 Removal of Ca2+ by active transport into the SR after the action potential ends
6 Tropomyosin blockage restored blocking actin active site;contraction ends and muscle fiber relaxes

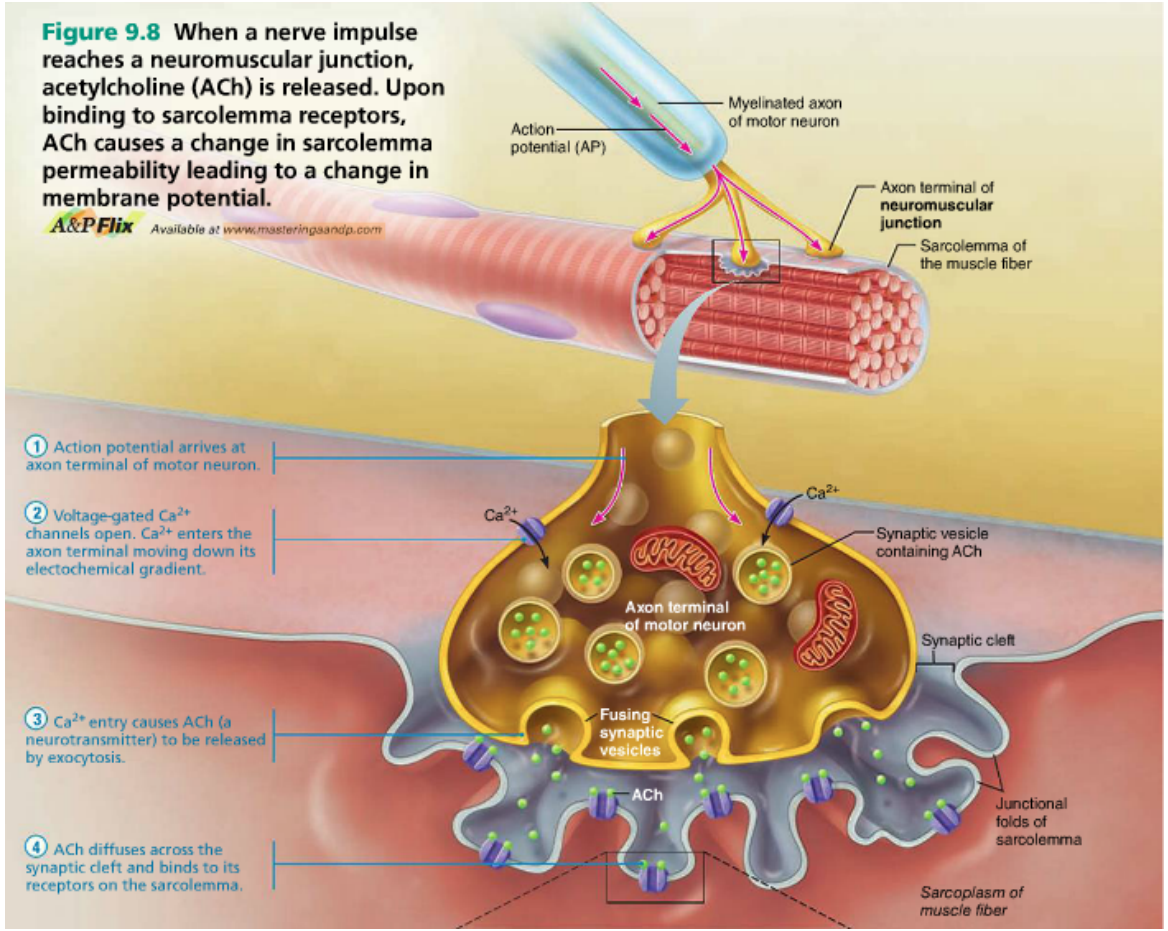
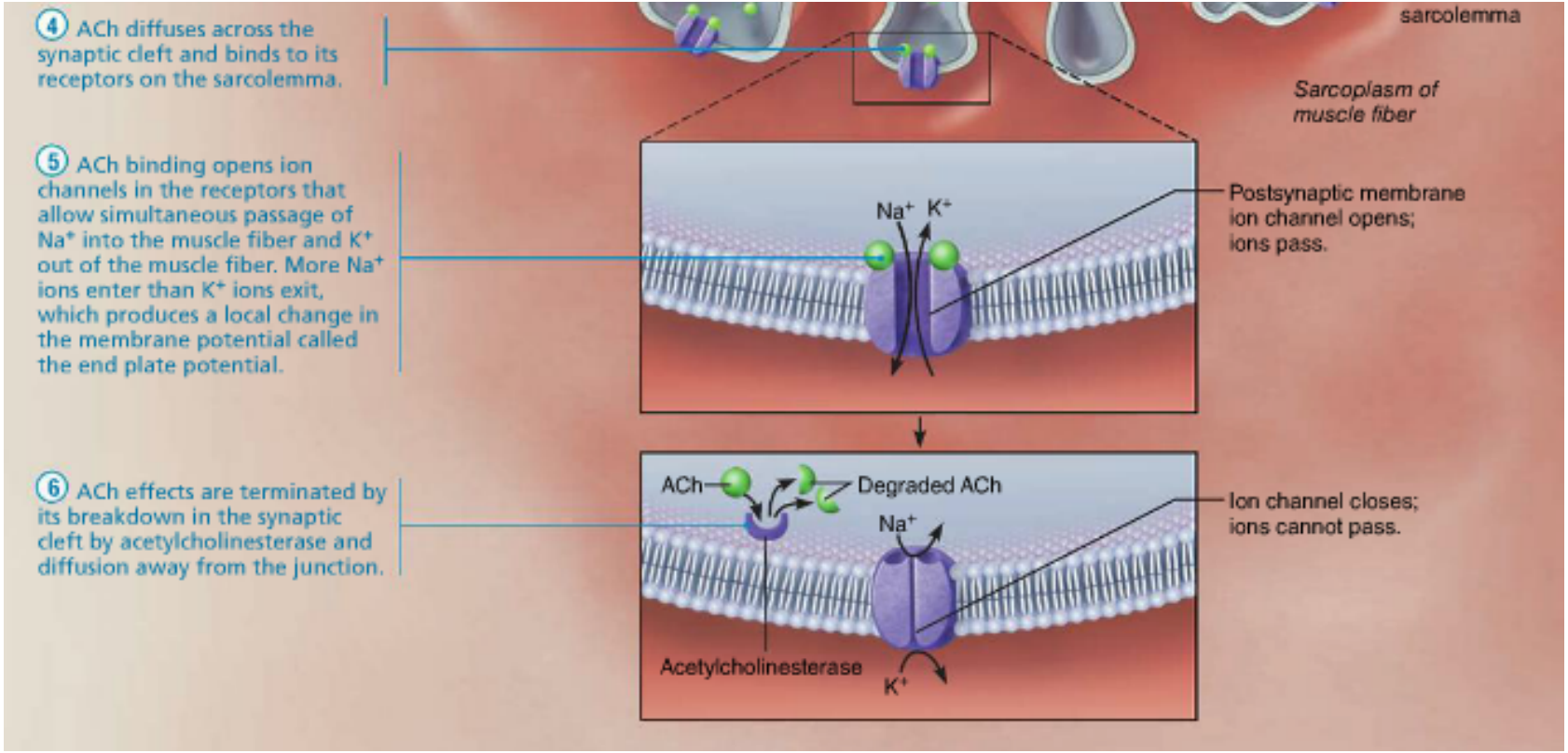


Figure 9.8 When a nerve impulse reaches a neuromuscular junction, acetylcholine (ACh) is released. Upon binding to sarcolemma receptors, ACh causes a change in sarcolemma permeability leading to a change in membrane potential.
A&P Flix Available at www.masteringaandp.com
Myelinated axon of motor neuron
Action potential (AP)
Axon terminal of neuromuscular junction
Sarcolemma of the muscle fiber
1 Action potential arrives at axon terminal of motor neuron.
2 Voltage-gated Ca^{2+} channels open. Ca^{2+} enters the axon terminal moving down its electochemical gradient.
3 Ca^{2+} entry causes ACh (a neurotransmitter) to be released by exocytosis.
4 ACh diffuses across the synaptic cleft and binds to its receptors on the sarcolemma.
Ca^{2+}
Ca^{2+}
Synaptic vesicle containing ACh
Axon terminal of motor neuron
Synaptic cleft
Fusing synaptic vesicles
ACh
Junctional folds of sarcolemma
Sarcoplasm of muscle fiber


4 ACh diffuses across the synaptic cleft and binds to its receptors on the sarcolemma.
sarcolemma
Sarcoplasm of muscle fiber
5 ACh binding opens ion channels in the receptors that allow simultaneous passage of Na+ into the muscle fiber and K+ out of the muscle fiber. More Na+ ions enter than K+ ions exit, which produces a local change in the membrane potential called the end plate potential.
Na+ K+
Postsynaptic membrane ion channel opens; ions pass.
6 ACh effects are terminated by its breakdown in the synaptic cleft by acetylcholinesterase and diffusion away from the junction.
ACh
Degraded ACh
Na+
Ion channel closes; ions cannot pass.
Acetylcholinesterase
K+

Get into groups of 7.

You have ~20 minutes to write, design, & direct a skit that demonstrates a sarcomere throughout contraction and relaxation.

Each student must participate. Yes, this is worth points.

Information in skit needs to be accurate & there must be visuals.