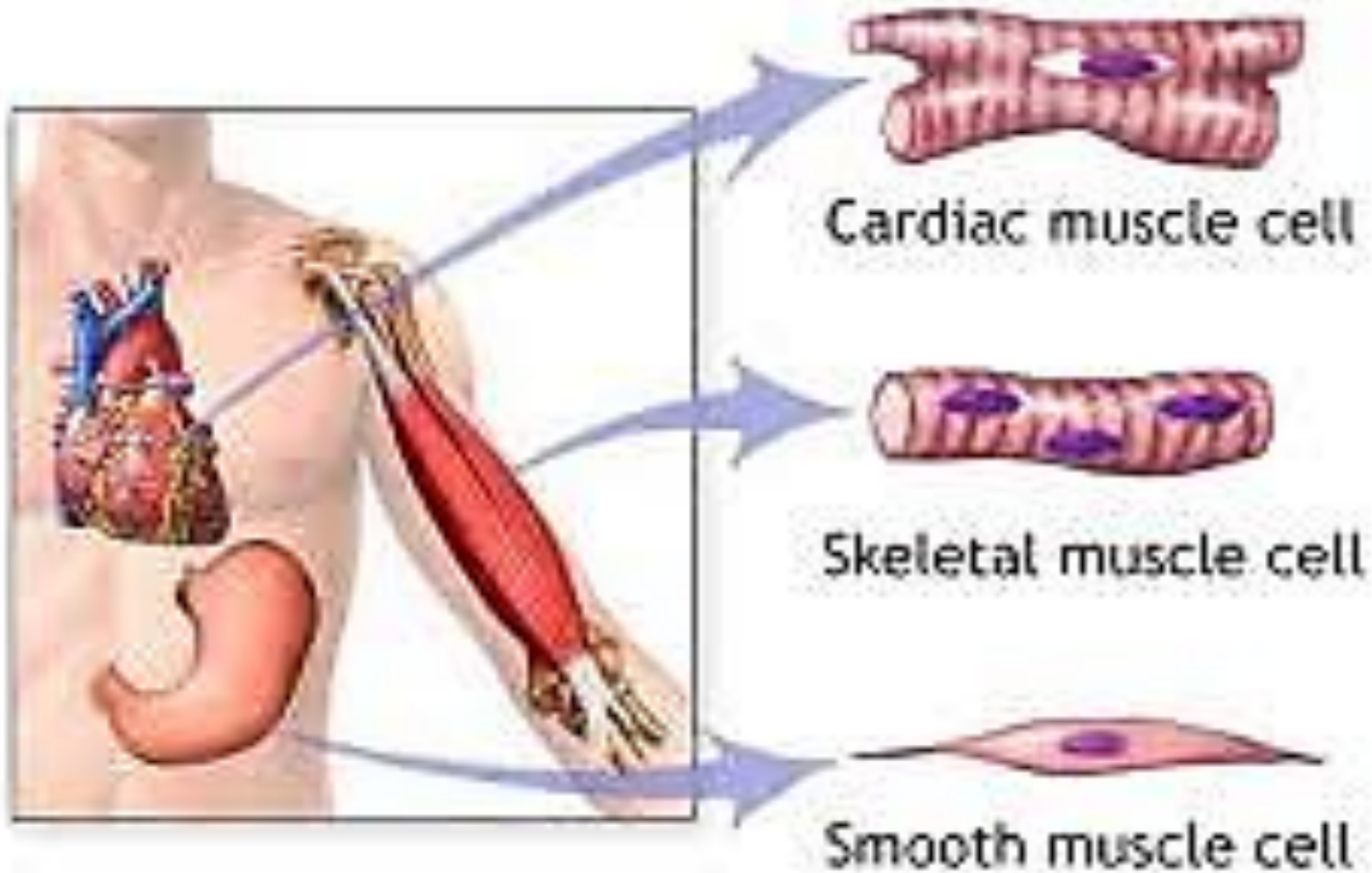


# *Muscle I (Skeletal Muscle)*

Ass. Prof. Dr. Heba Hassan Abd El-Gawad



# *Types of muscles* *(Muscle is a basic tissue)*

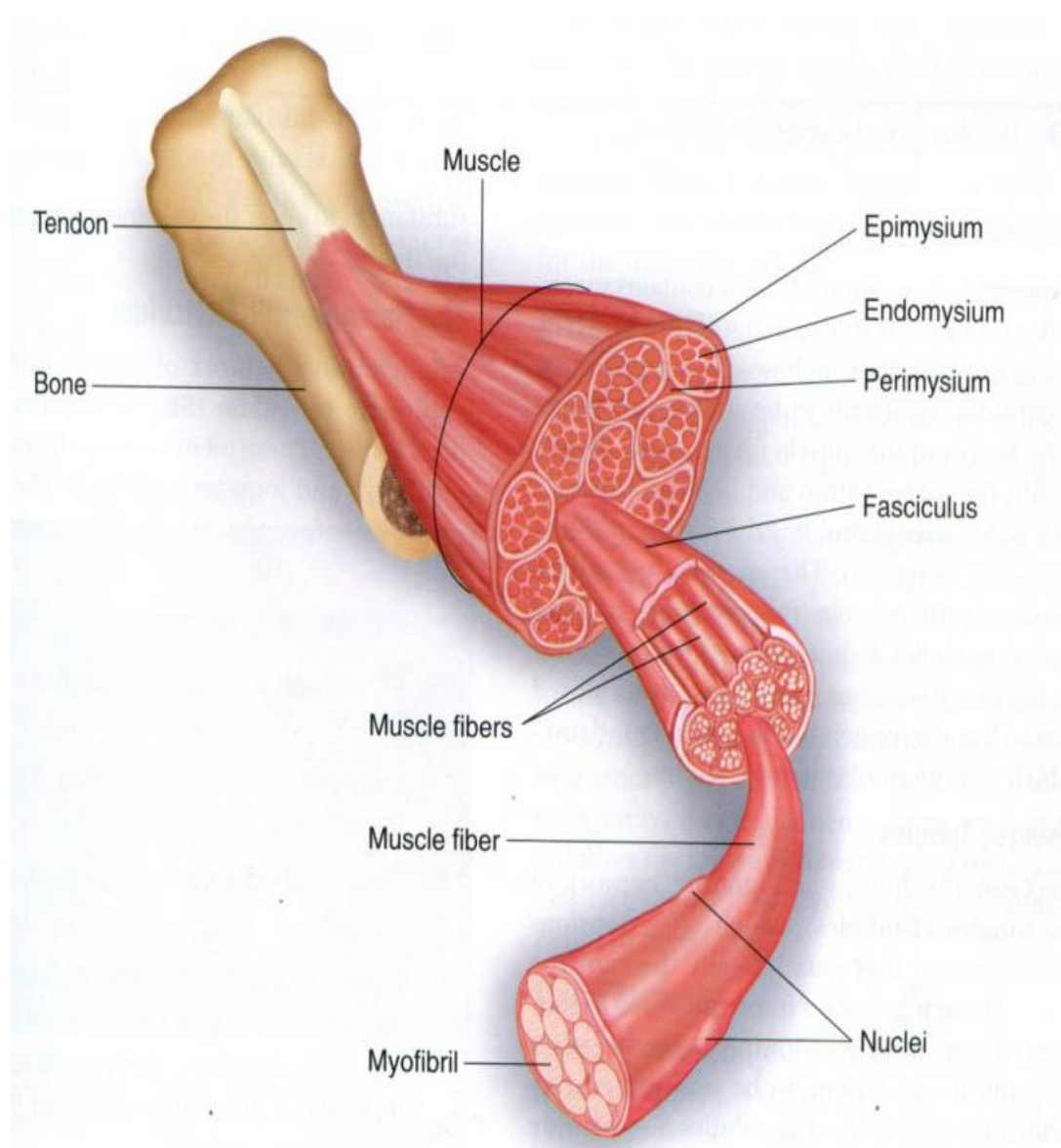


# *Types of muscles*

- **Skeletal muscle** contains bundles of very long, cells with cross-striations. Their contraction is quick, forceful, and under voluntary control.
- **Cardiac muscle** also has cross-striations. Their contraction is involuntary, vigorous, and rhythmic.
- **Smooth muscle** lacks striations and have slow, involuntary contractions

# Skeletal muscle

- They are called skeletal as they are attached to the skeleton
- They are voluntary in action because they are under the control of will.



# Organization of a Skeletal Muscle

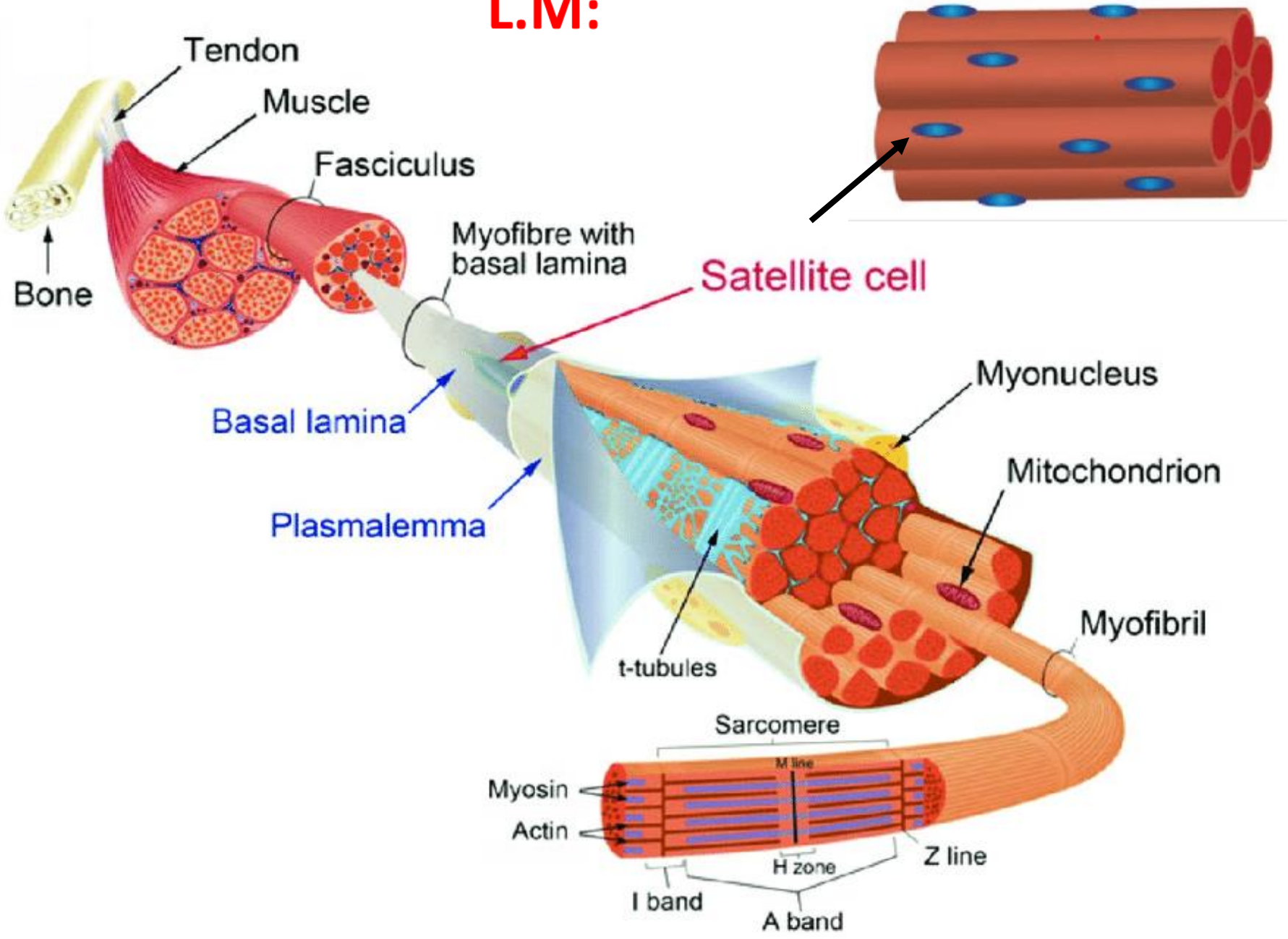
- **The epimysium:** an external sheath of dense connective tissue, surrounds the entire muscle. Septa of this tissue extend inward, carrying the larger nerves, blood vessels, and lymphatics of the muscle.
- **The perimysium:** is a thin connective tissue layer that immediately surrounds each bundle of muscle fibers termed a fascicle. Nerves, blood vessels, and lymphatics penetrate the perimysium to supply each fascicle.
- **The endomysium:** a very thin, delicate layer of reticular fibers and scattered fibroblasts surrounds the **external lamina** of individual muscle fiber.

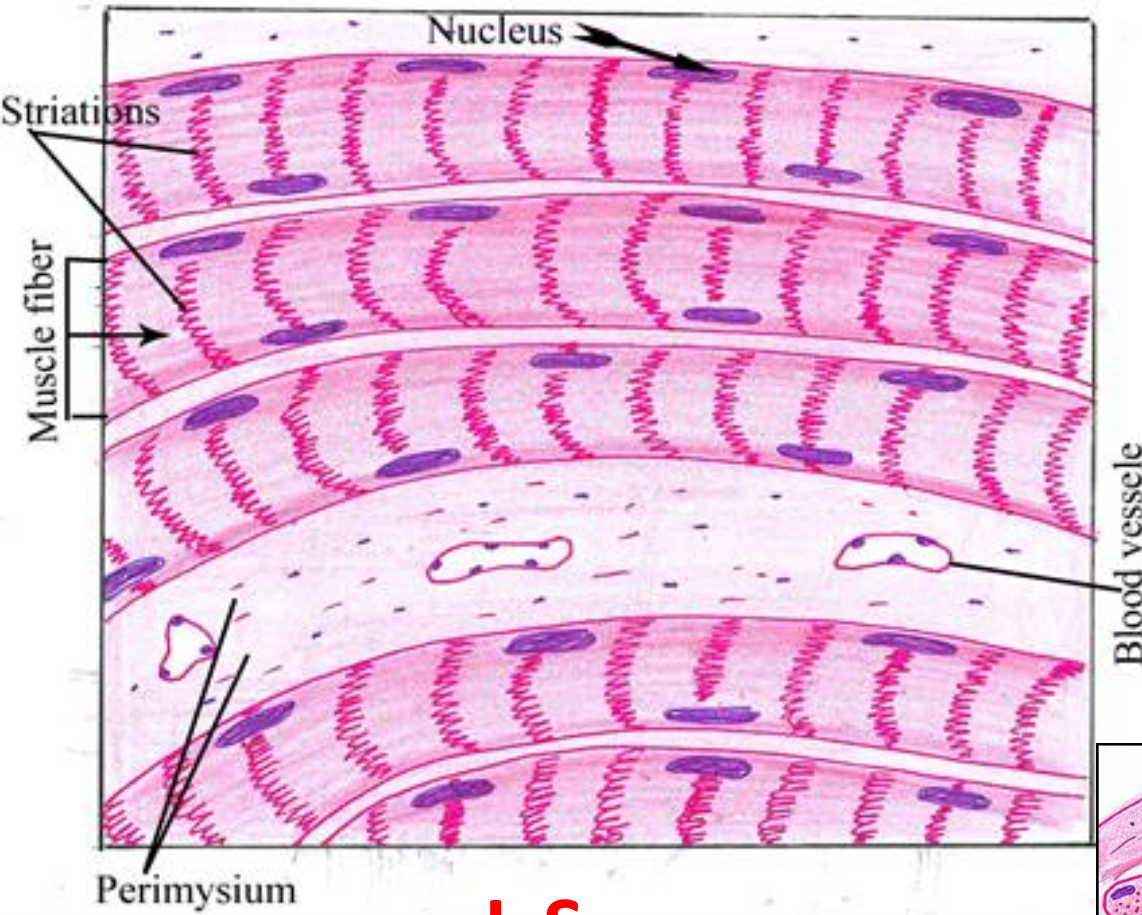
# Skeletal muscle

## L.M:

- Muscle fibers are very long tubular cells. They are about (10-100  $\mu\text{m}$ ) in diameter and several centimeters in length "up to 40cm".
- Skeletal muscle fibers contain many peripherally placed nuclei located just beneath the plasma membrane (sarcolemma)
- A small population of reserve progenitor cells called muscle satellite cells located on the external surface of muscle fibers inside the basal lamina. Satellite cells proliferate and produce new muscle fibers following muscle injury.

**L.M:**

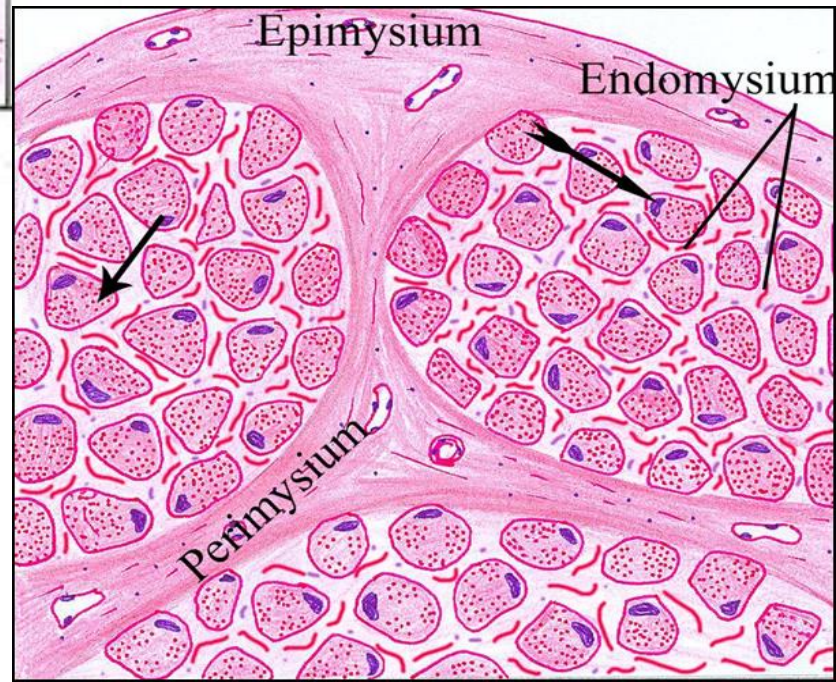




**L.M**

Perimysium

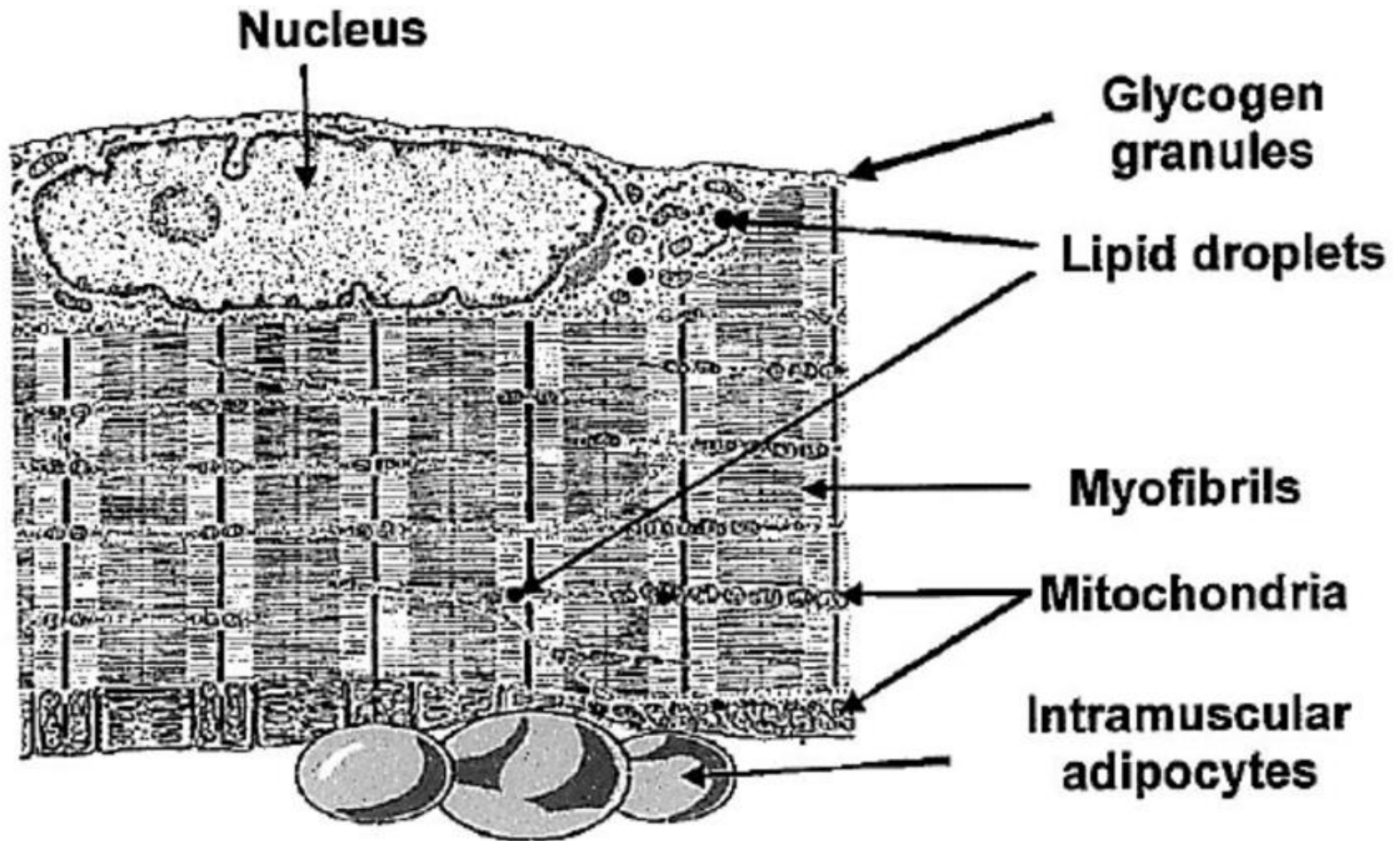
**L.S**



**T.S**

- The cytoplasm (sarcoplasm) contains longitudinal, cylindrical fibrils (myofibrils).
- **In longitudinal section**, skeletal muscle fibers show cross-striations in the form of alternating **dark (A)** and light (I) bands.
- **In transverse sections**, the muscle fibers appear rounded or polygonal in shape, the cytoplasm filled with dark dots representing the myofibrils

**EM: *The sarcoplasm of the skeletal muscle fiber contains:***

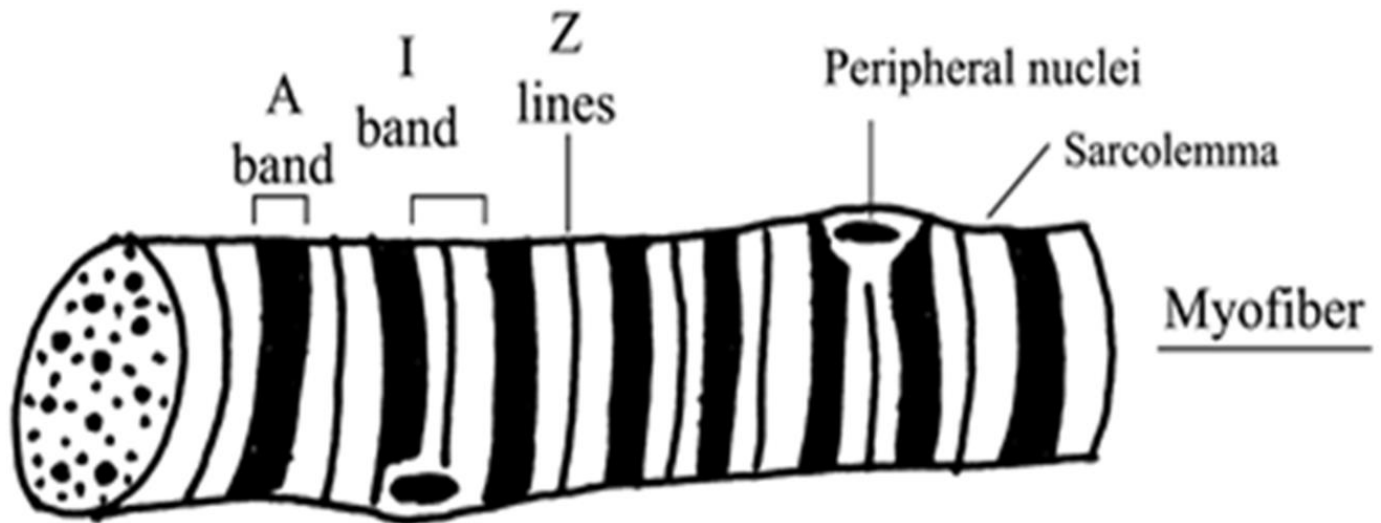


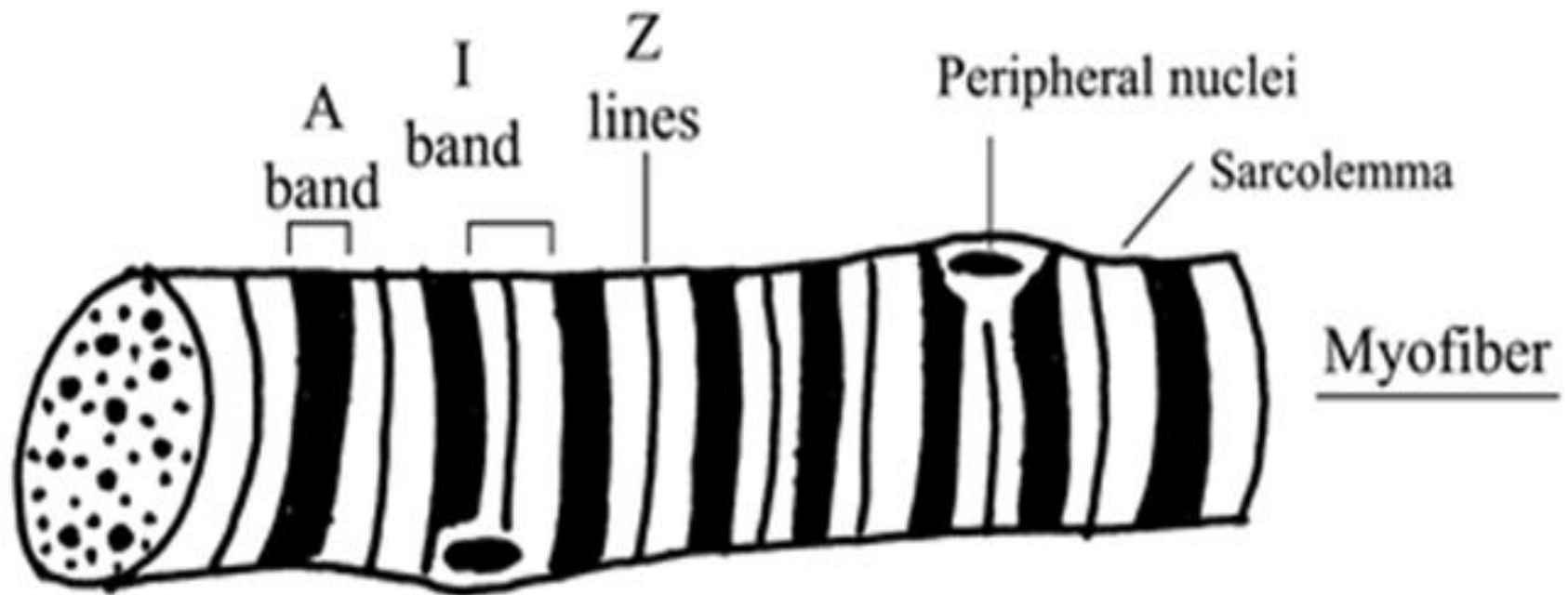
**EM: The sarcoplasm of the skeletal muscle fiber contains:**

- 1. Myofibrils:** they are long, parallel cylindrical structures, formed of the contractile proteins (microfilaments)
- 2. Sarcoplasmic reticulum:** It is well developed and highly modified SER. It is responsible for storing and releasing of  $\text{Ca}^{++}$  needed for contraction.
- 3. Long mitochondria** are found near to the nucleus and form longitudinal rows between the myofibrils.
- 4. A small Golgi** is associated with one nuclear pole.
- 5. Glycogen and few lipid droplets.**
- 6. Myoglobin pigment** is oxygen-binding protein that is responsible for the red brown color of muscle and is related to oxygen supply for the muscle.

# Myofibrils and myofilaments

- In the TEM , each I band is seen to be bisected by a dark transverse line, the Z disc. The repetitive functional subunit of the contractile apparatus, the sarcomere, extends from Z disc to Z disc and is about 2.5  $\mu\text{m}$  long in resting muscle.

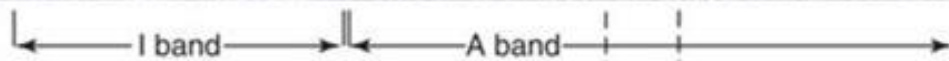
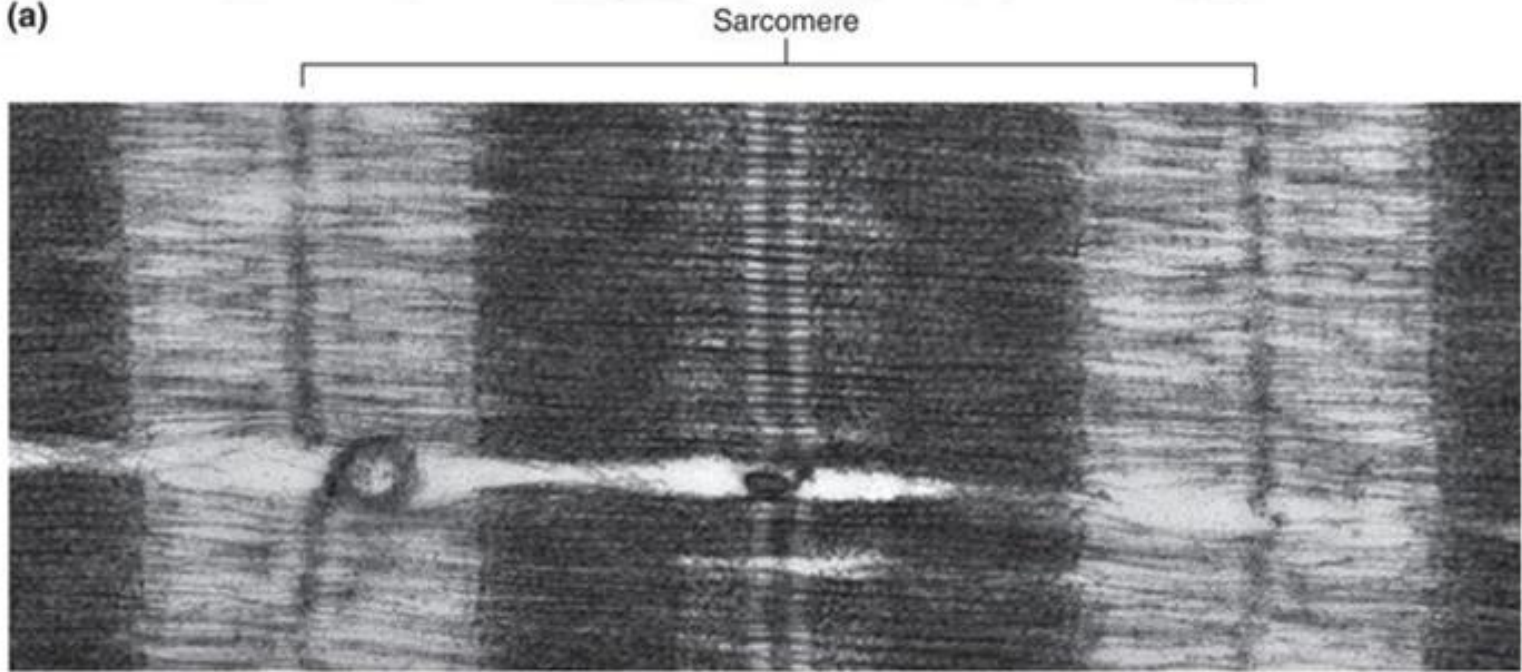




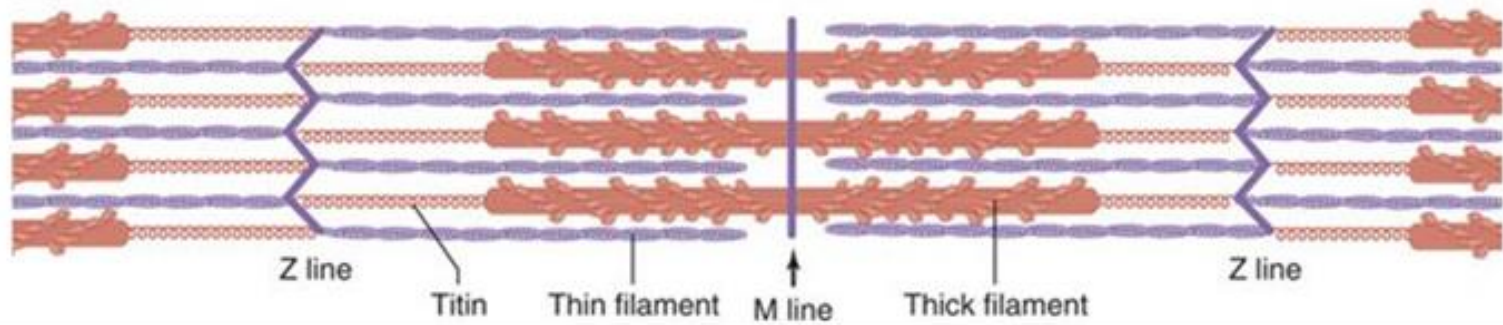
**Sarcomere** is the part of the myofibril between two successive Z lines. Sarcomere is the functional unit of the muscle fiber. Each sarcomere contains one complete A band separating two halves I bands on both sides of the A band.

# EM

(a)

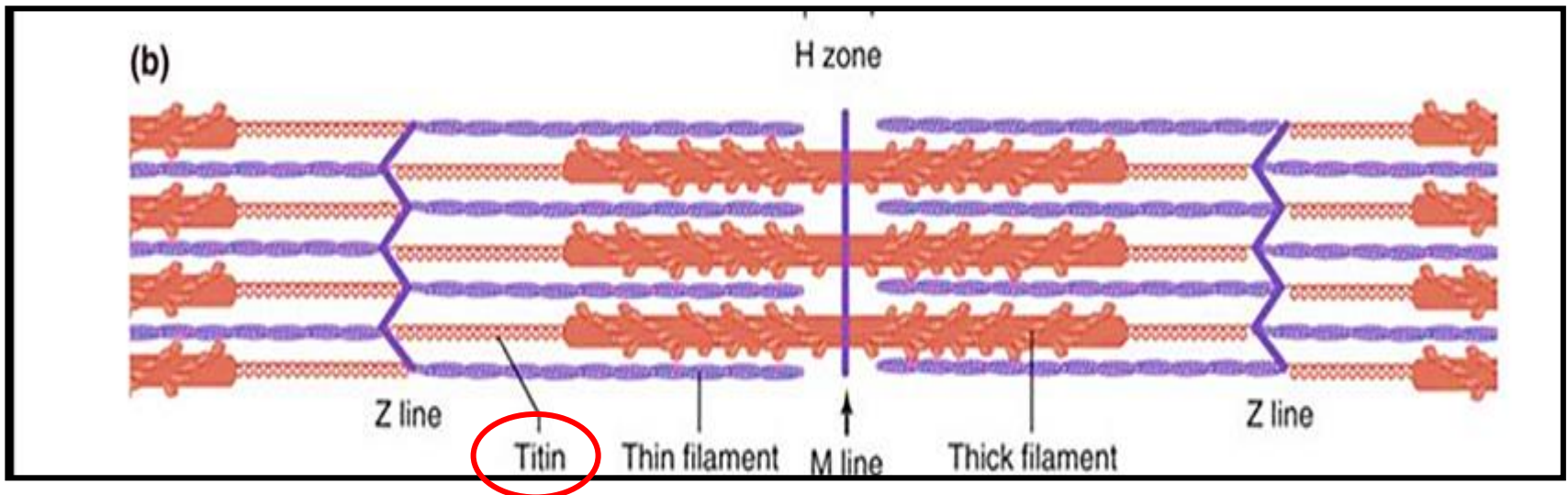


(b)

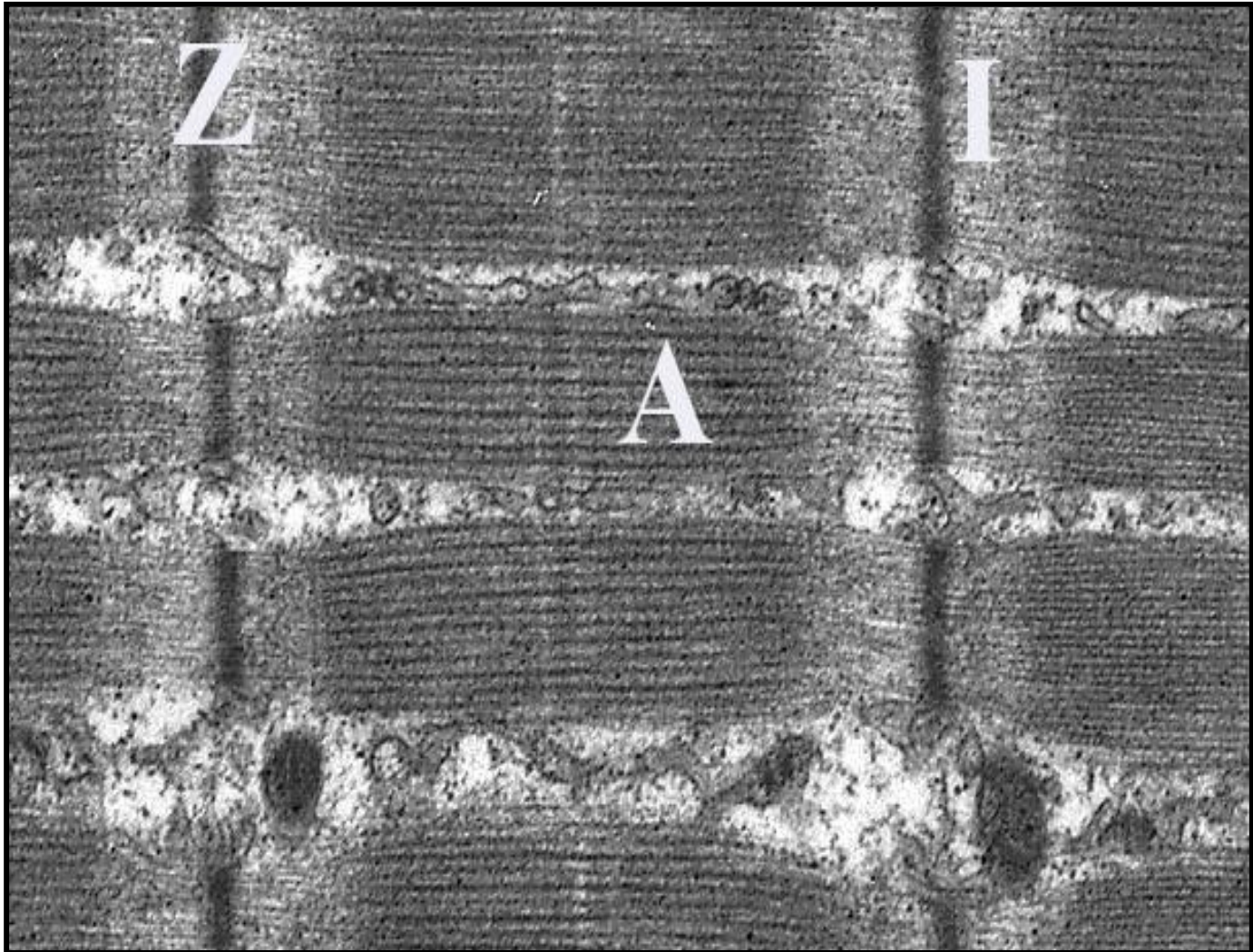


- The A and I banding pattern in sarcomeres is due mainly to the regular arrangement of thick and thin myofilaments, composed of myosin and F-actin, respectively.
- A band contains myosin and actin myofilaments.
- **H zone** is a paler central region in the A band and consists only of myosin myofilaments.
- H zone is bisected by dark **M line**, which is the site of attachment of myosin myofilaments.
- I bands contains actin myofilaments only which are attached to **Z lines**.

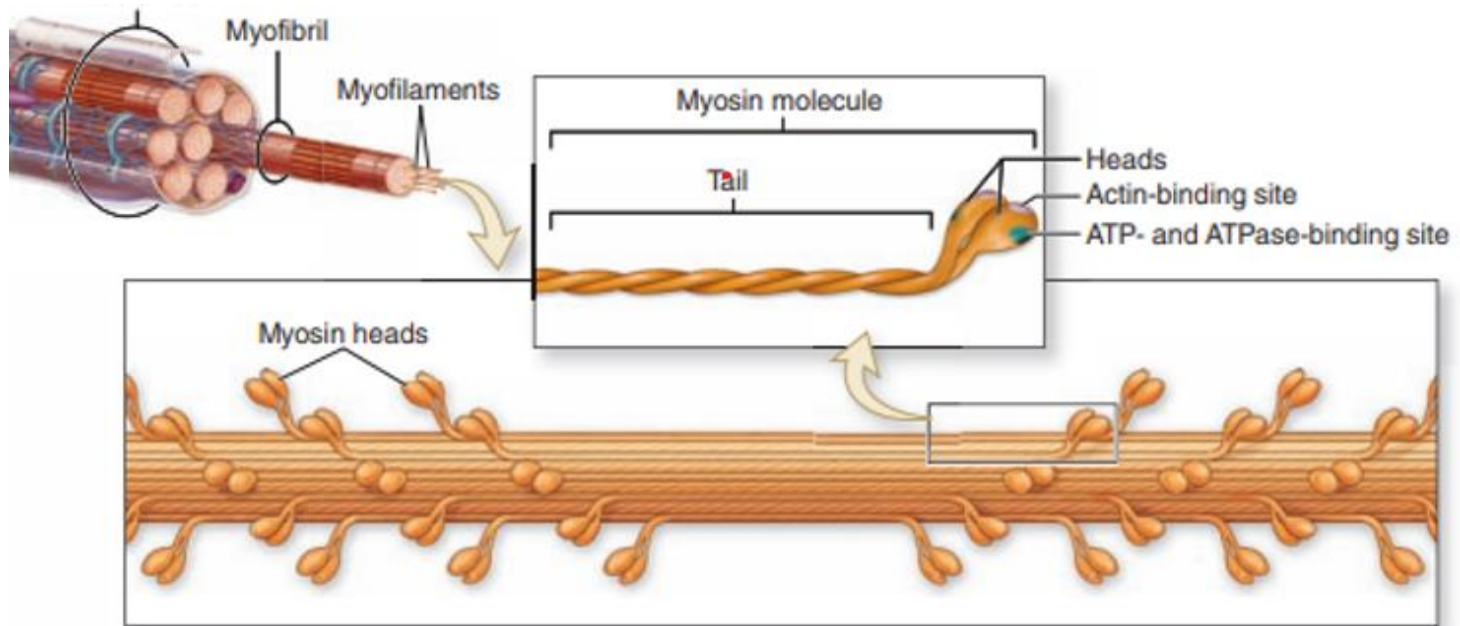
- Actin filaments are anchored perpendicularly on the Z disc by the actin-binding protein  **$\alpha$ -actinin**.
- M line contains a myosin-binding protein **myomesin** that holds the thick filaments in place.
- **Titin**, the largest protein in the body, which supports the thick myofilaments and connects them to the Z disc.



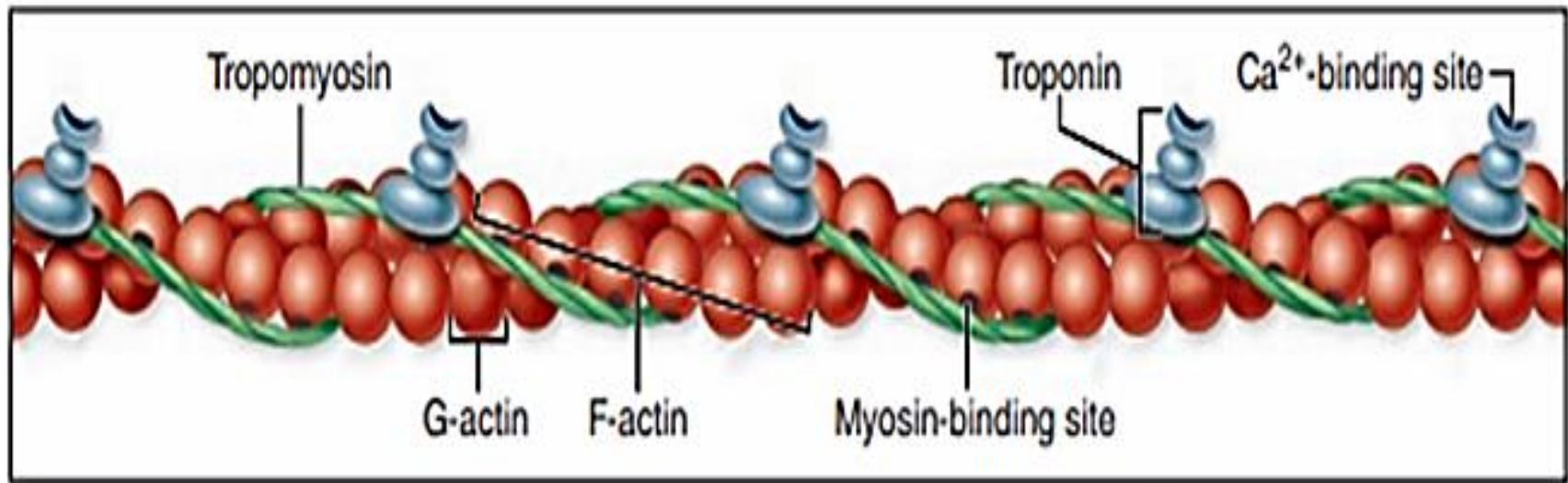
# LS skeletal ms showing sarcomere



- **Myosin** is a large complex with two identical heavy chains and two pairs of light chains.
- **Myosin heavy chains** twisted together as **myosin tails**.
- The four **myosin light chains** form **a head** at one end of each heavy chain.

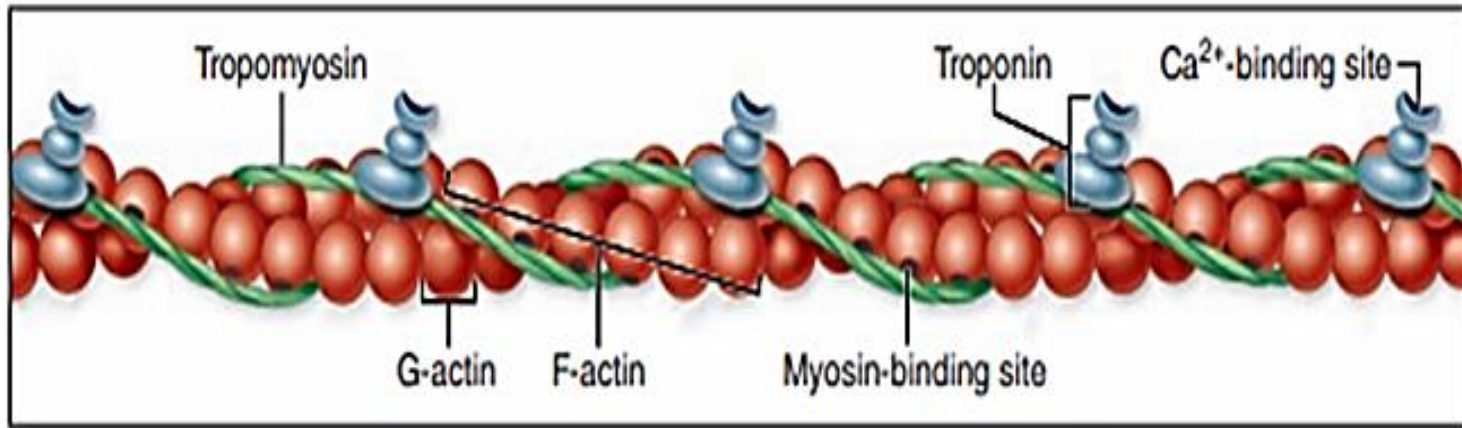


- **G-actin** monomers form F-actin filaments (two twisted actin strands)
- The thin, helical actin filaments run between the thick filaments. Each G-actin monomer contains a binding site for myosin.

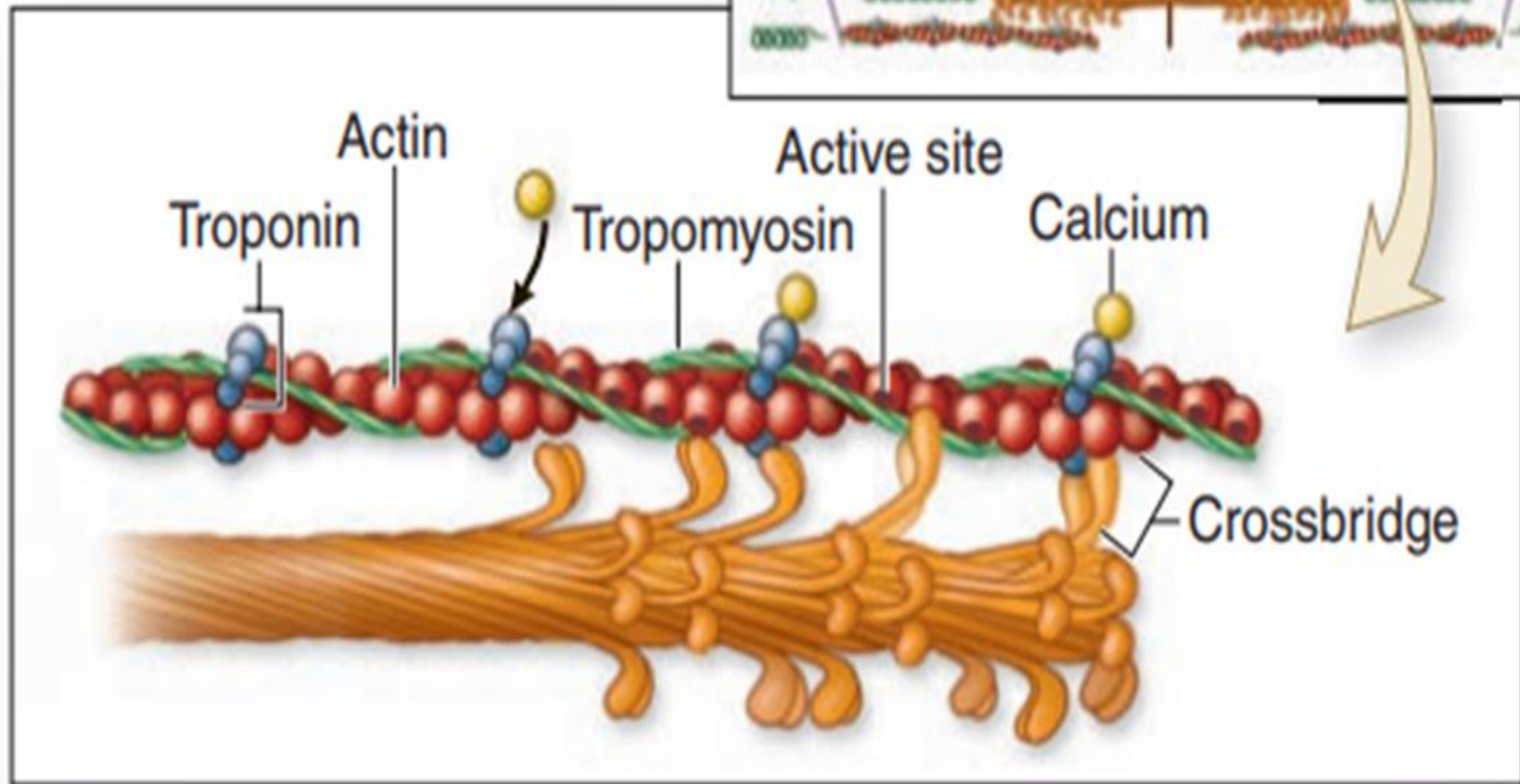
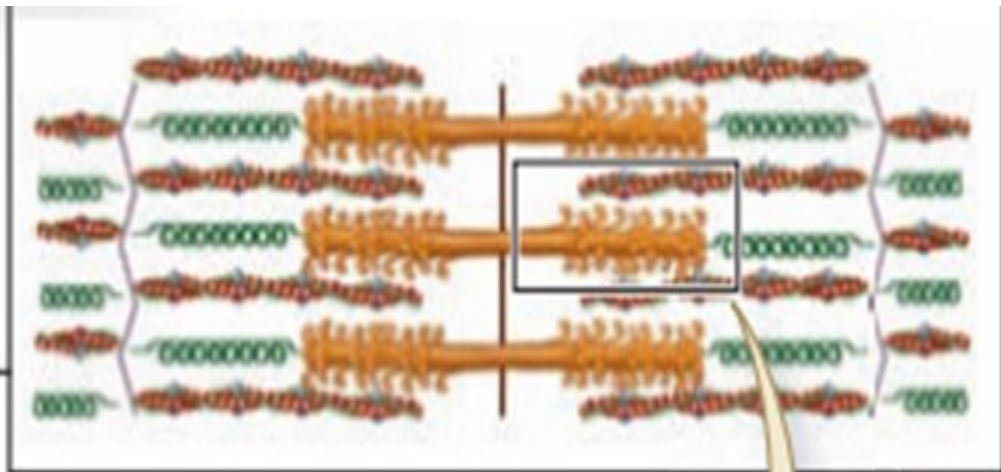


**b Thin filament**

- Thin filaments are also tightly associated with two regulatory proteins:
- ■ **Tropomyosin**, two polypeptide chains located in the groove between the two twisted actin strands.
- ■ **Troponin**, a complex of three subunits: **TnT**, which attaches to tropomyosin; **TnC**, which binds  $\text{Ca}^{2+}$ ; and **TnI**, which regulates the actin-myosin interaction.

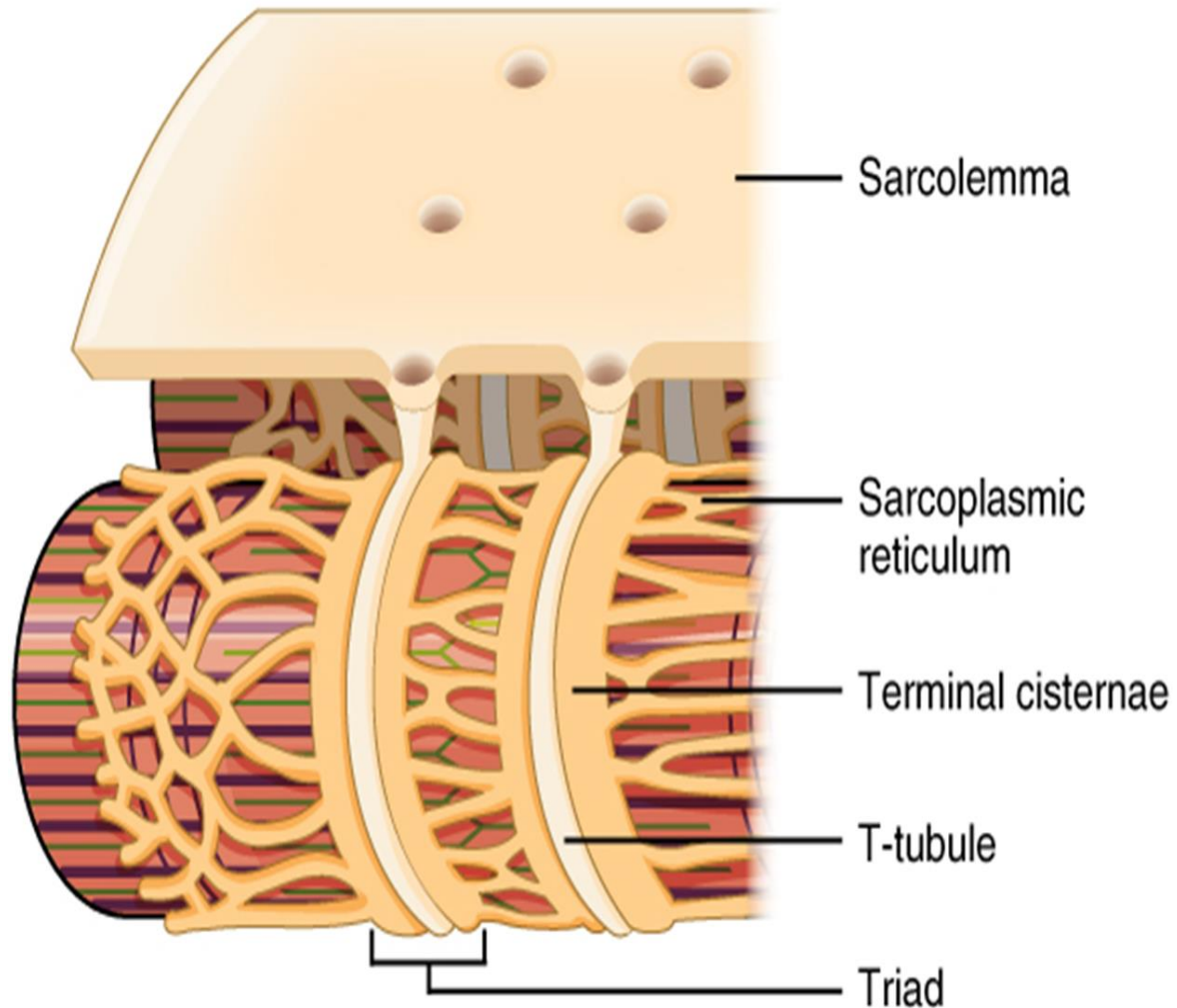


b Thin filament



# Sarcoplasmic Reticulum & Transverse Tubule System

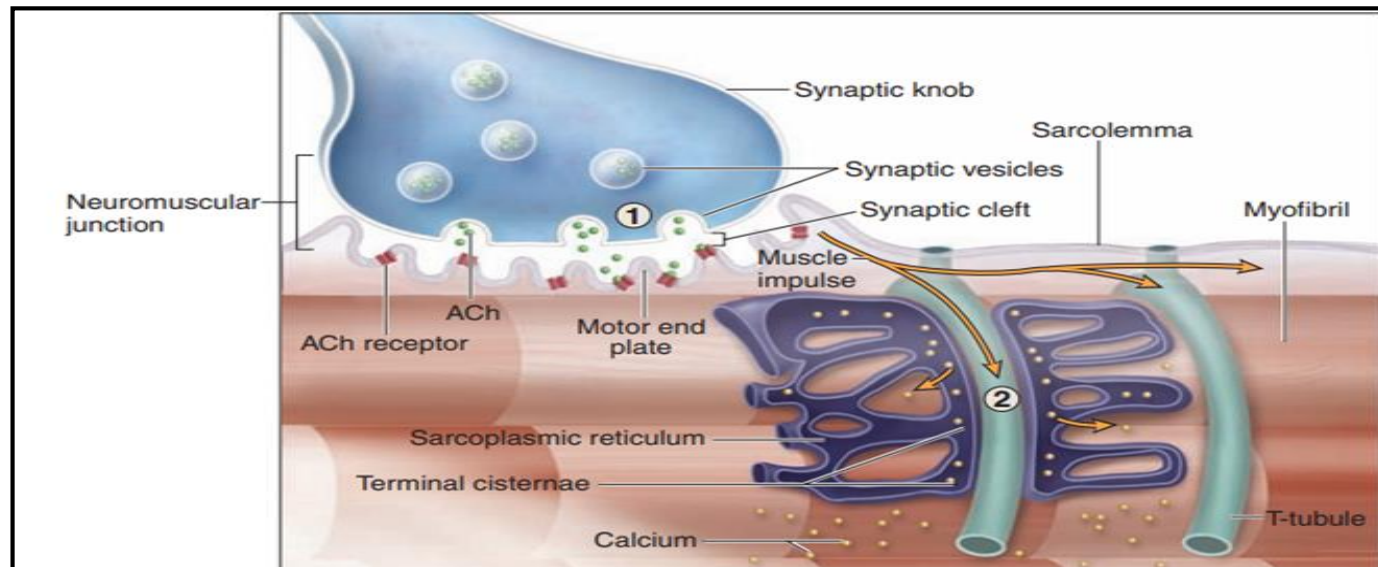
- In skeletal muscle fibers the smooth ER, or sarcoplasmic reticulum, is specialized for  $\text{Ca}^{2+}$  sequestration.



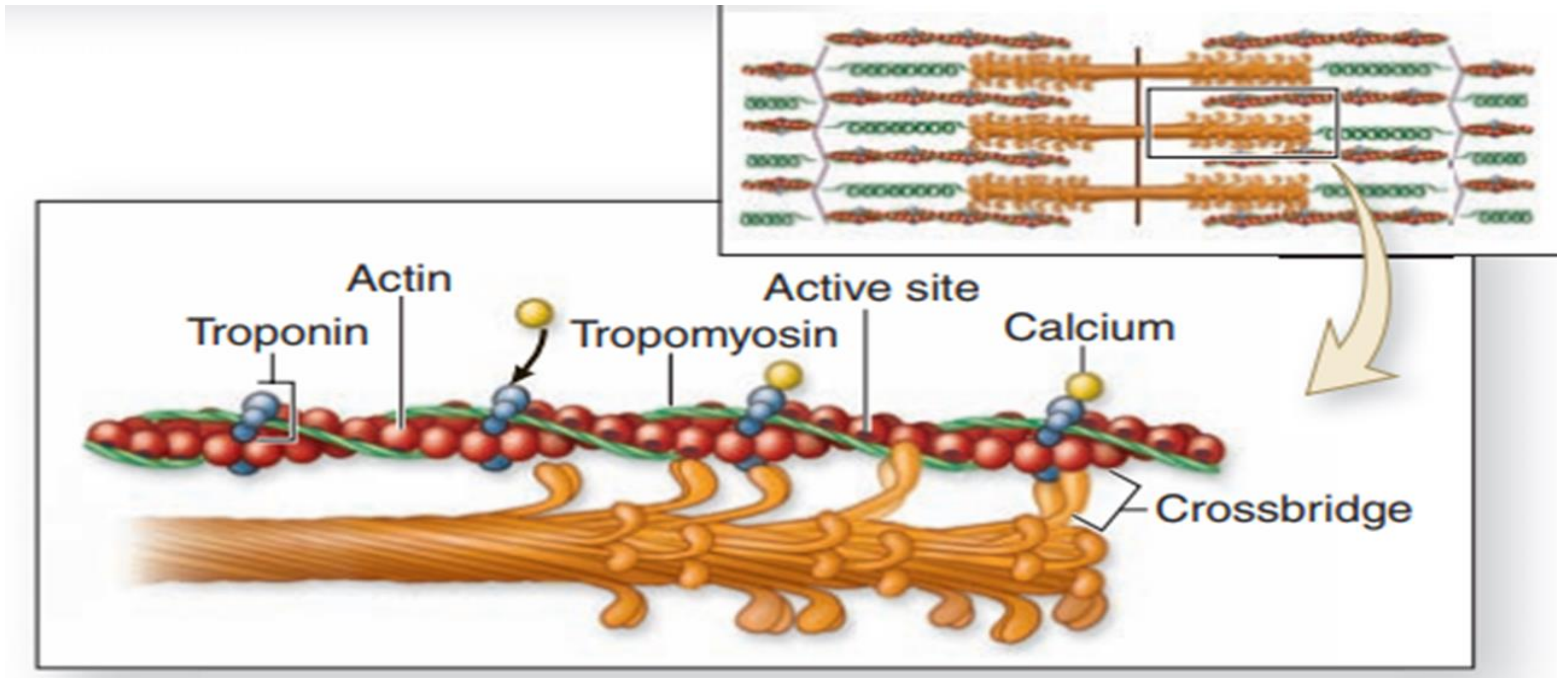
- the sarcolemma is folded into a system of transverse or T tubules. These long fingerlike invaginations of the cell membrane penetrate deeply into the sarcoplasm and encircle every myofibril near **the A- and I-band** boundaries of sarcomeres.
- Adjacent to each side of every T tubule are expanded terminal cisterna of the sarcoplasmic reticulum. In longitudinal TEM sections, this complex of a T tubule with two closely associated small cisterns of sarcoplasmic reticulum on each side is known as **a triad**.

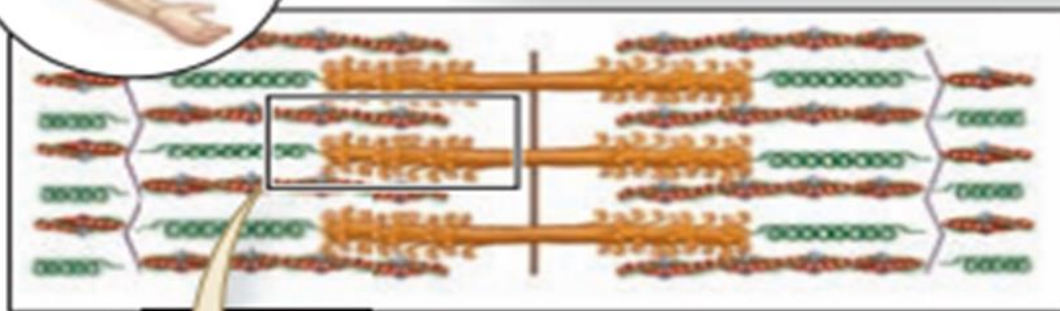
## Mechanism of muscle contraction

- Depolarization of sarcolemma is initiated at specialized motor nerve synapses **→ T-tubule → sarcoplasmic reticulum**
- After depolarization of the sarcoplasmic reticulum membrane, calcium ions are released into cytoplasm surrounding the thick and thin filaments.

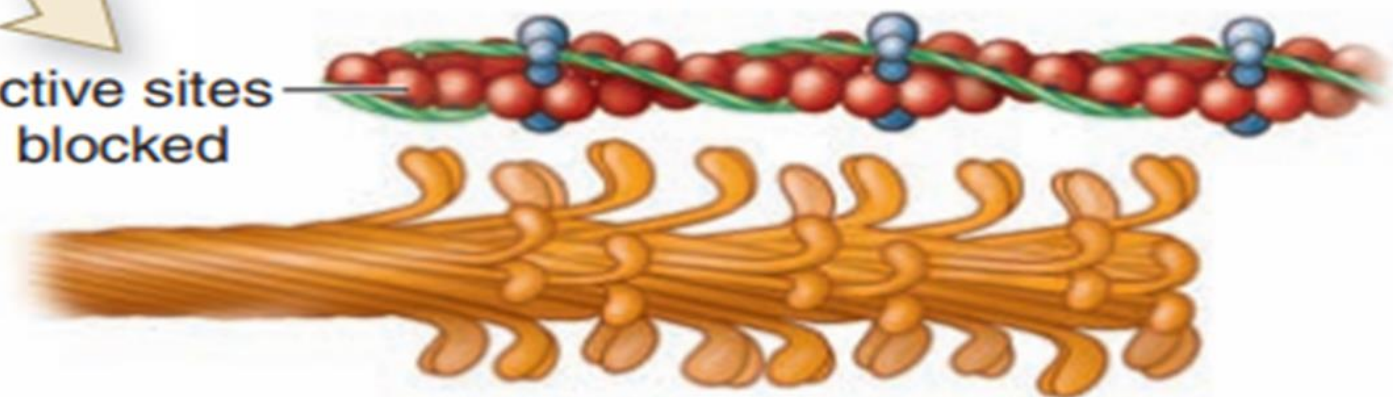


- $\text{Ca}^{2+}$  binds troponin  $\longrightarrow$  moving tropomyosin  $\longrightarrow$  expose active site of actin  $\longrightarrow$  bridging between actin and myosin molecules.
- When the membrane depolarization ends, the sarcoplasmic reticulum pumps  $\text{Ca}^{2+}$  back into the cisternae, ending contractile activity.

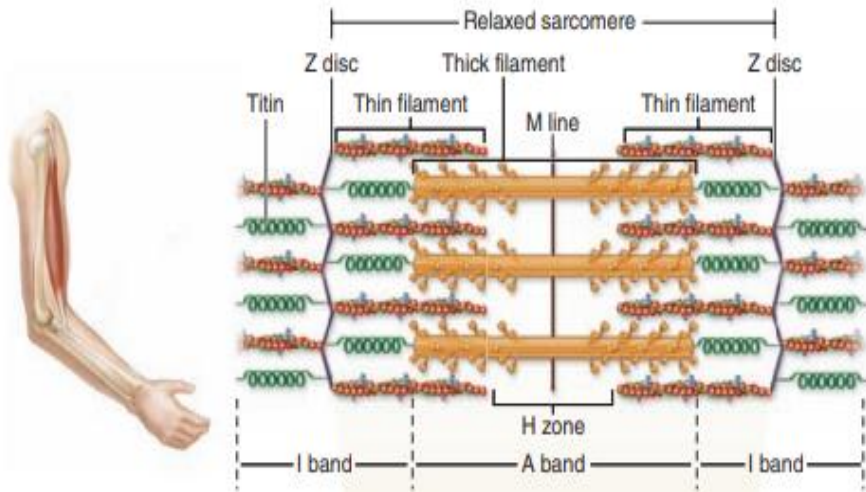




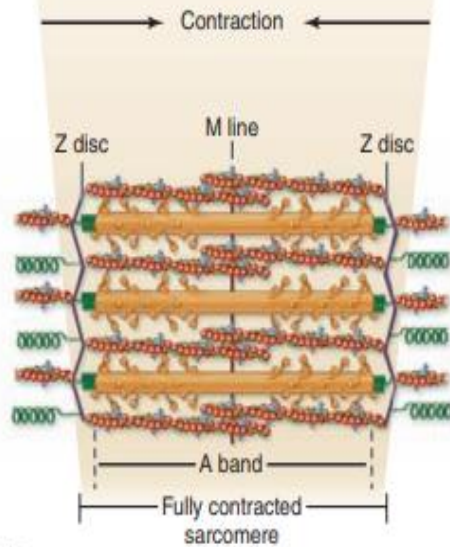
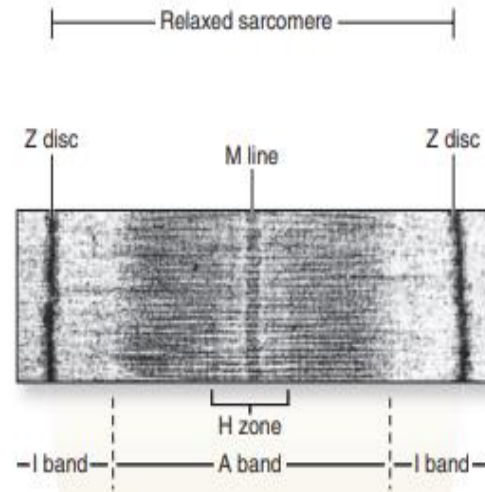
Active sites  
blocked



When the impulse stops, calcium ions are actively transported into the sarcoplasmic reticulum, tropomyosin re-covers active sites, and filaments passively slide back to their relaxed state.



**a Relaxed skeletal muscle**



**b Fully contracted skeletal muscle**

