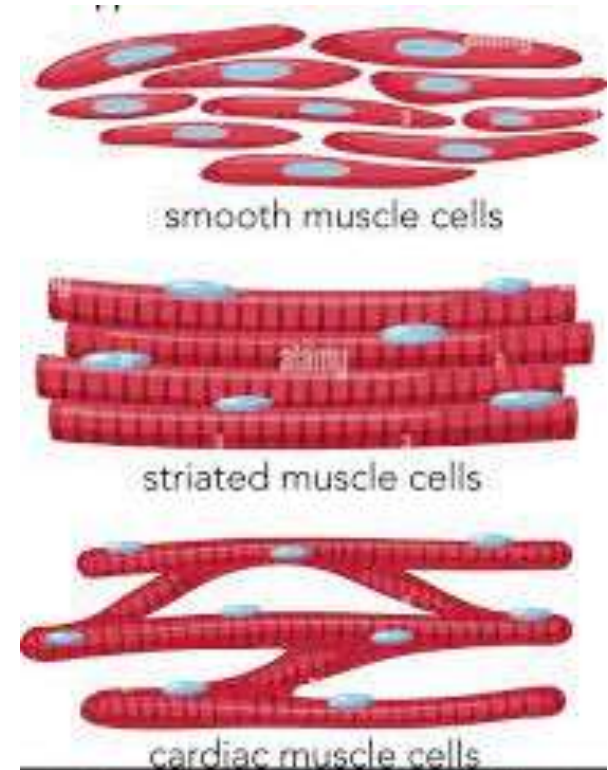


GENERAL HISTOLOGY

MUSCULAR TISSUE

Dr AMAL ALBTOOSH

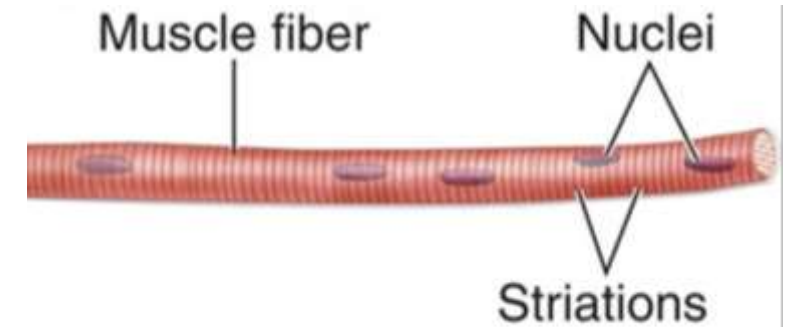


Three muscle tissues

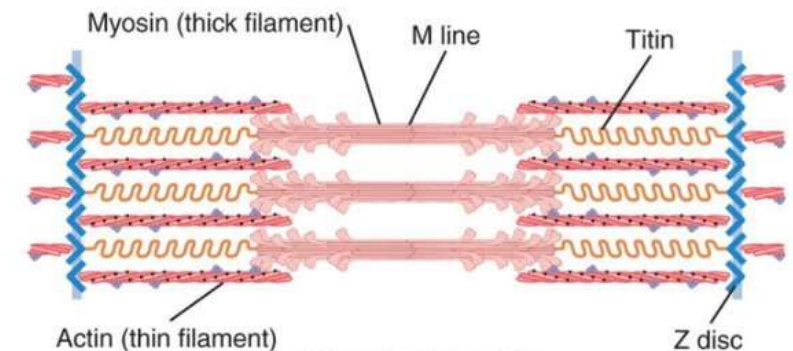
1. Skeletal muscle
2. Cardiac muscle
3. Smooth muscle

Skeletal Muscle

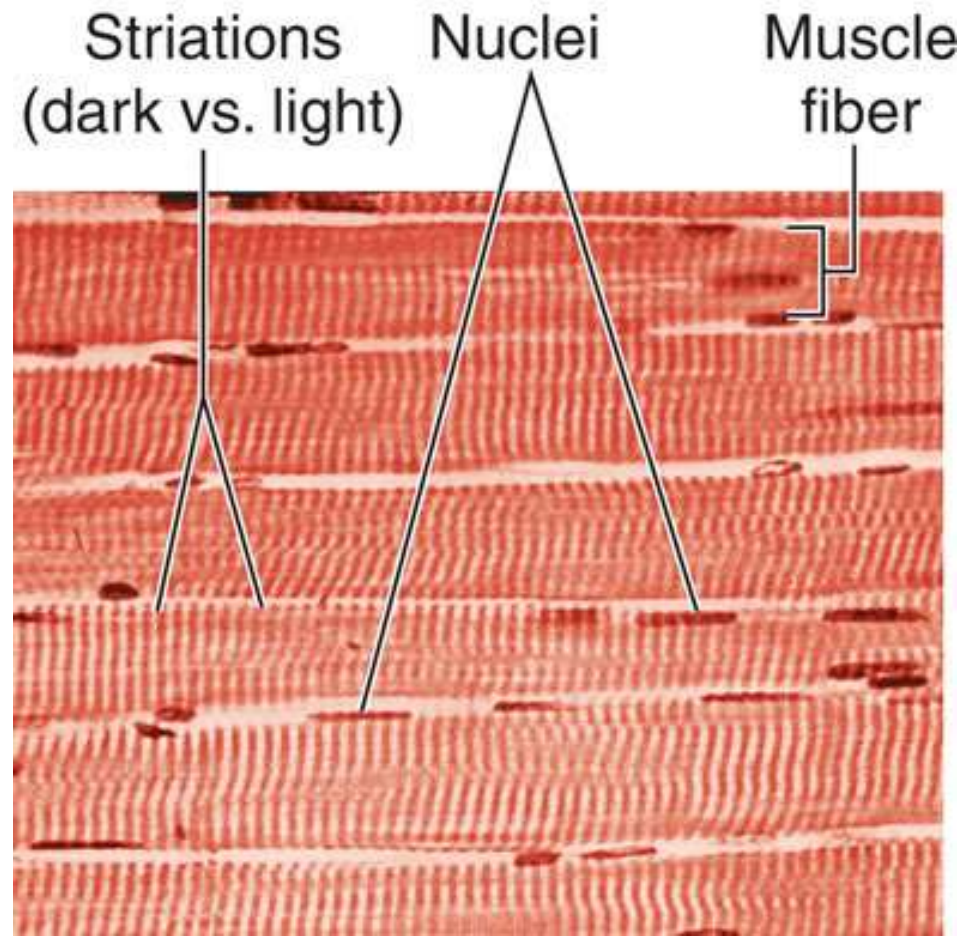
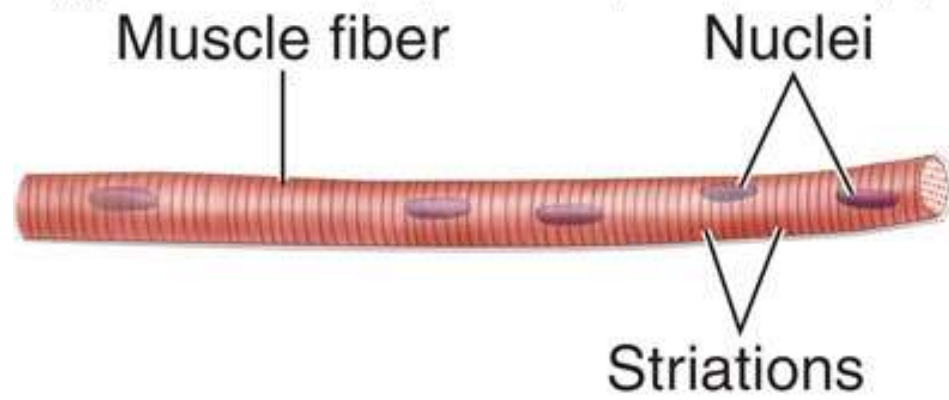
- Cells are long and cylindrical in shape
- Cells are multi-nucleated
- Cross-striations present
- Under voluntary control
- Sarcomere is contractile unit of skeletal muscle; defined as the distance between 2 “Z” discs.
- Contractile proteins: actin, myosin and tinin.
- Regulatory proteins: troponin and tropomyosin.



The Sarcomere



Hall: Guyton and Hall Textbook of Medical Physiology, 12th Edition
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Prefixes referring to Skeletal Muscle Tissue

- Myo- and Sarco-
- Myofibril, myofilament, endomysium, perimysium, epimysium
- Sarcolemma, sarcoplasm, sarcoplasmic reticulum, sarcomere

TABLE 10.1

Structural Components of a Muscle Fiber

Term	Definition
<i>General Structure and Contents of the Muscle Fiber</i>	
Sarcolemma	The plasma membrane of a muscle fiber
Sarcoplasm	The cytoplasm of a muscle fiber
Glycogen	An energy-storage polysaccharide abundant in muscle
Myoglobin	An oxygen-storing red pigment of muscle
T tubule	A tunnel-like extension of the sarcolemma extending from one side of the muscle fiber to the other; conveys electrical signals from the cell surface to its interior
Sarcoplasmic reticulum	The smooth ER of a muscle fiber; a Ca^{2+} reservoir
Terminal cisternae	The dilated ends of sarcoplasmic reticulum adjacent to a T tubule
<i>Myofibrils</i>	
Myofibril	A bundle of protein microfilaments (myofilaments)
Myofilament	A threadlike complex of several hundred contractile protein molecules
Thick filament	A myofilament about 11 nm in diameter composed of bundled myosin molecules
Elastic filament	A myofilament about 1 nm in diameter composed of a giant protein, titin, that emerges from the core of a thick filament and links it to a Z disc; aids in the recoil of a relaxing muscle fiber.

Thin filament	A myofilament about 5 to 6 nm in diameter composed of actin, troponin, and tropomyosin
Myosin	A protein with a long shaftlike tail and a globular head; constitutes the thick myofilament
F actin	A fibrous protein made of a long chain of G actin molecules twisted into a helix; main protein of the thin myofilament
G actin	A globular subunit of F actin with an active site for binding a myosin head
Regulatory proteins	Troponin and tropomyosin, proteins that do not directly engage in the sliding filament process of muscle contraction but regulate myosin-actin binding
Tropomyosin	A regulatory protein that lies in the groove of F actin and, in relaxed muscle, blocks the myosin-binding active sites
Troponin	A regulatory protein associated with tropomyosin that acts as a calcium receptor
Titin	A springy protein that forms the elastic filaments and Z discs
Striations and Sarcomeres	
Striations	Alternating light and dark transverse bands across a myofibril
A band	Dark band formed by parallel thick filaments that partly overlap the thin filaments
H band	A lighter region in the middle of an A band that contains thick filaments only; thin filaments do not reach this far into the A band in relaxed muscle
I band	A light band composed of thin filaments only
Z disc	A disc of titin to which thin filaments and elastic filaments are anchored at each end of a sarcomere; appears as a narrow dark line in the middle of the I band

Connective tissues and fascicles

- Myofibril- composed of bundles of myofilaments
- Endomysium- areolar CT covering each muscle fiber and binding it to its neighbors.
- Perimysium- dense irregular CT covering muscle fascicles.
- Fascicles- bundles of muscle fibers surrounded by perimysium.
- Epimysium- covering of dense irregular CT surrounding the entire muscle.

Skeletal Muscle Structure/ Organization

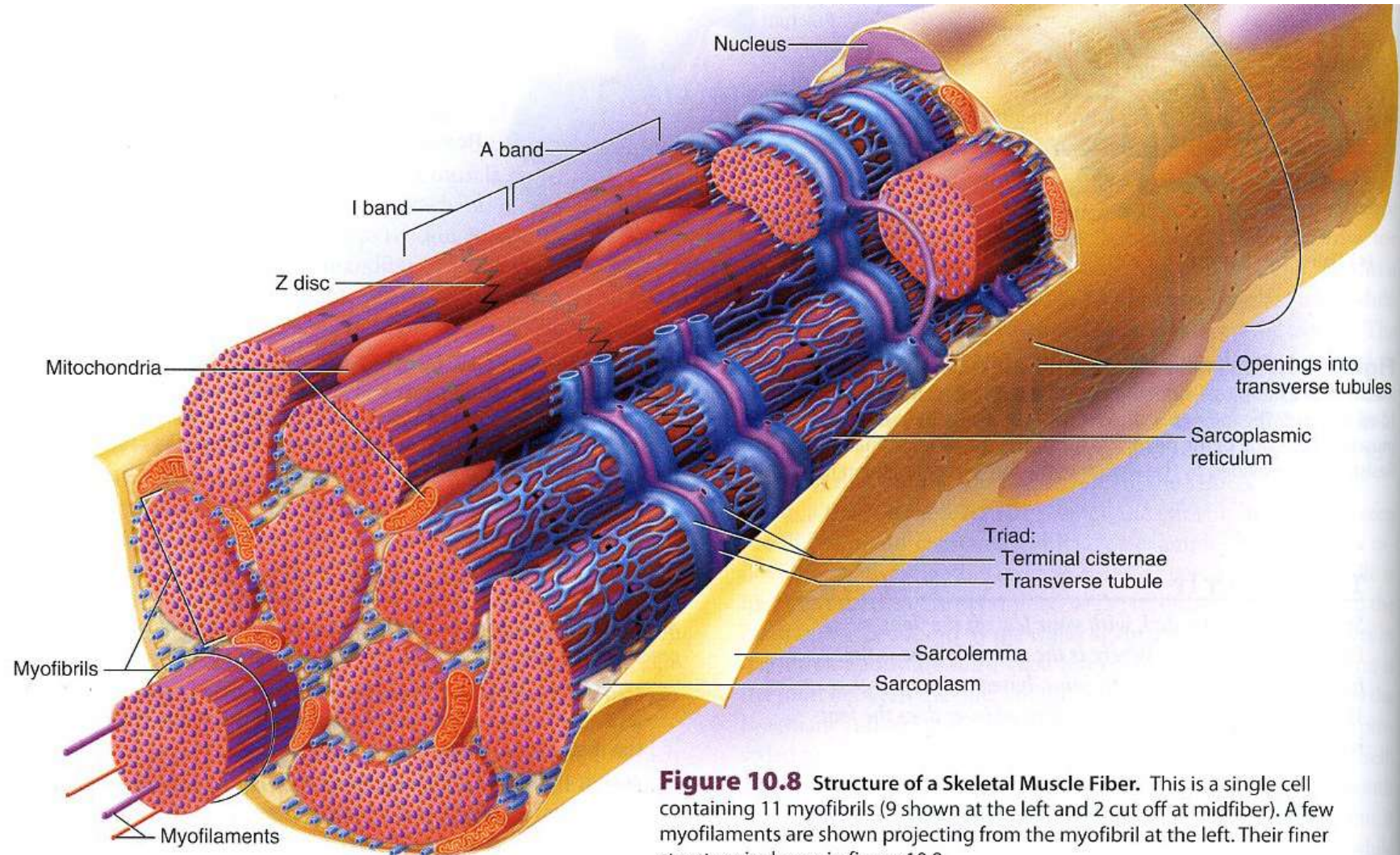
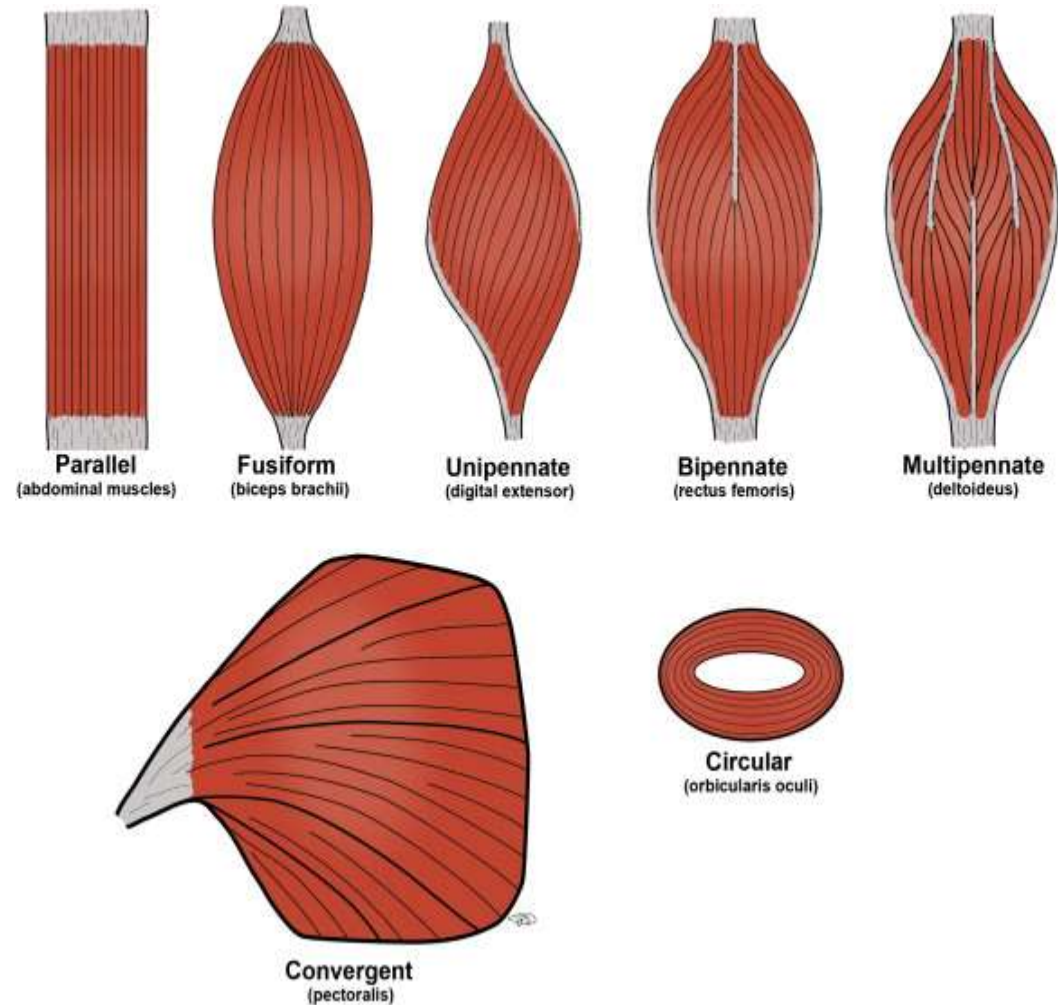


Figure 10.8 Structure of a Skeletal Muscle Fiber. This is a single cell containing 11 myofibrils (9 shown at the left and 2 cut off at midfiber). A few myofilaments are shown projecting from the myofibril at the left. Their finer structure is shown in figure 10.9.

• Why is it important for the transverse tubule to be so closely associated with the terminal cisternae?

Skeletal Muscle Fascicle Arrangements

- **FUSIFORM** – thick in the middle and taper at the ends
- **PARALLEL** – muscle fibers are all parallel
- **PENNATE** – fascicles are short and attach obliquely to a central tendon (feather shaped)
- **CONVERGENT** – spread out as a fan or converge to a point
- **CIRCULAR** – muscle fibers arranged concentrically

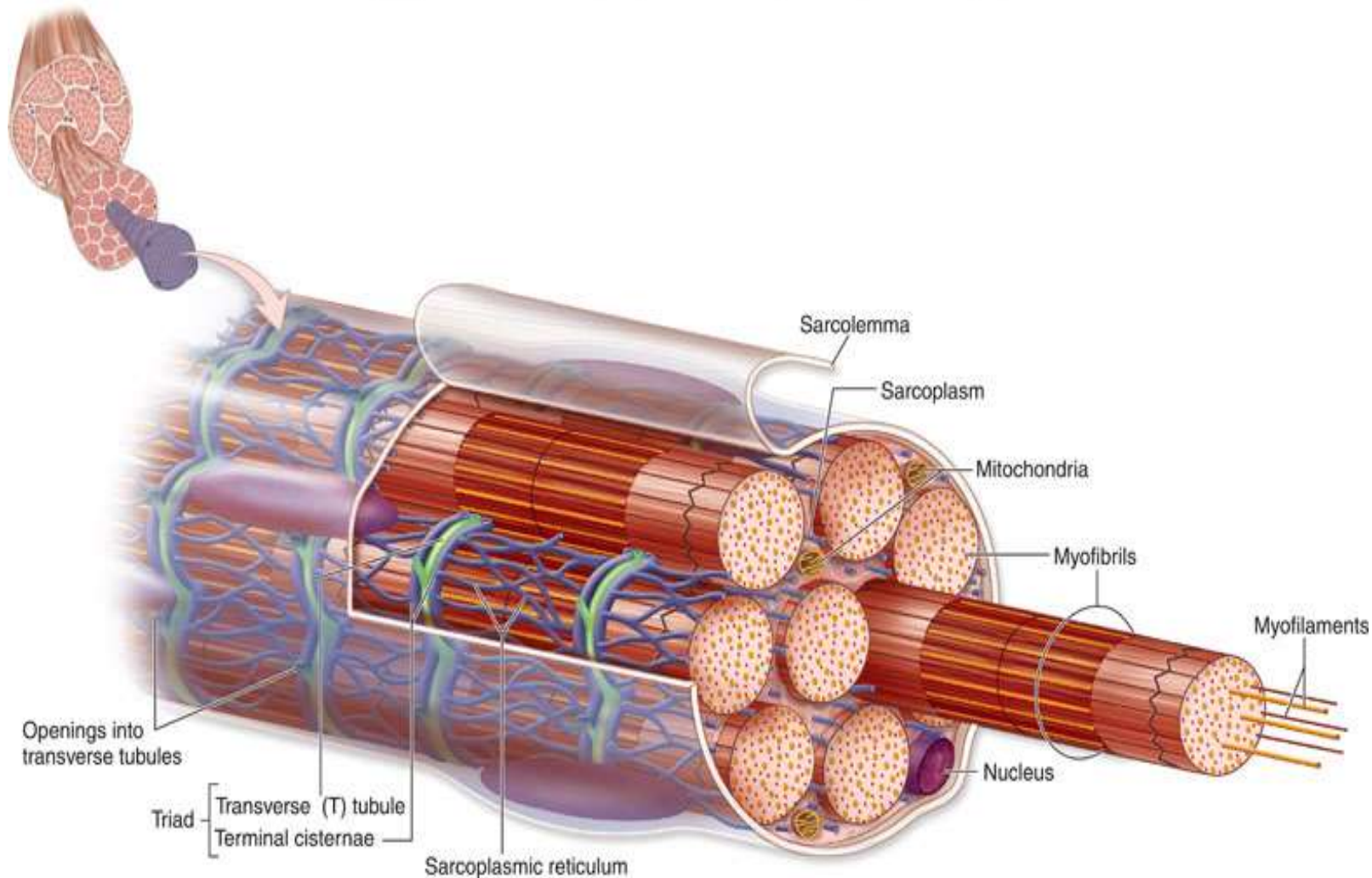


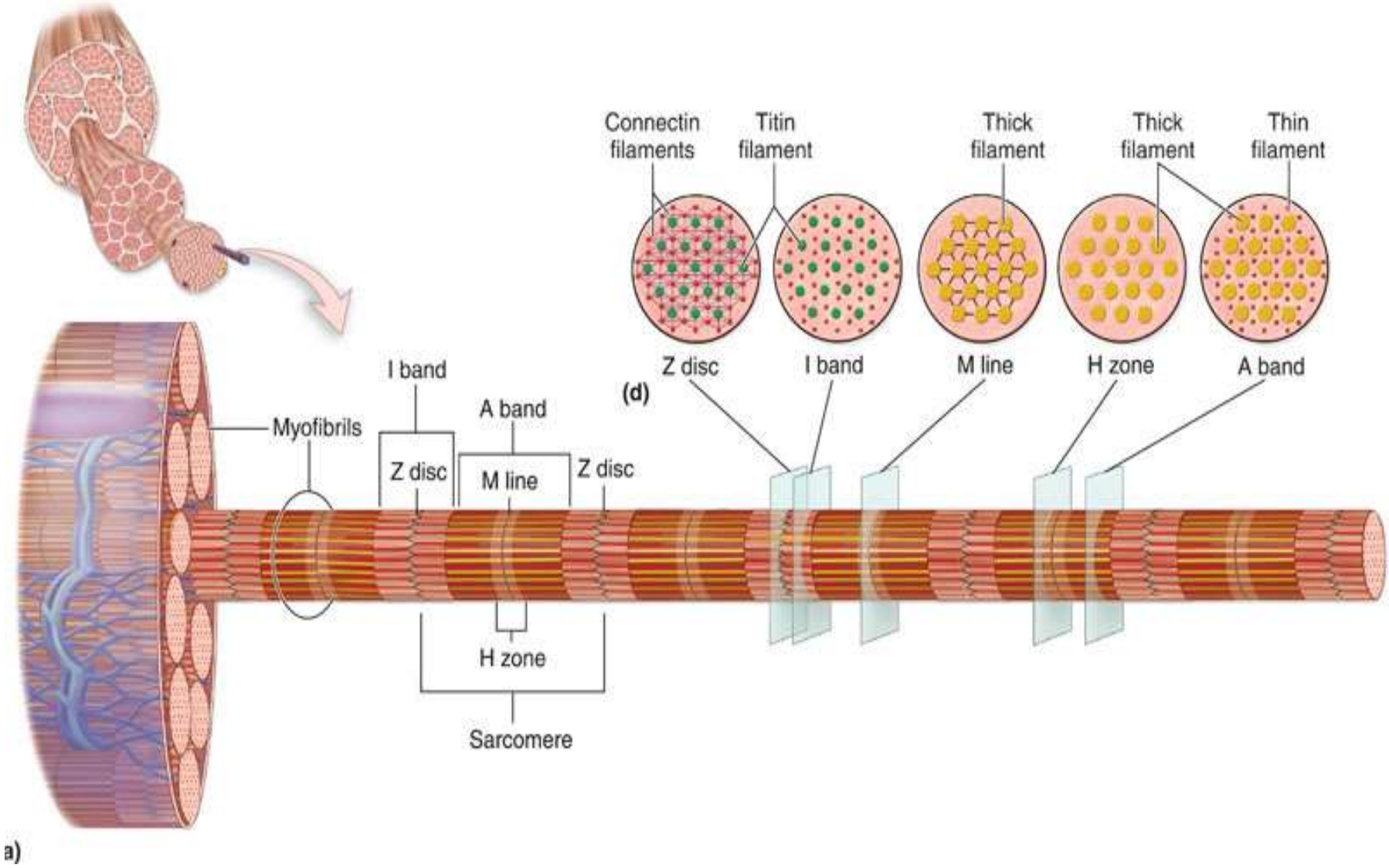
Terms to know and identify

- **Sarcolemma** - plasma membrane covering each muscle cell.
- **Sarcoplasm** - muscle cell cytoplasm.
- **Thick filaments** – contractile protein **myosin** molecules, shaped like a golf club head. Thin filaments slide over thick filaments but do not shorten.
- **Thin filaments** – contractile protein **actin** molecules (f and G actin) also contains the **regulatory proteins tropomyosin** and **troponin**.
- **Elastic filaments** - titin and connectin keep thick and thin filaments aligned over one another for proper contraction to occur; comprise the “Z” line.

Ultrastructure of skeletal muscle: **sarcomere** = distance between 2 “Z” lines (discs).

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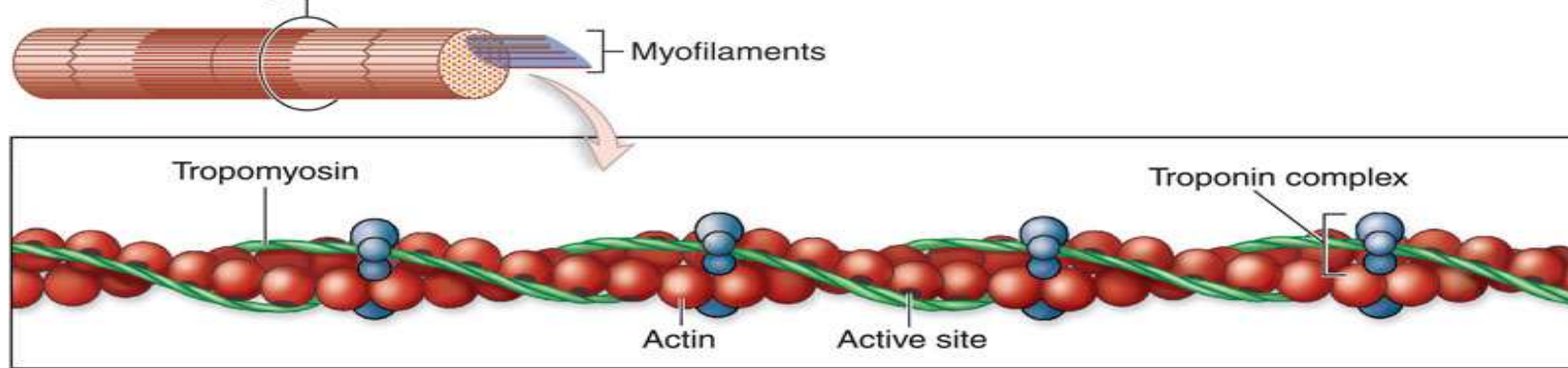




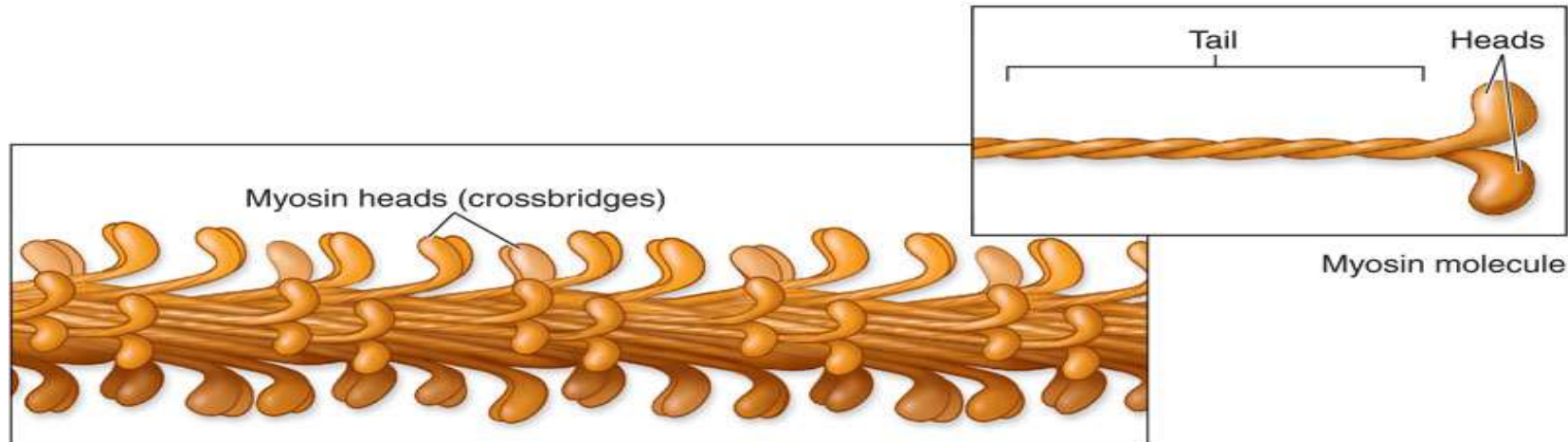
Molecular structure - Myofilaments

Actin, Myoisin, Troponin, Tropomyosin

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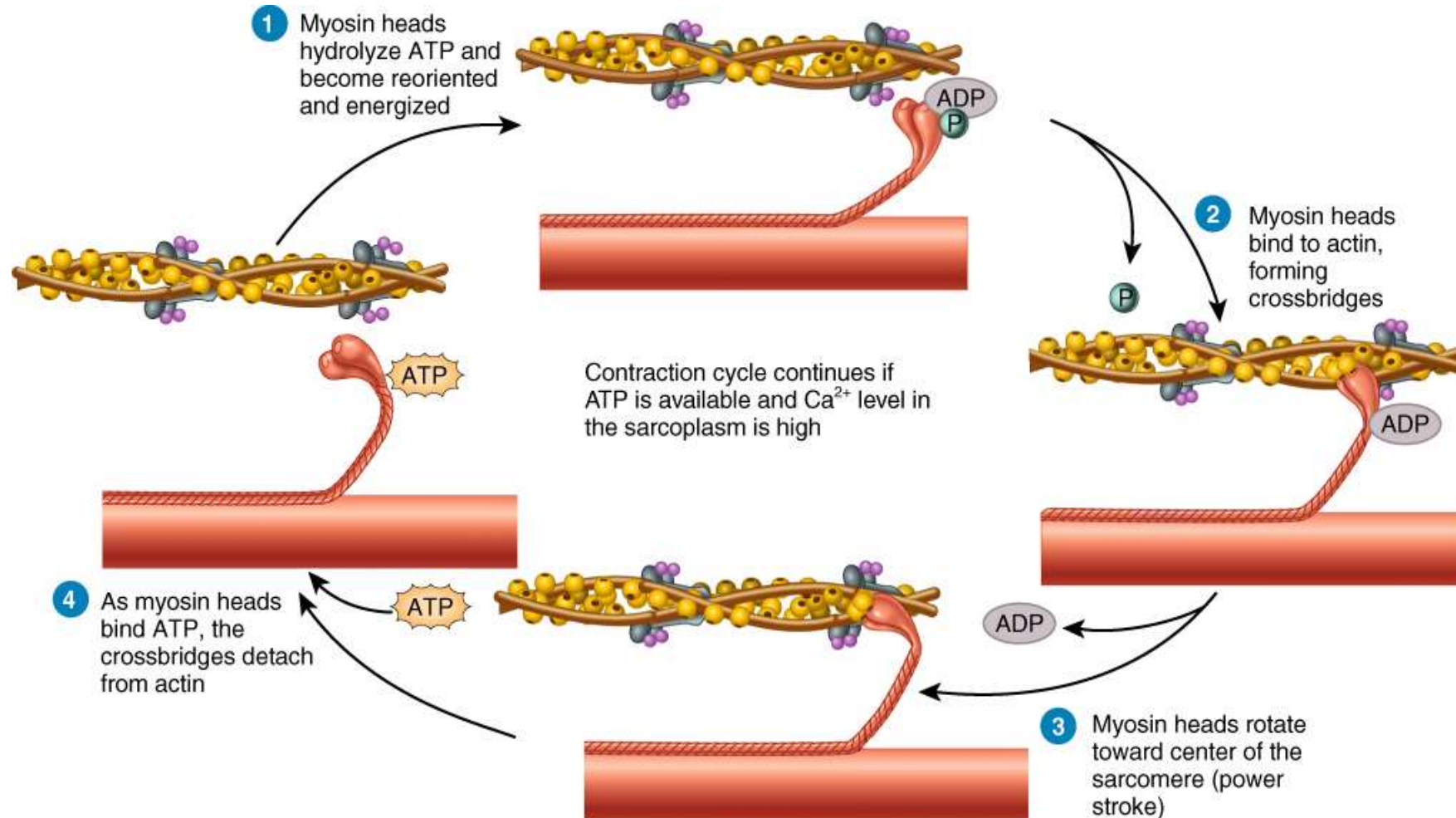


(a) Thin myofilament

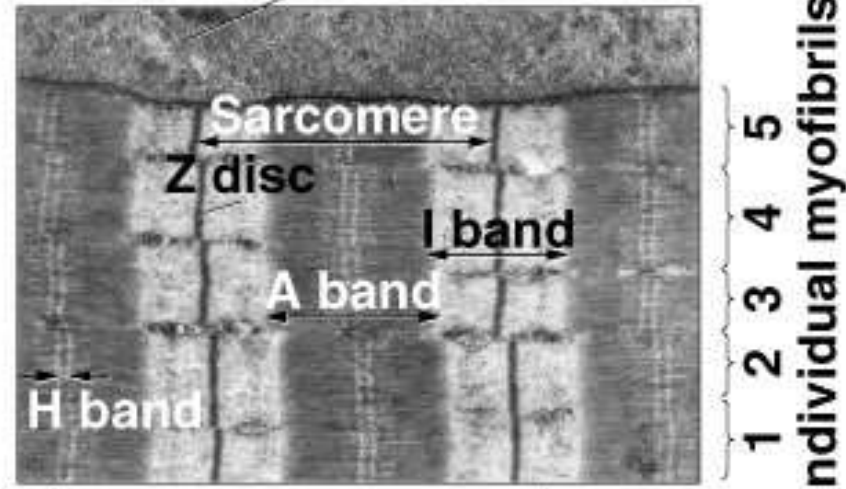


(b) Thick myofilament

Muscle contraction

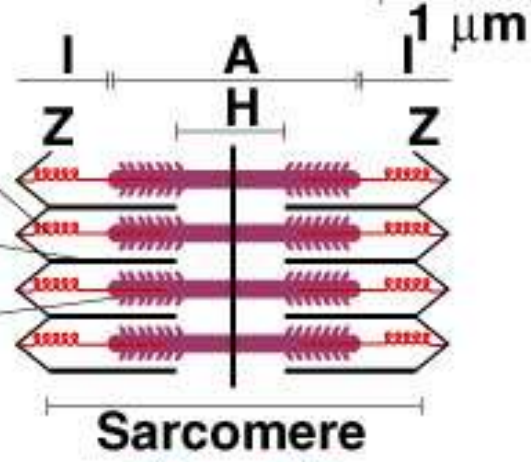


Nucleus

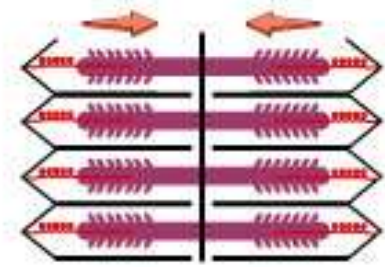


(a)

Elastic filament
Thin filament
Thick filament



(b)



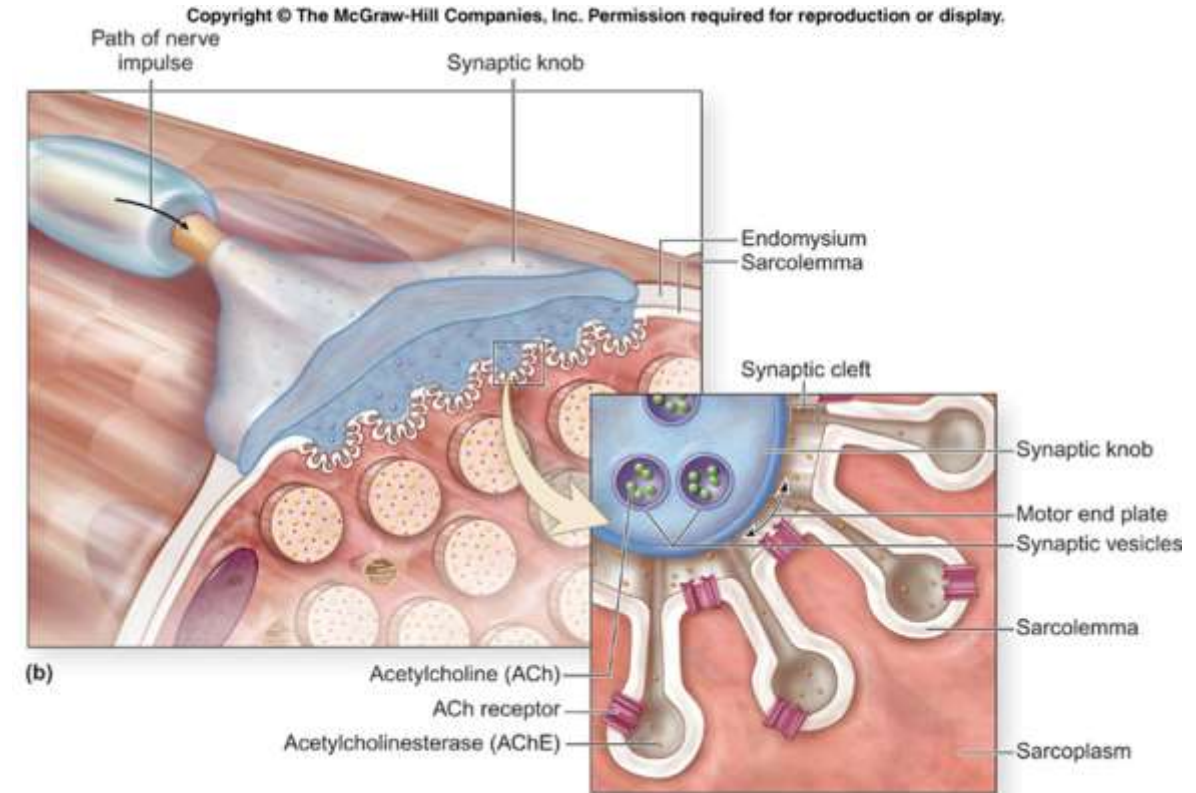
(c)

Neuromuscular control

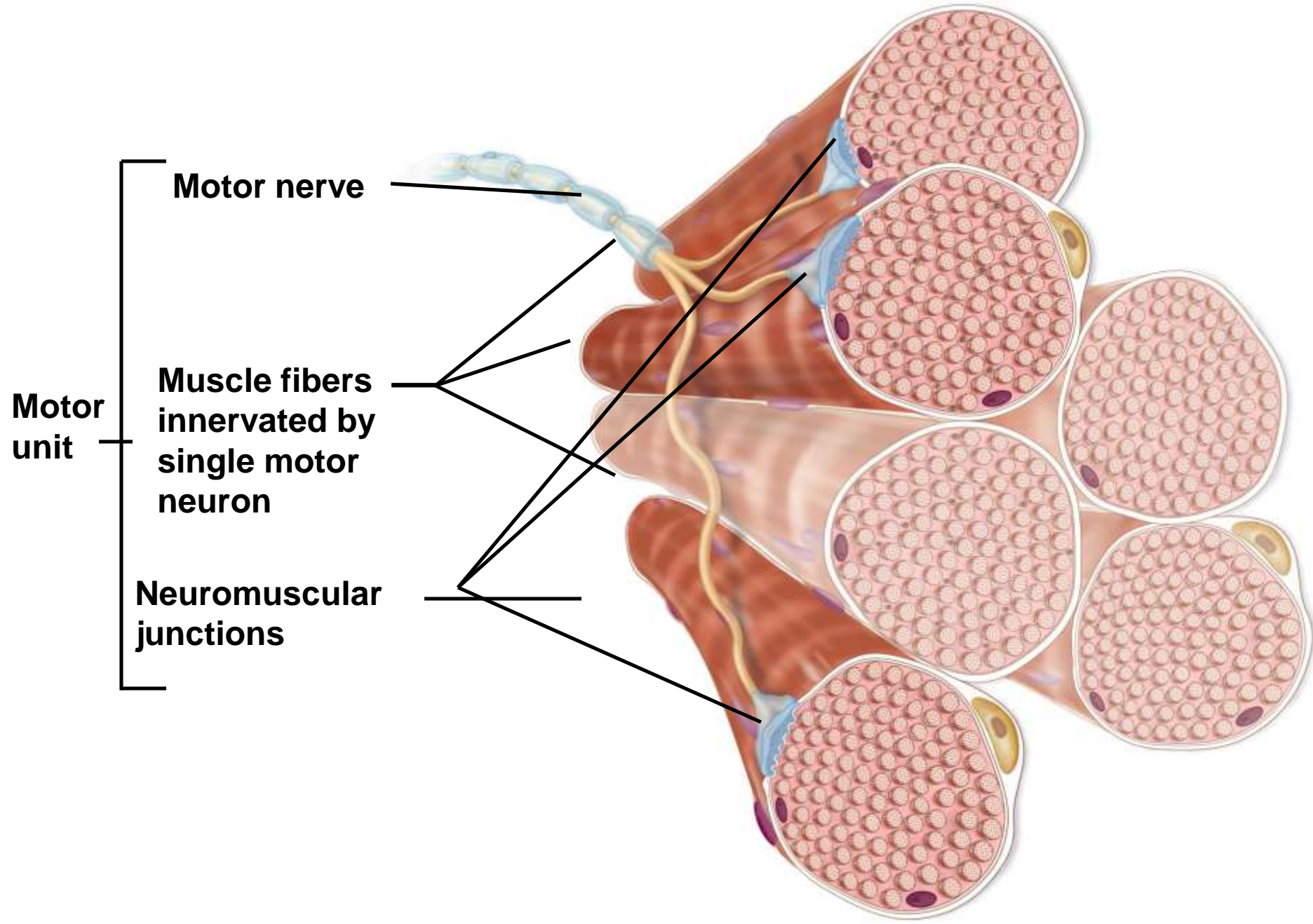
- Skeletal muscle contraction is controlled by a nerve impulse (action potential) transmitted by the motor nerve from the brain or spinal cord.
- A **MOTOR UNIT** consists of all the muscle fibers controlled by a single motor neuron.
- Fine control muscles (i.e. eyelid muscles) have fewer muscle fibers/ nerve (2:1).
- A contraction is initiated by an action potential (nerve impulse) and followed by the release a chemical neurotransmitter at the neuromuscular junction (NMJ).
- Neurotransmitter for skeletal muscle is acetylcholine.

Neuromuscular control

- Each muscle fiber is innervated by a single motor neuron
- Contractions may be graded or full due to the number of muscle fibers that respond to the stimulus. The more fibers, the greater the muscle contraction
- Synapse – functional connection between a nerve fiber and its target cell.
- Neuromuscular junction – synapse between a motor nerve and a muscle fiber.



Every muscle contraction is preceded by a nerve impulse from the CNS.

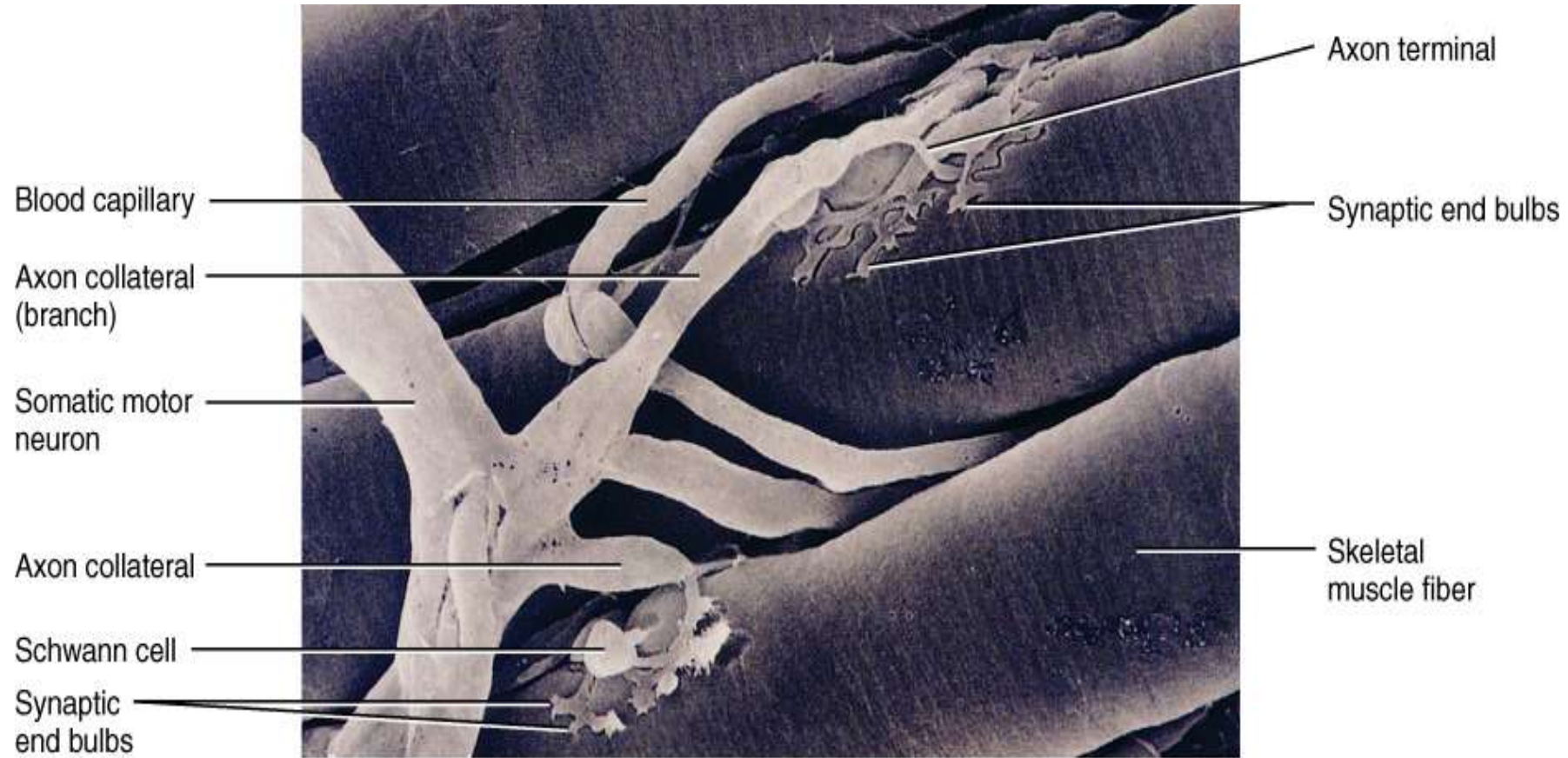


Neuromuscular Junction

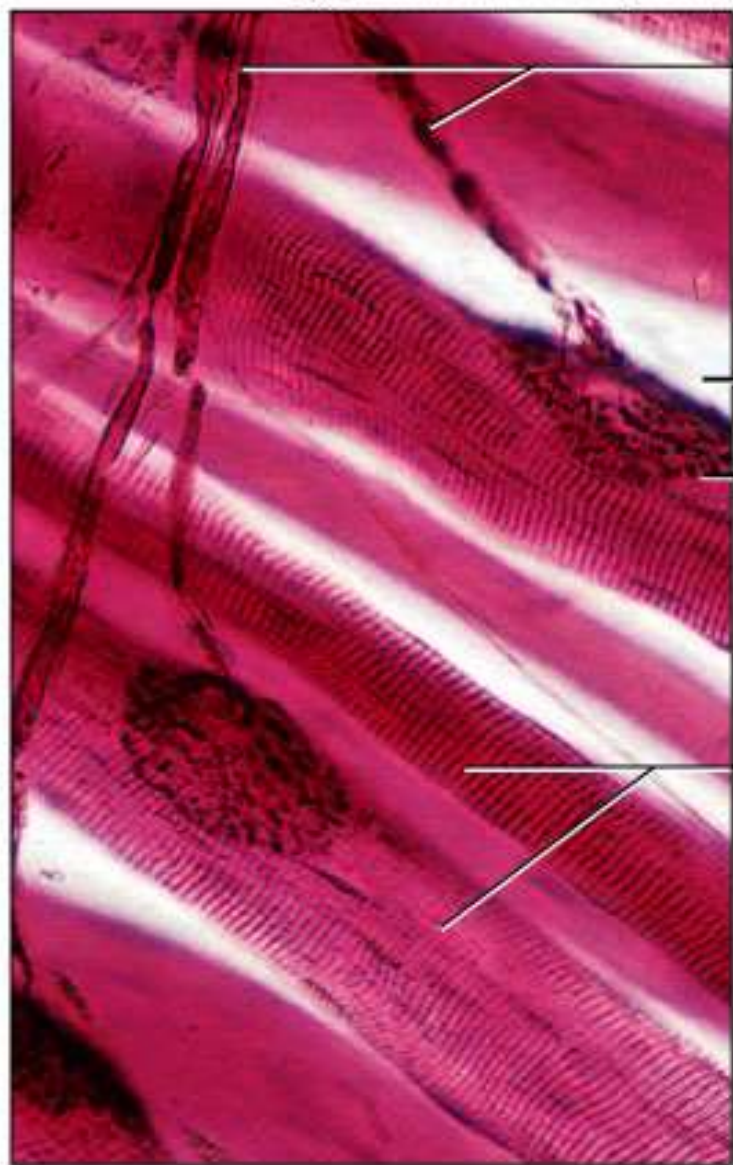
Synaptic knob, terminal or bouton – bulbous swelling at the end of a motor nerve above the motor end plate on the muscle fiber.

- Synaptic cleft – gap between the synaptic knob and the motor end plate.
- Synaptic vesicles – small packets of neurotransmitter chemical (e.g. acetylcholine, norepinephrine, etc.)

SEM of Neuromuscular Junction



SEM 1650x



Motor nerve fibers

Neuromuscular junction

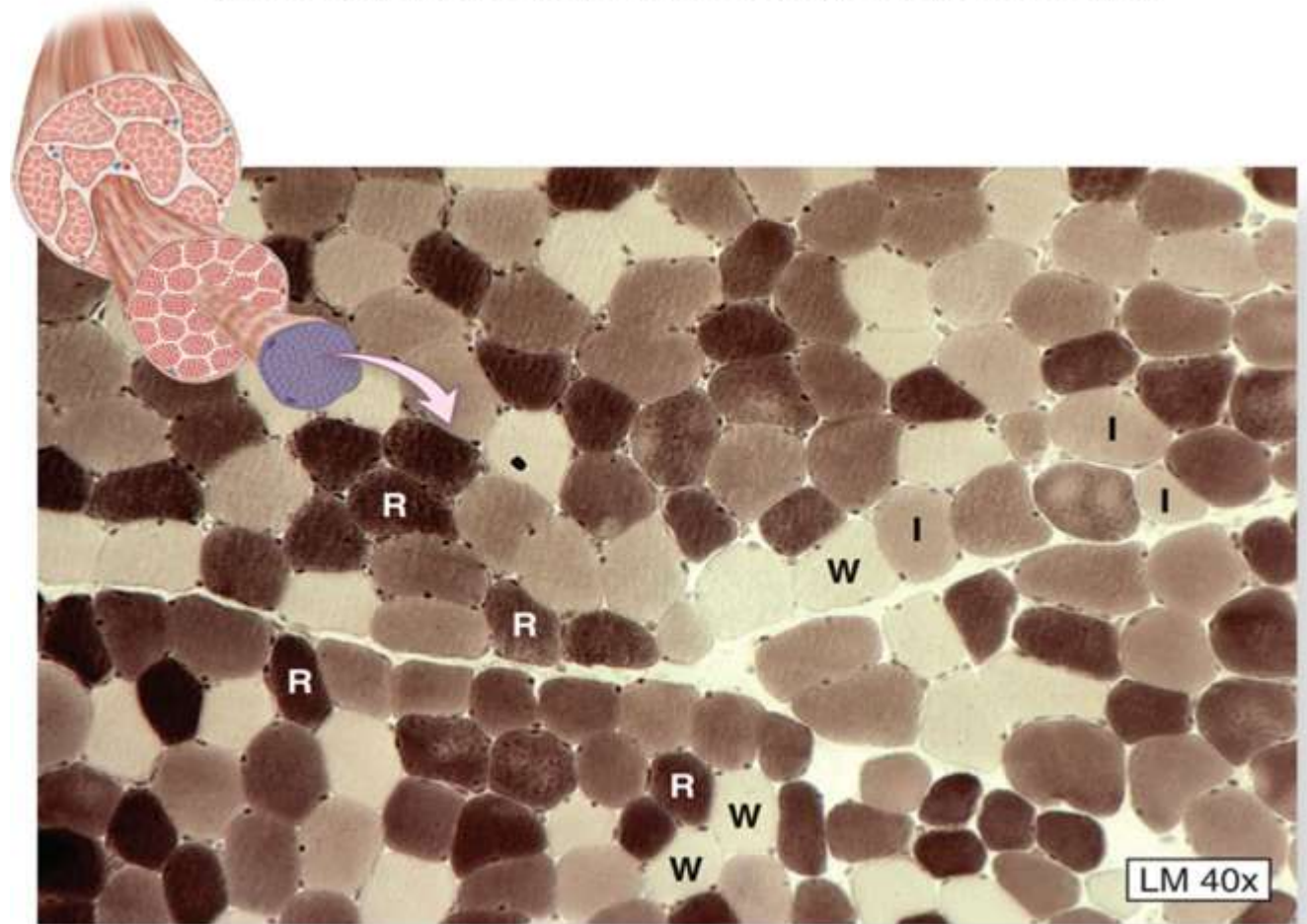
Muscle fibers

100 μm

Skeletal muscle fiber types

- Skeletal muscle is composed of 3 different fiber types:
 - The fiber type is based on the biochemical process for making ATP and how fast the fibers contract.
 - Red or slow oxidative fibers [dark staining (R)]
 - Intermediate or Fast oxidative fibers [lighter (I) staining]
 - Fast glycolytic fibers [white (W) or non staining]

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Red slow fibers (R)

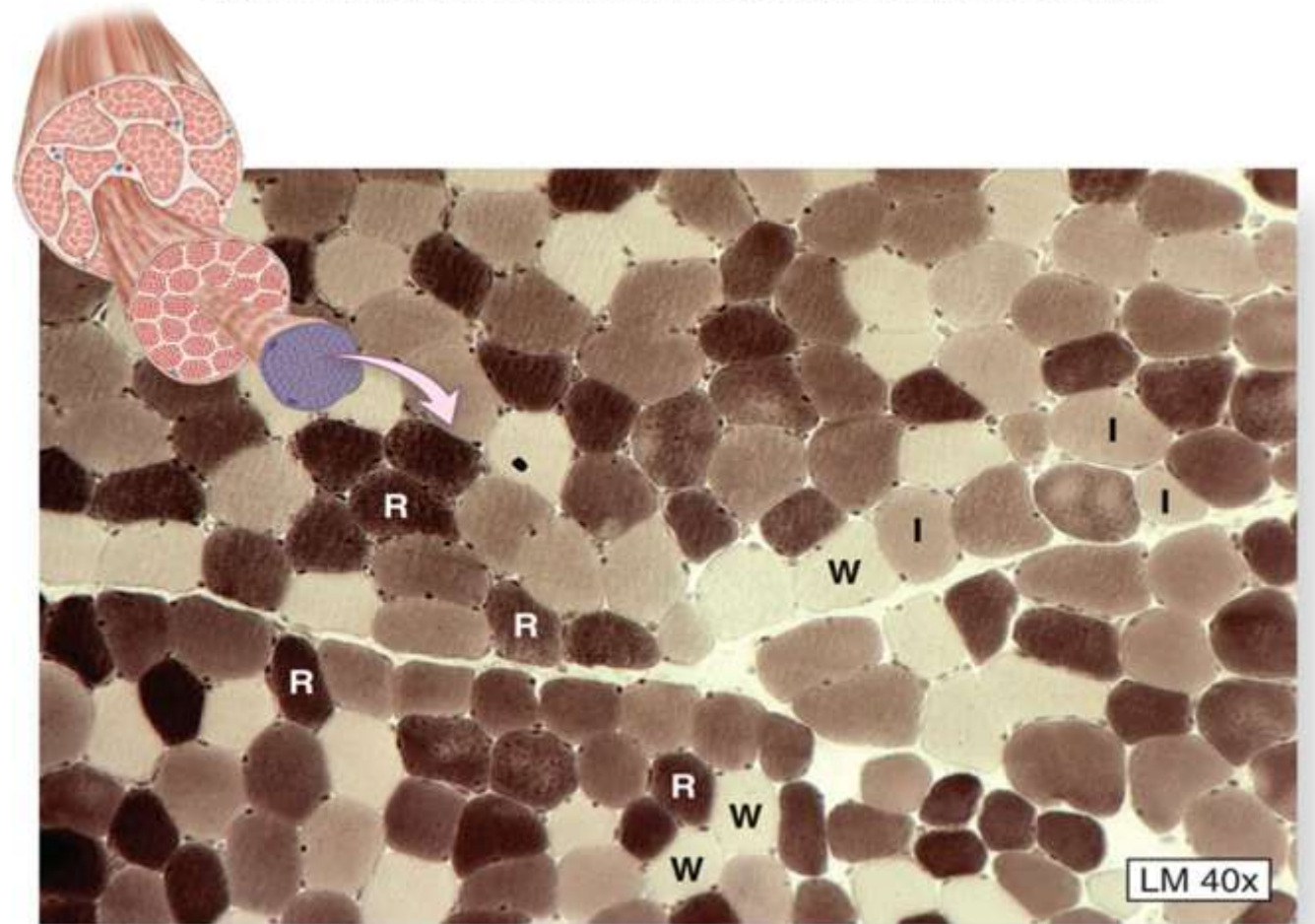
White fast fibers (W)

Intermediate fast fibers (I)

Fiber type characteristics

- Slow oxidative (R):
 - Dark staining red in color = abundant myoglobin
 - Manufactures ATP by aerobic glycolysis
 - Contract slowly and are more resistant to fatigue.
 - Ex. back muscles and support muscles
- Intermediate Fast oxidative (I):
 - Stains less darkly than Red but slightly larger
 - Produce ATP via aerobic metabolism like slow
 - Contract faster and more powerfully than slow
 - Abundant in lower limbs = contract for long periods

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Red slow fibers (R)

White fast fibers (W)

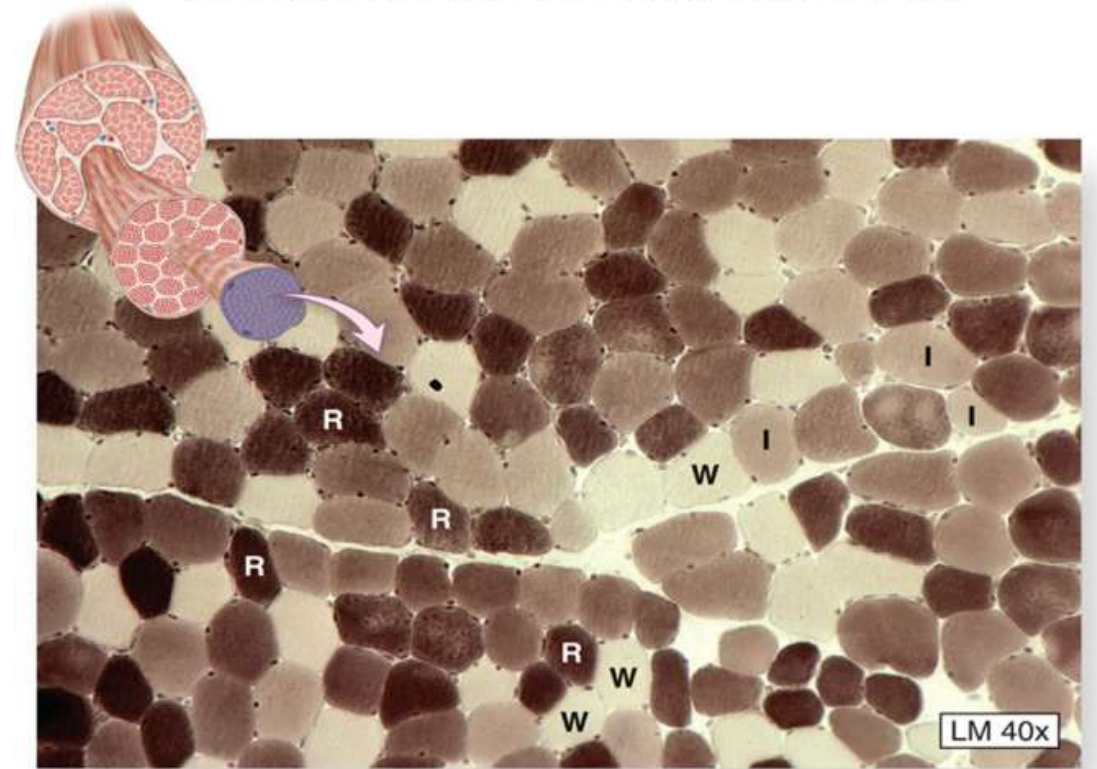
Intermediate fast fibers (I)

Fiber type characteristics

White or Fast glycolytic fibers (W):

- Stain a pale color due to little myoglobin.
- Largest in diameter of all three fiber types
- Depend on anaerobic glycogenolysis to make ATP.
- Contract rapidly and fatigue easily.
- More prominent in upper limbs for large work loads.
- Majority of fibers in body are white.

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Red slow fibers (R)

White fast fibers (W)

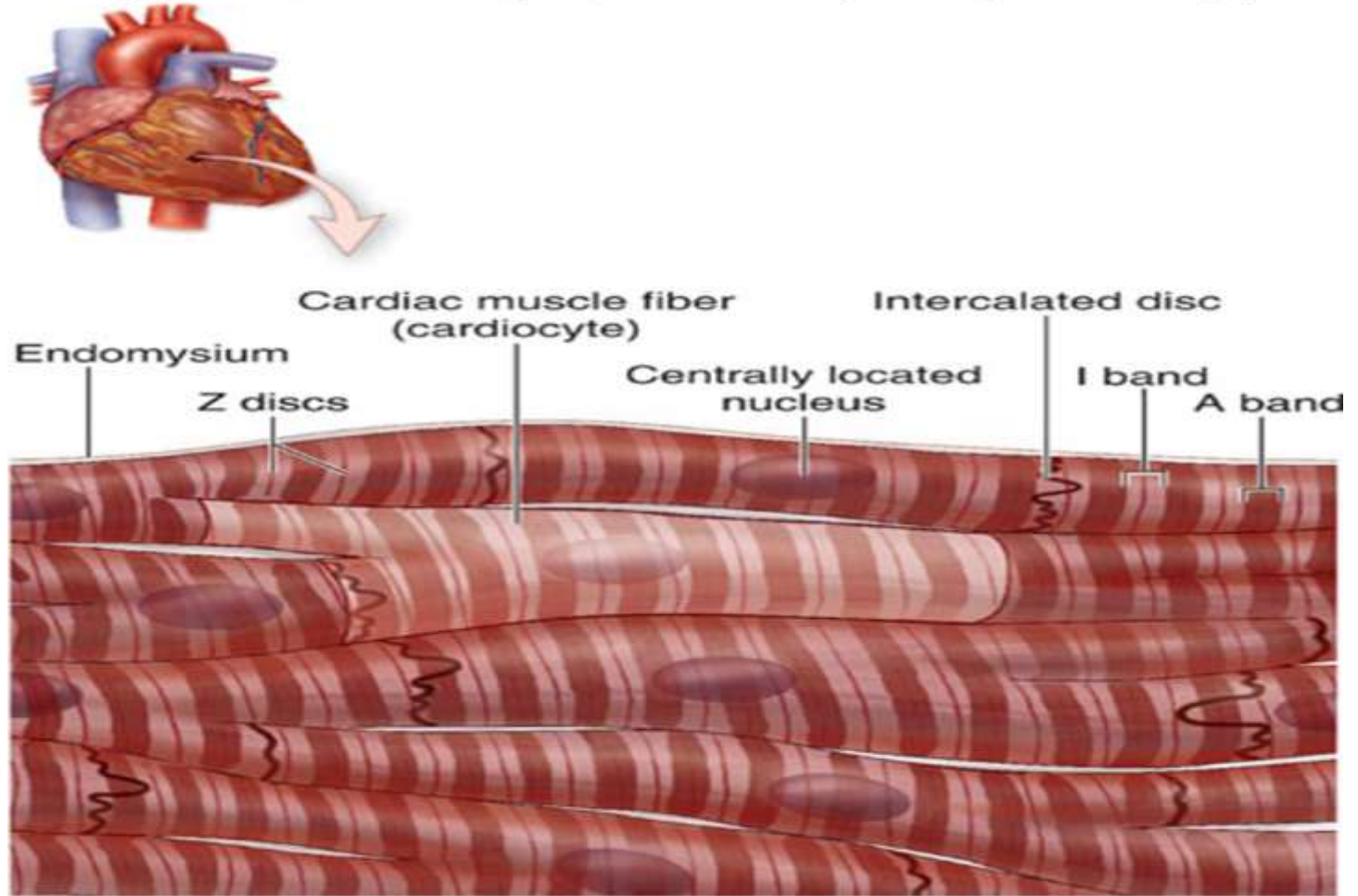
Intermediate fast fibers (I)

Cardiac muscle

Characterized by:

- cross-striations
- intercalated discs
- uni-nucleate cells
- automaticity
- Composed of the same contractile proteins as skeletal muscle.

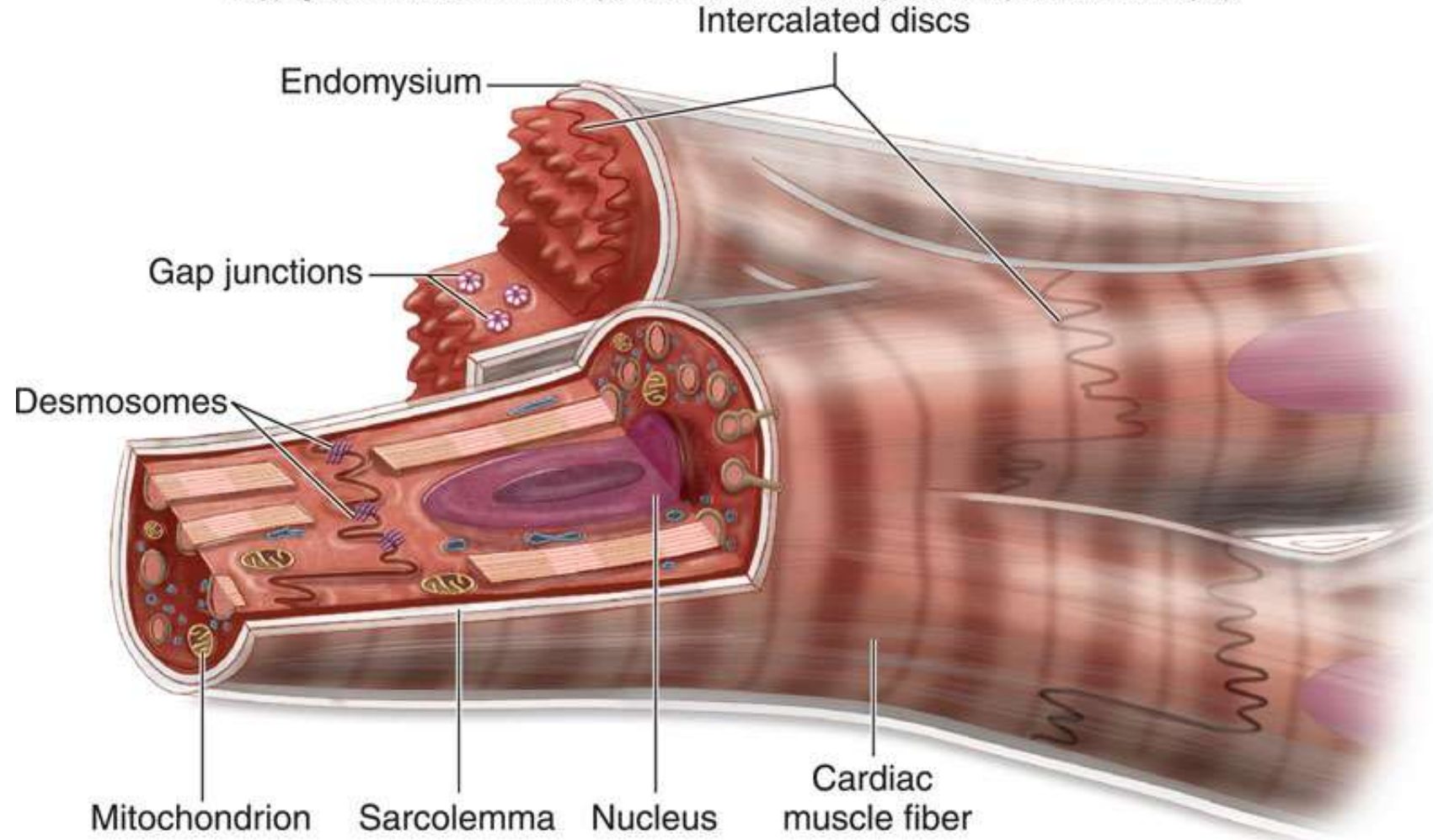
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(a)

Cardiac Muscle

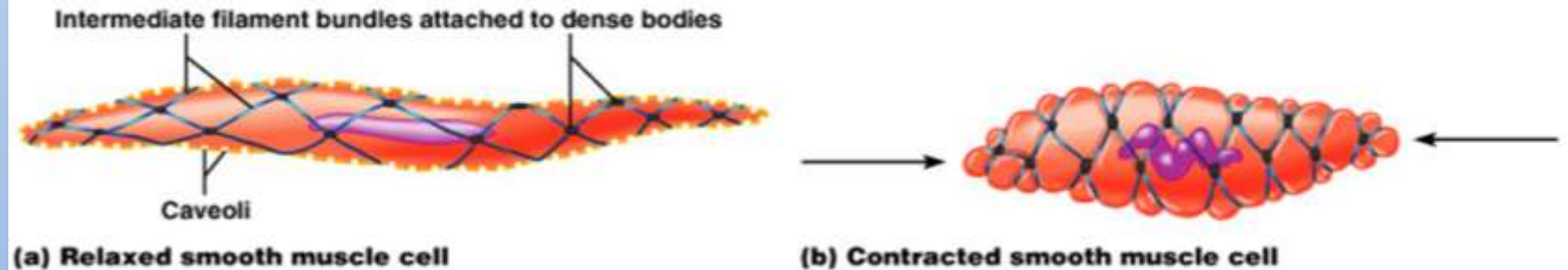
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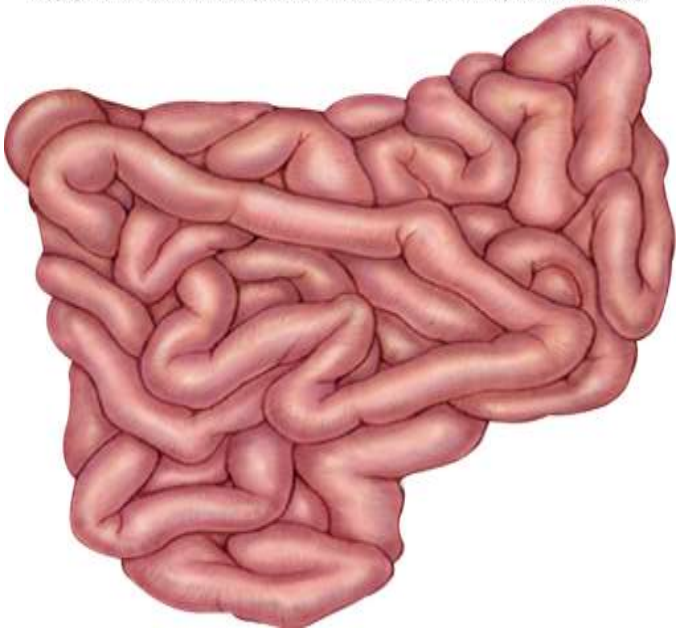
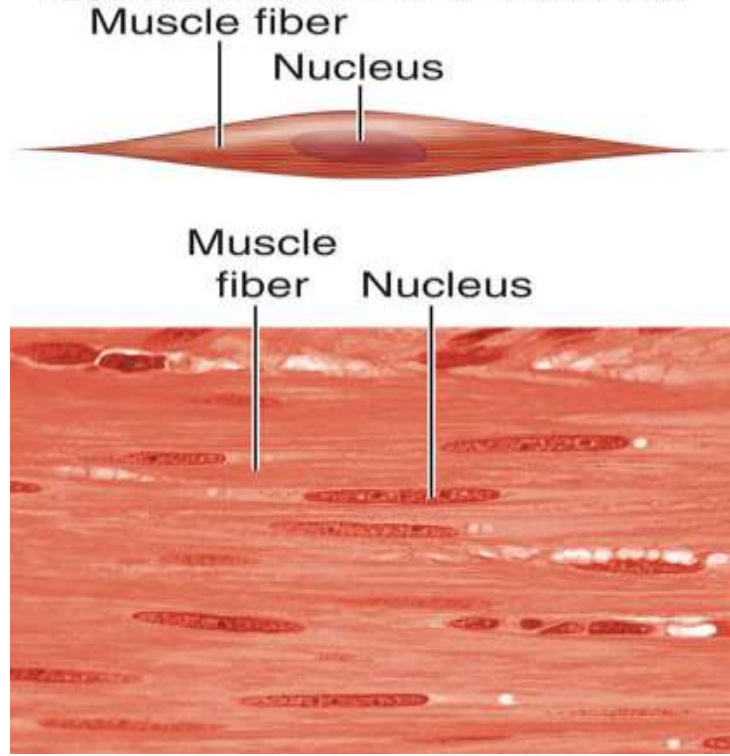
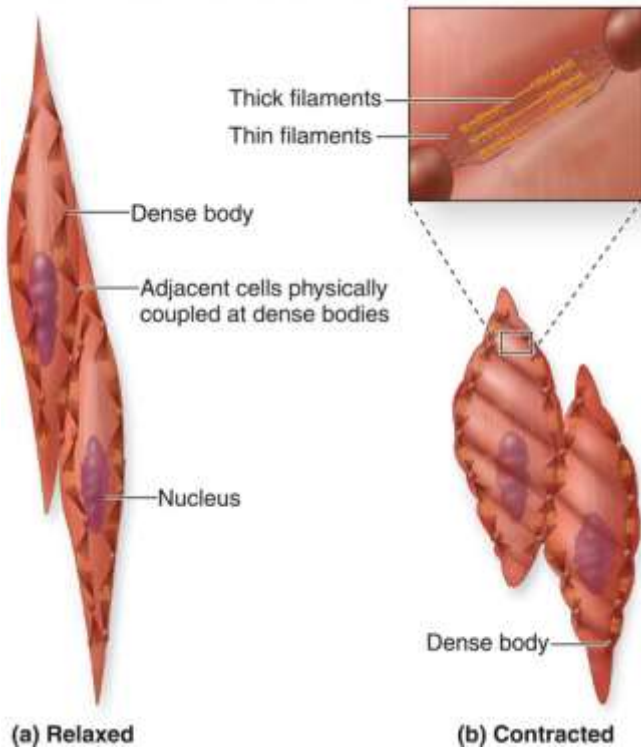


(b)

Smooth muscle

- Characterized by:
 - Spindle shaped cells
 - Uni-nucleate cells
 - Involuntary control
 - Found in walls of hollow organs, blood vessels and glands





BY THE END OF THIS LECTURE I CAN

1. Describe and identify the 3 major muscle groups (skeletal, cardiac and, smooth).
2. Describe the general anatomy of muscles.
3. Describe the ultra-structure of skeletal muscle and its role in muscle contraction.
4. Describe nerve-muscle relationship, the motor unit and the neuromuscular junction.
5. Define the physiologic fiber types of muscle.