

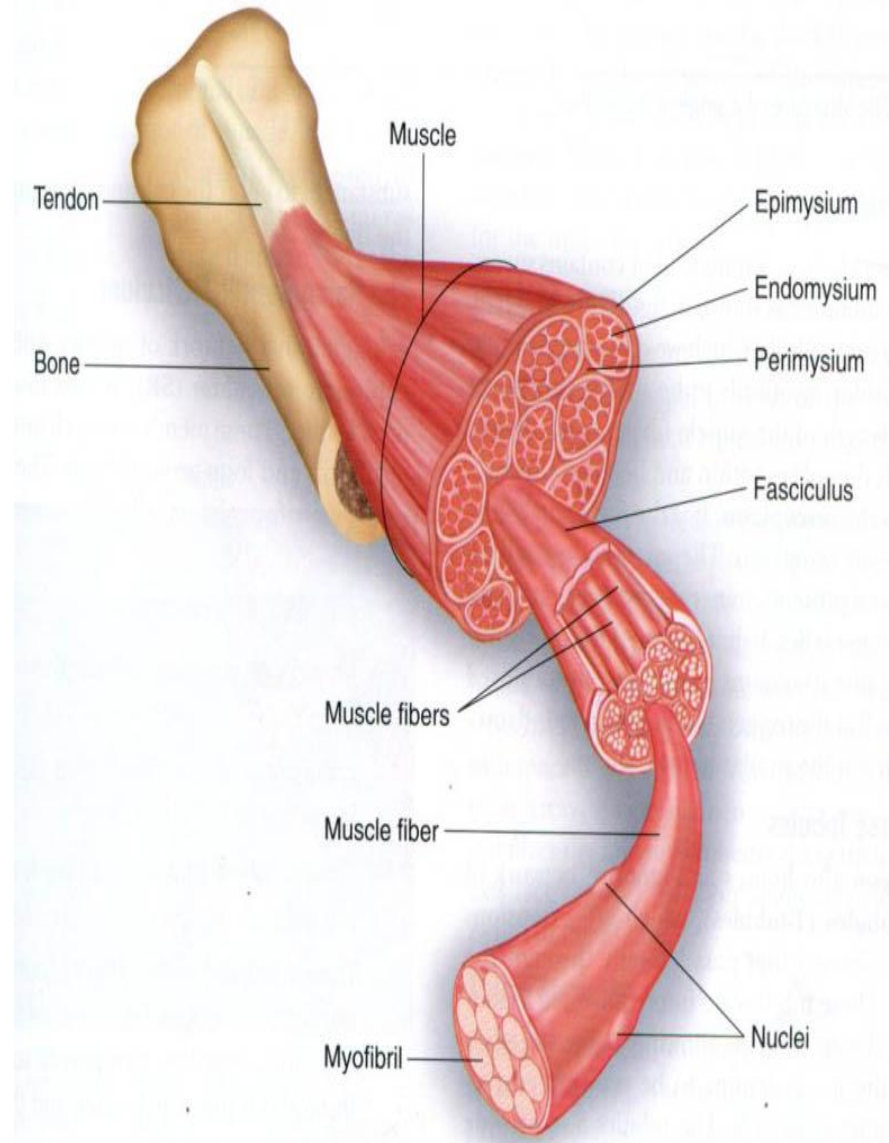
Skeletal Muscle

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Skeletal muscle

- Skeletal muscle contains bundles of very long, multinucleated cells with cross-striations. Their contraction is quick, forceful, and under voluntary control.
- They are called skeletal as they are attached to the skeleton



Organization of a Skeletal Muscle (C.T Coverings)

- **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.

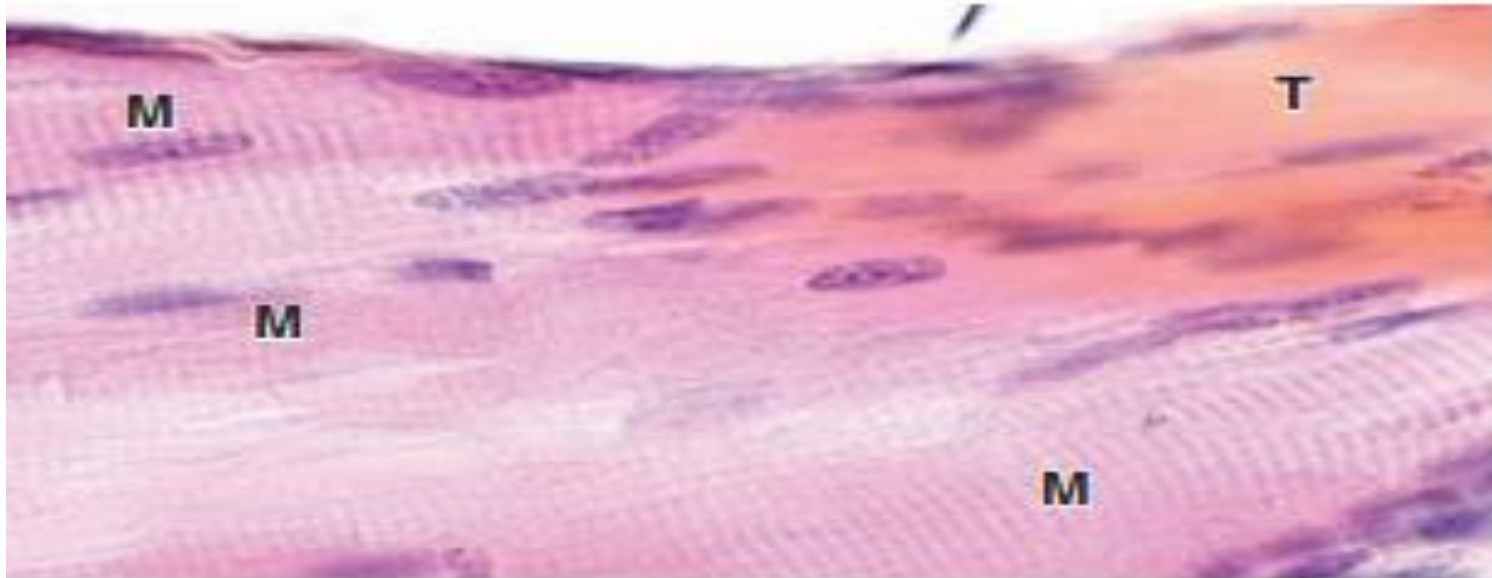
- **The perimysium:** is a thin connective tissue layer that immediately surrounds each bundle of muscle fibers termed a fascicle. Each fascicle of muscle fibers makes up a functional unit in which the fibers work together. Nerves, blood vessels, and lymphatics penetrate the perimysium to supply each fascicle.

- **The endomysium:** a very thin, delicate layer of reticular fibers and scattered fibroblasts and many blood capillaries. It surrounds the external lamina of individual muscle fiber.



The blood vessels were injected with a dark plastic polymer before the muscle was collected and sectioned longitudinally. A rich network of capillaries in endomysium surrounding muscle fibers is revealed by this method. X200. Giemsa with polarized light.

Myotendinous junctions



Tendons develop together with skeletal muscles and join muscles to the periosteum of bones. The collagen fibers of a tendon (**T**) are continuous with those in the connective tissue layers around muscle fibers (**M**), forming a strong unit that allows muscle contraction to move the skeleton. X400. H&E.

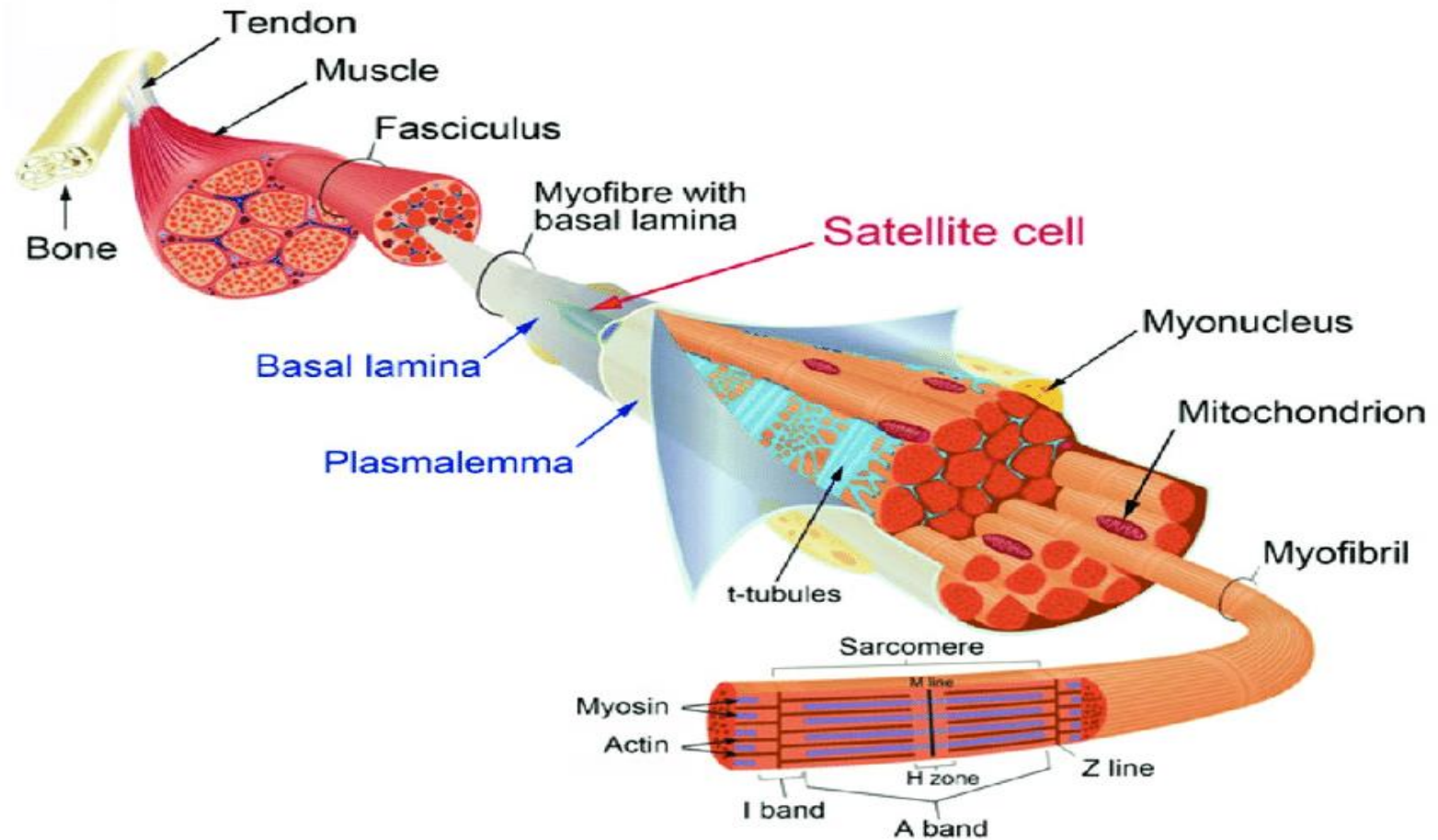
- Collagen in these connective tissue coverings of muscle serve to transmit the mechanical forces generated by the contracting muscle cells.
- Some skeletal muscles taper at their ends, where the epimysium is continuous with the **dense regular connective tissue of a tendon** at myotendinous junctions.
- Ultrastructural studies show that in these transitional regions, collagen fibers from the tendon insert themselves among muscle fibers and associate directly with complex infoldings of sarcolemma.

Skeletal muscle

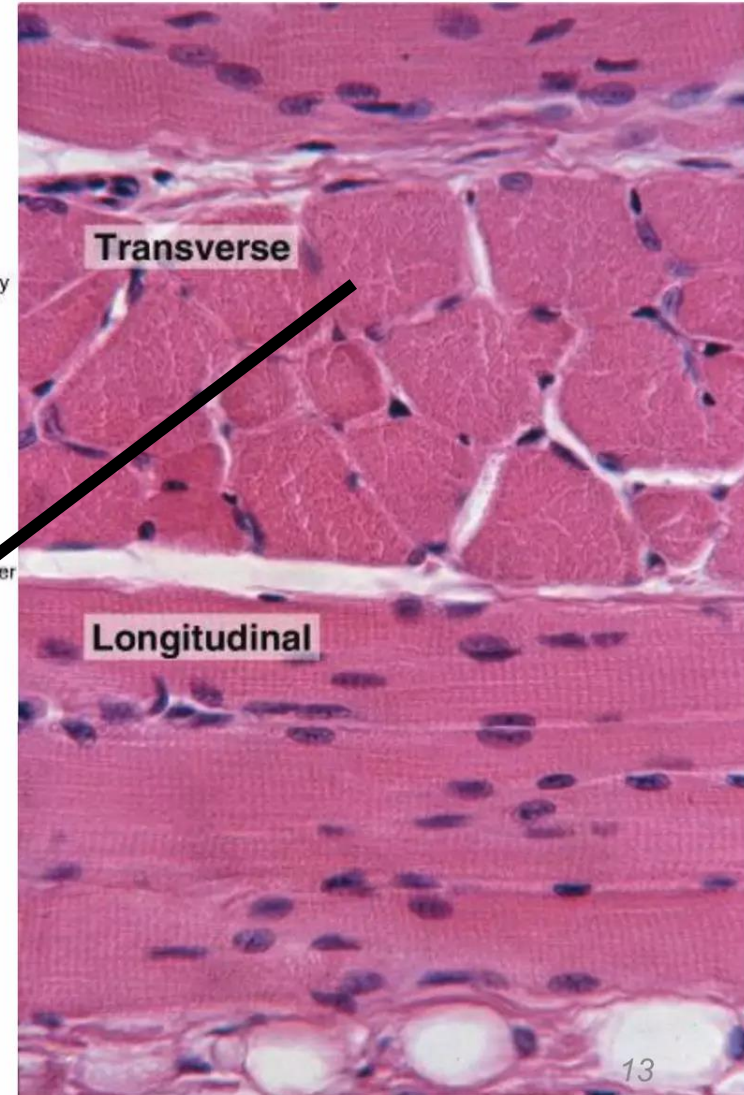
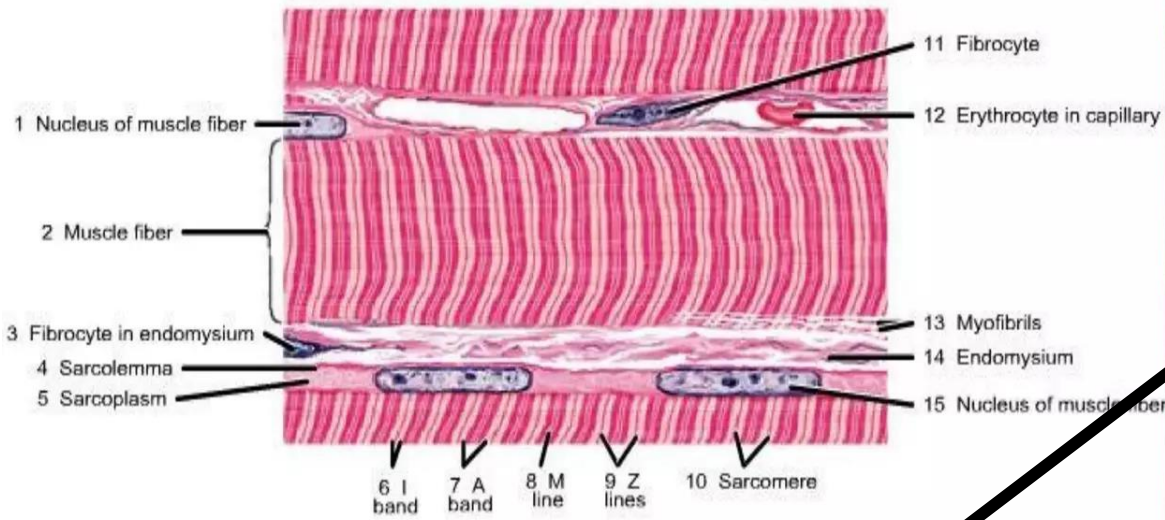
L.M:

- Muscle fibers are very long tubular cells. They are about (10-100 μm) 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.

Satellite cell



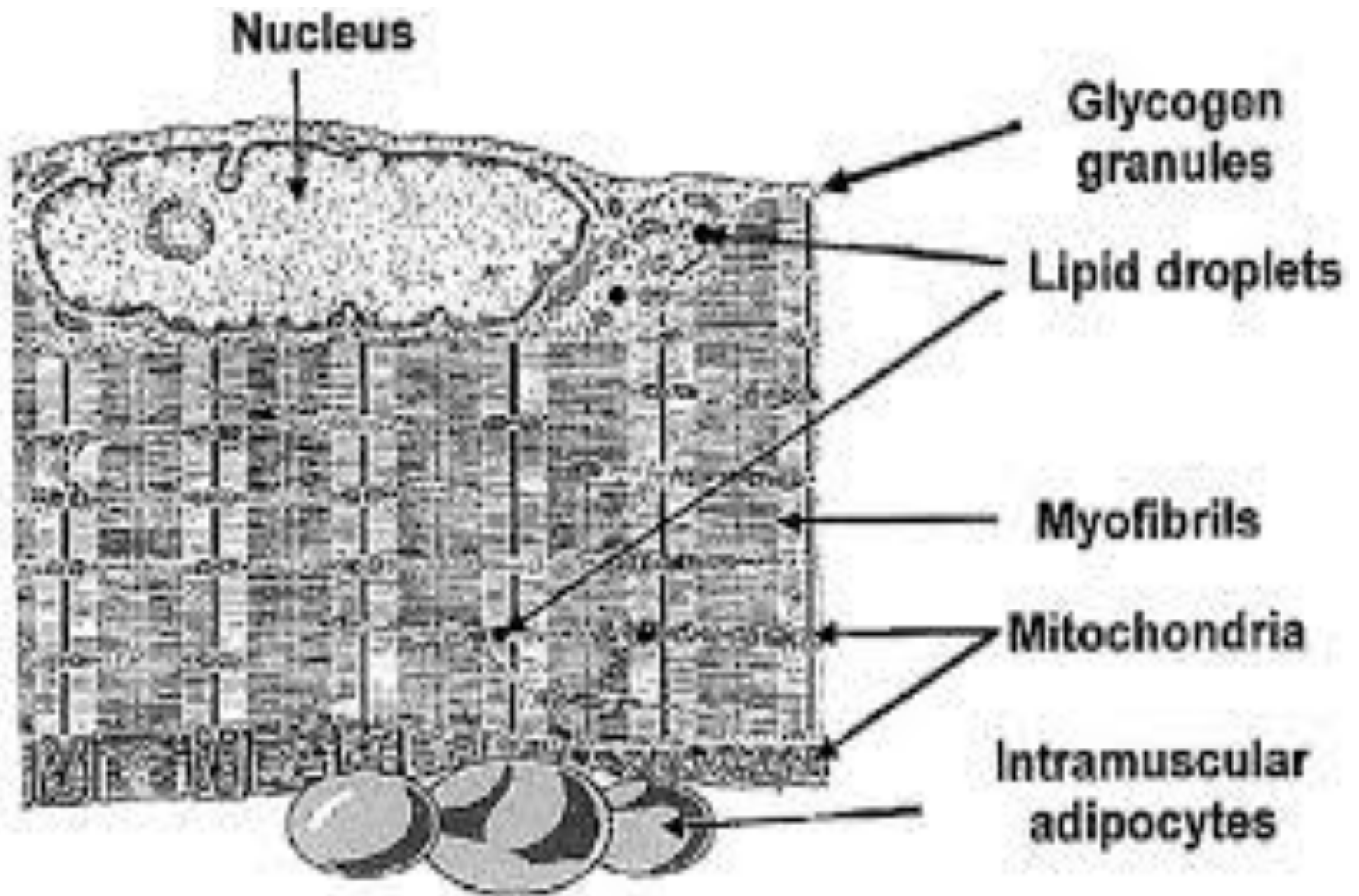
Skeletal muscle –L.S & T.S



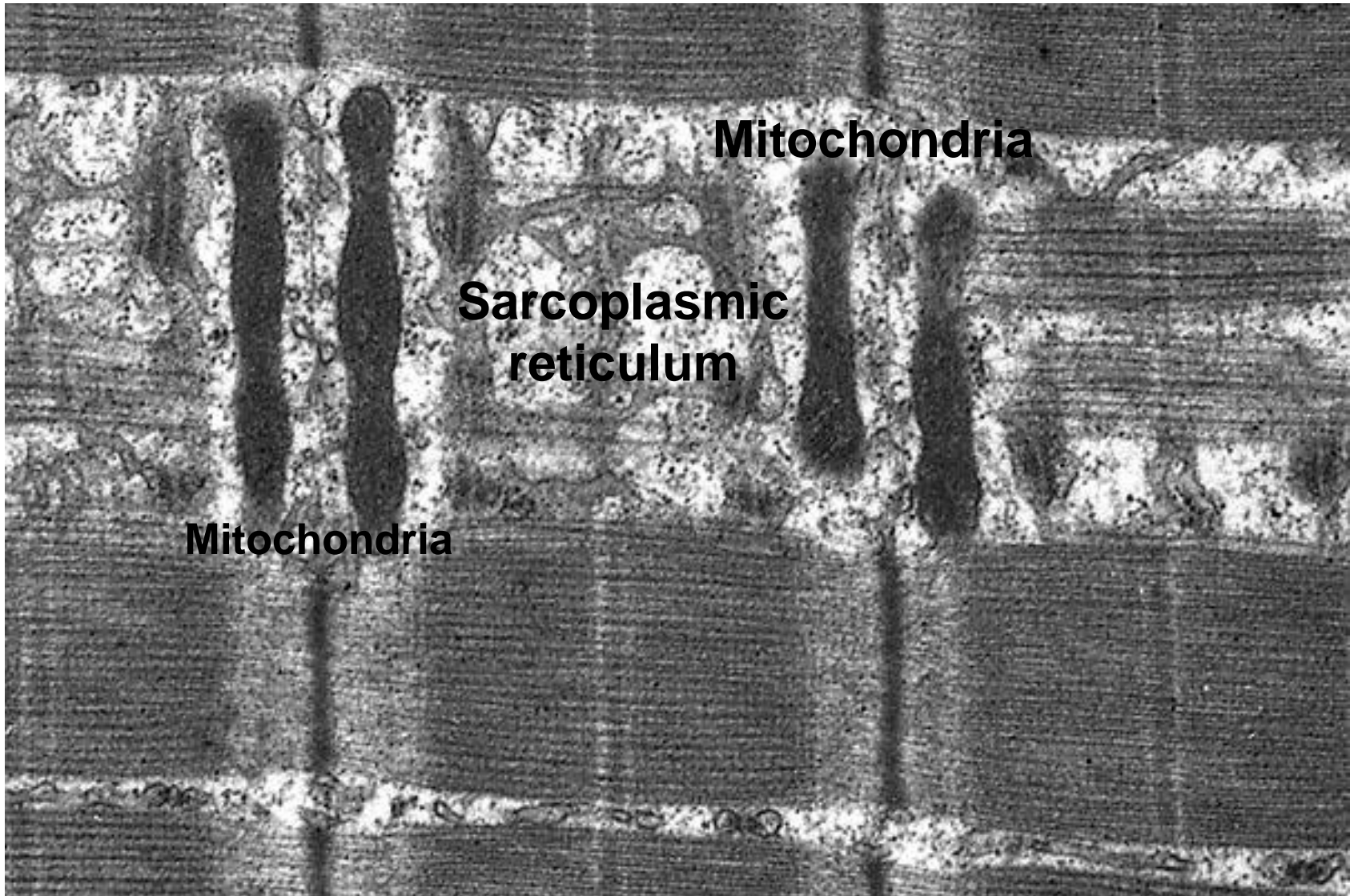
L.M:

- 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 (Cohnheim areas)

EM



EM

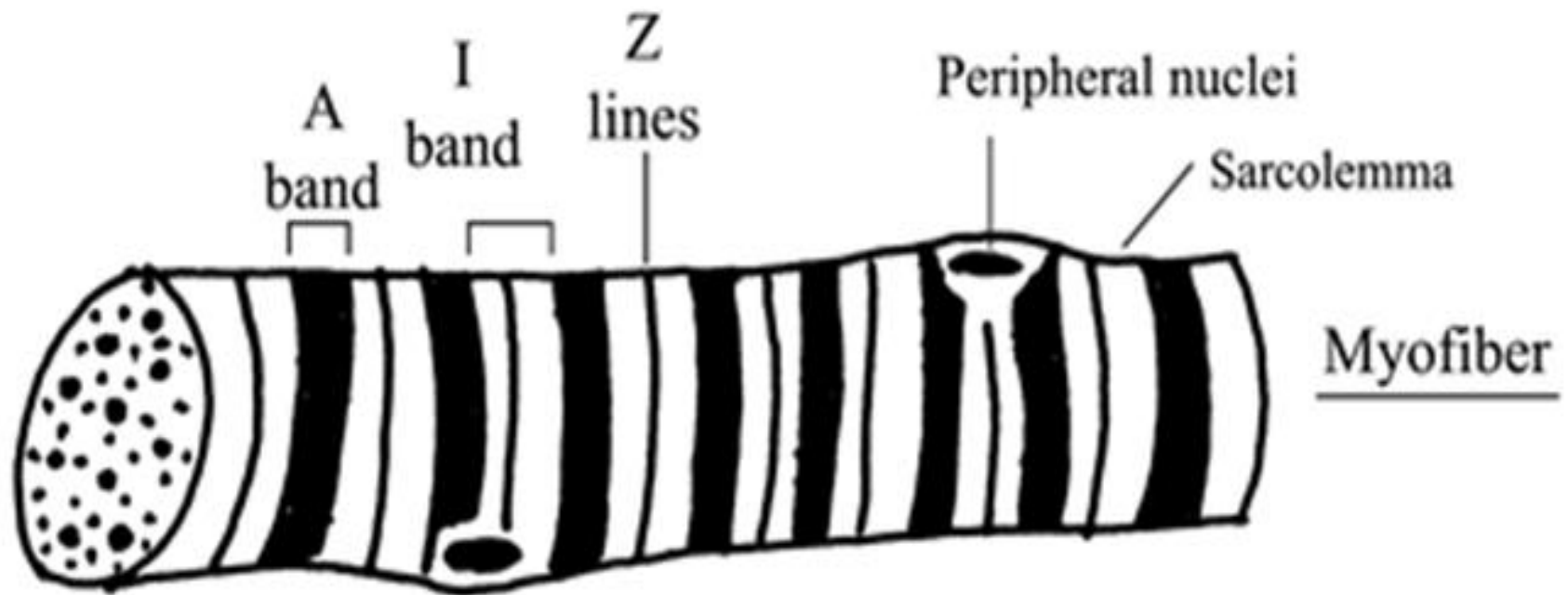


EM: The sarcoplasm of the skeletal muscle fiber contains:

- 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 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 iron and 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

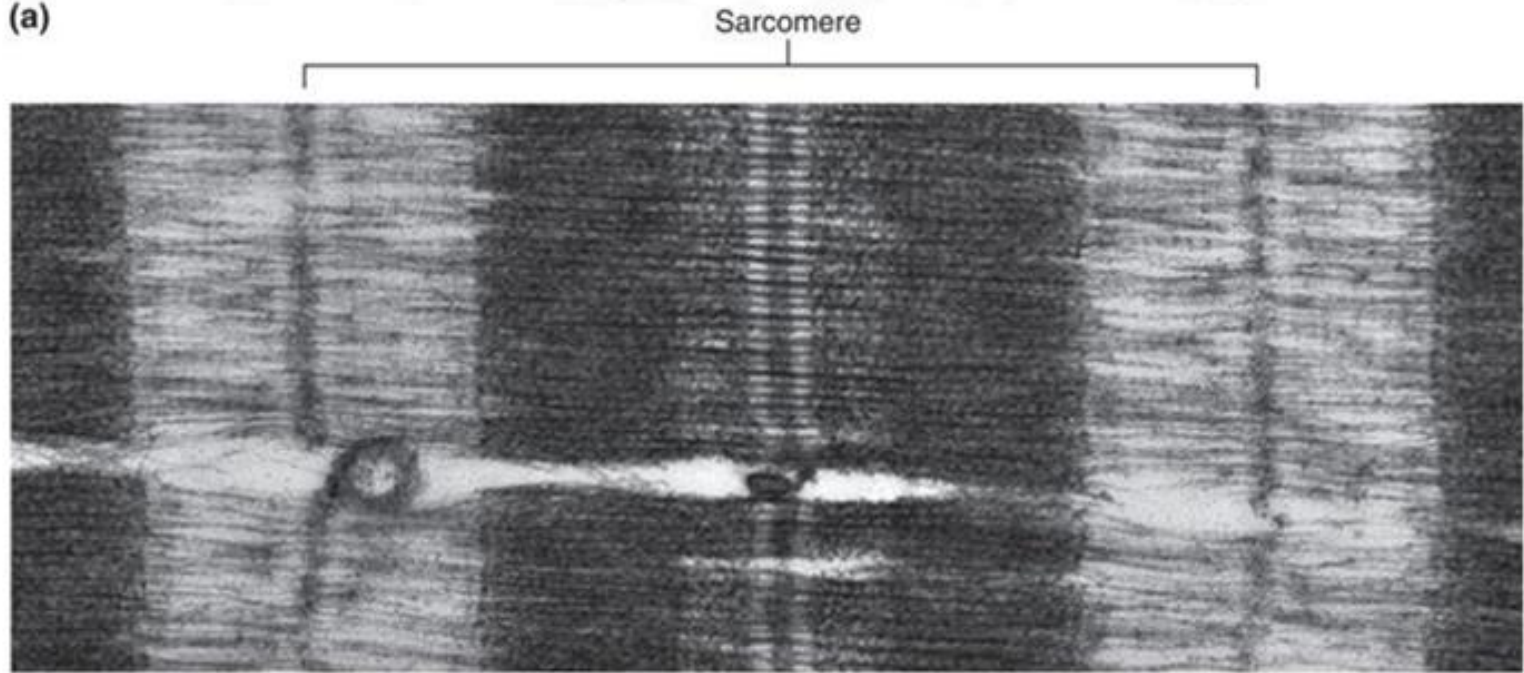
- Longitudinally sectioned skeletal muscle fibers show cross striations of alternating light and dark bands. The dark bands are called A bands the light bands are called I bands.
- In the TEM , each I band is seen to be bisected by a dark transverse line, the Z disc. The repetitive functional subunit of the contractile apparatus, **the sarcomere**, extends from Z disc to Z disc and is about 2.5 μm 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.

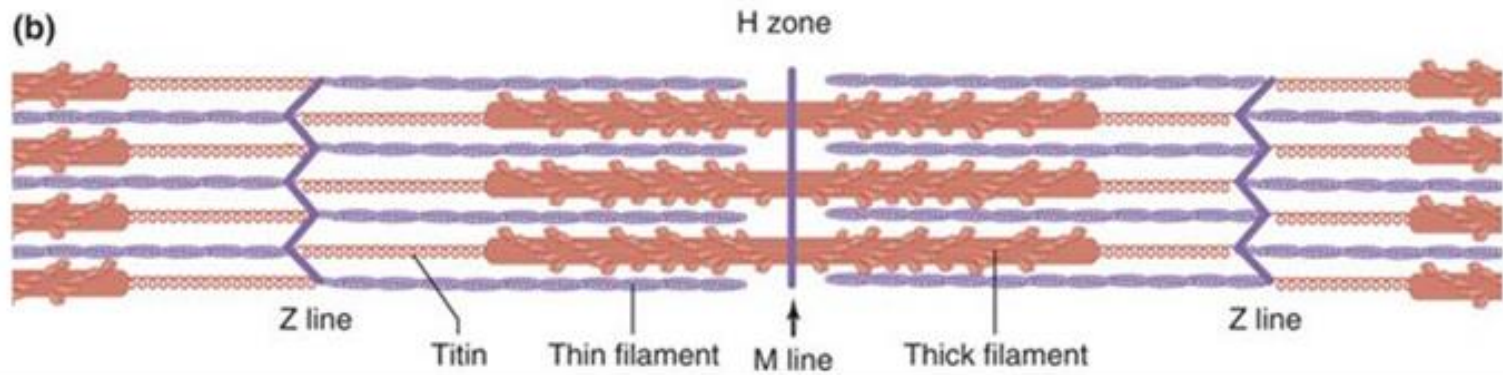
EM

(a)



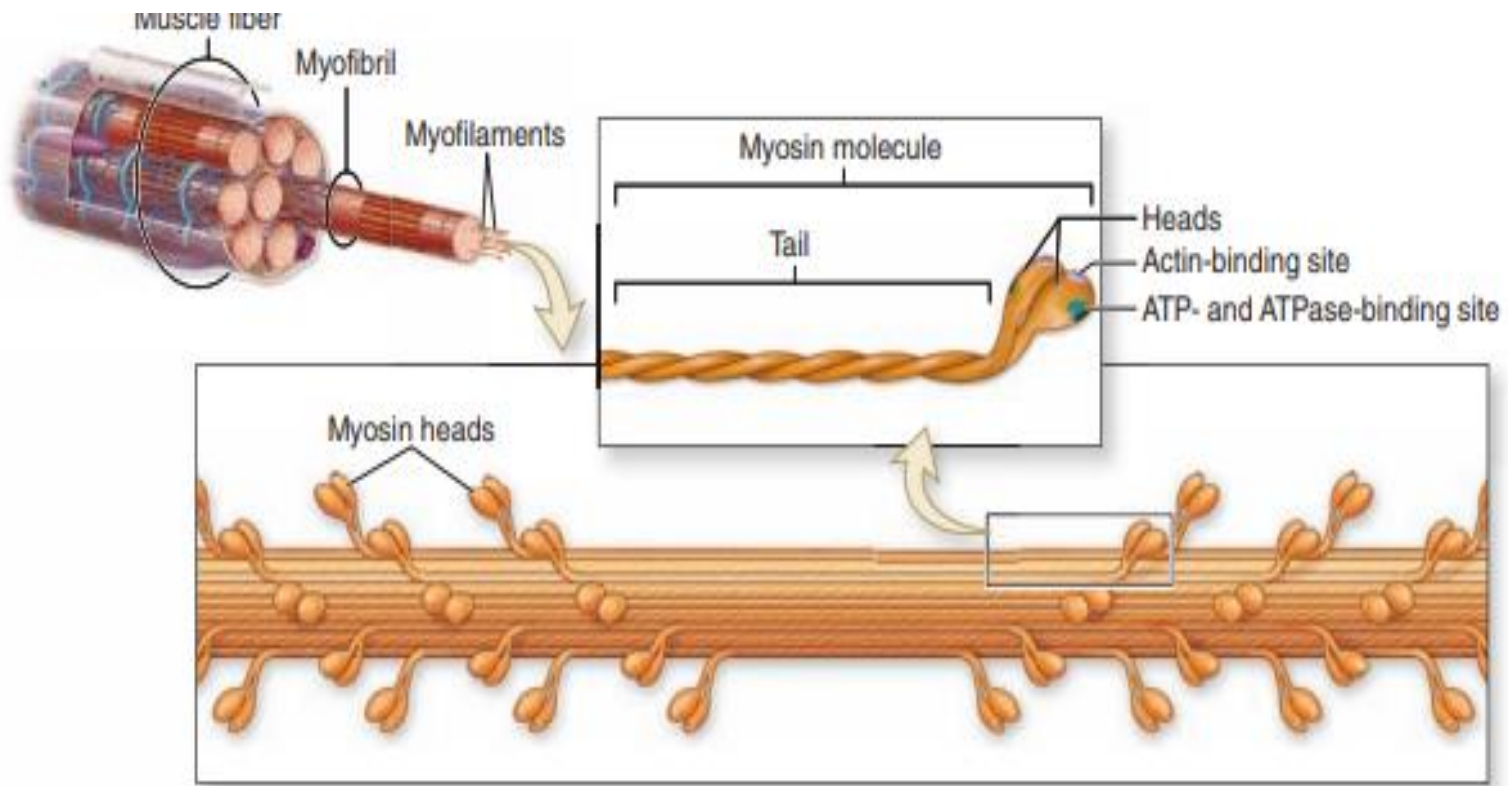
I band A band

(b)

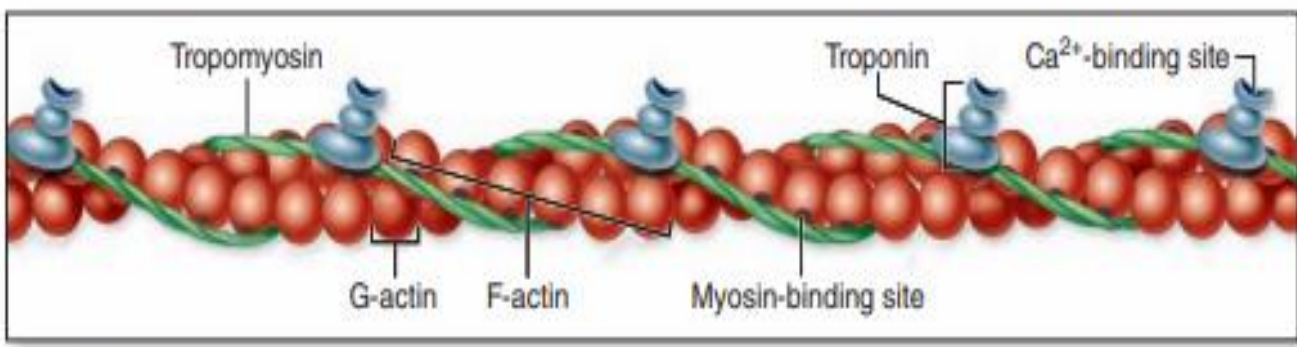


- The A and I banding pattern in sarcomeres is due mainly to the regular arrangement of thick and thin myofilaments, composed of myosin and F-actin, respectively.
- A band contains myosin and actin myofilaments.
- **H zone** is a paler central region in the A band and consists only of myosin myofilaments.
- 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**.

- **Myosin** is a large complex with two identical heavy chains and two pairs of light chains.
- **Myosin heavy chains** are thin, rodlike motor proteins twisted together as **myosin tails**.
- Globular projections containing the four **myosin light chains** form **a head** at one end of each heavy chain.
- The myosin heads bind both **actin**, forming transient cross bridges between the thick and thin filaments, and **ATP**, catalyzing energy release. Several hundred myosin molecules are arranged within each thick filament with overlapping rodlike portions and the globular heads directed toward either end.

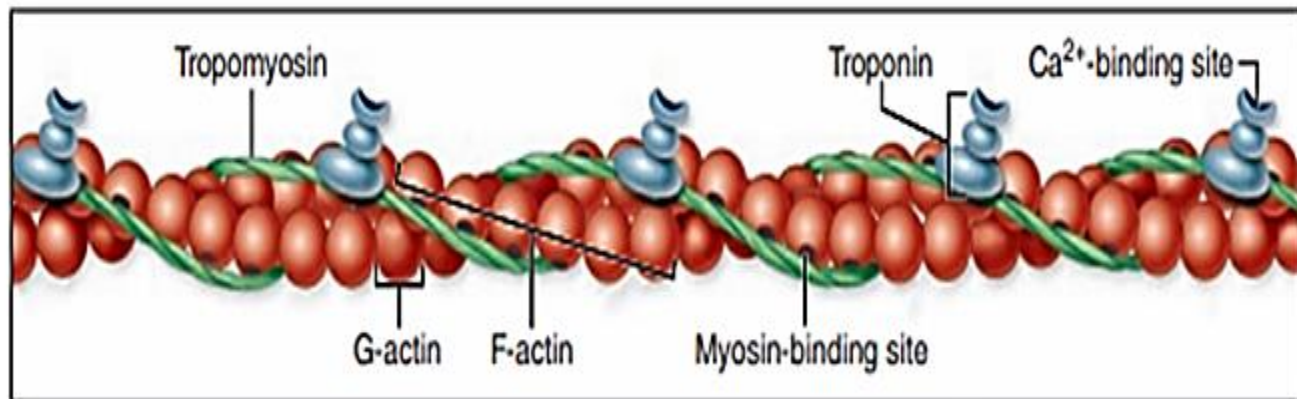


a Thick filament



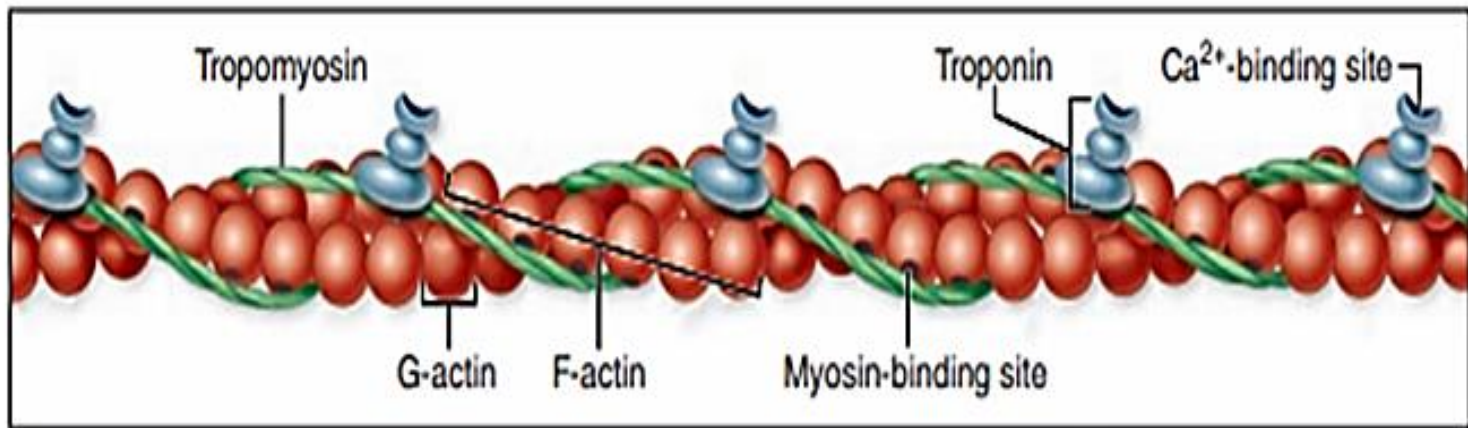
b Thin filament

- **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.
- Actin filaments are anchored perpendicularly on the Z disc by the actin-binding protein **α -actinin**

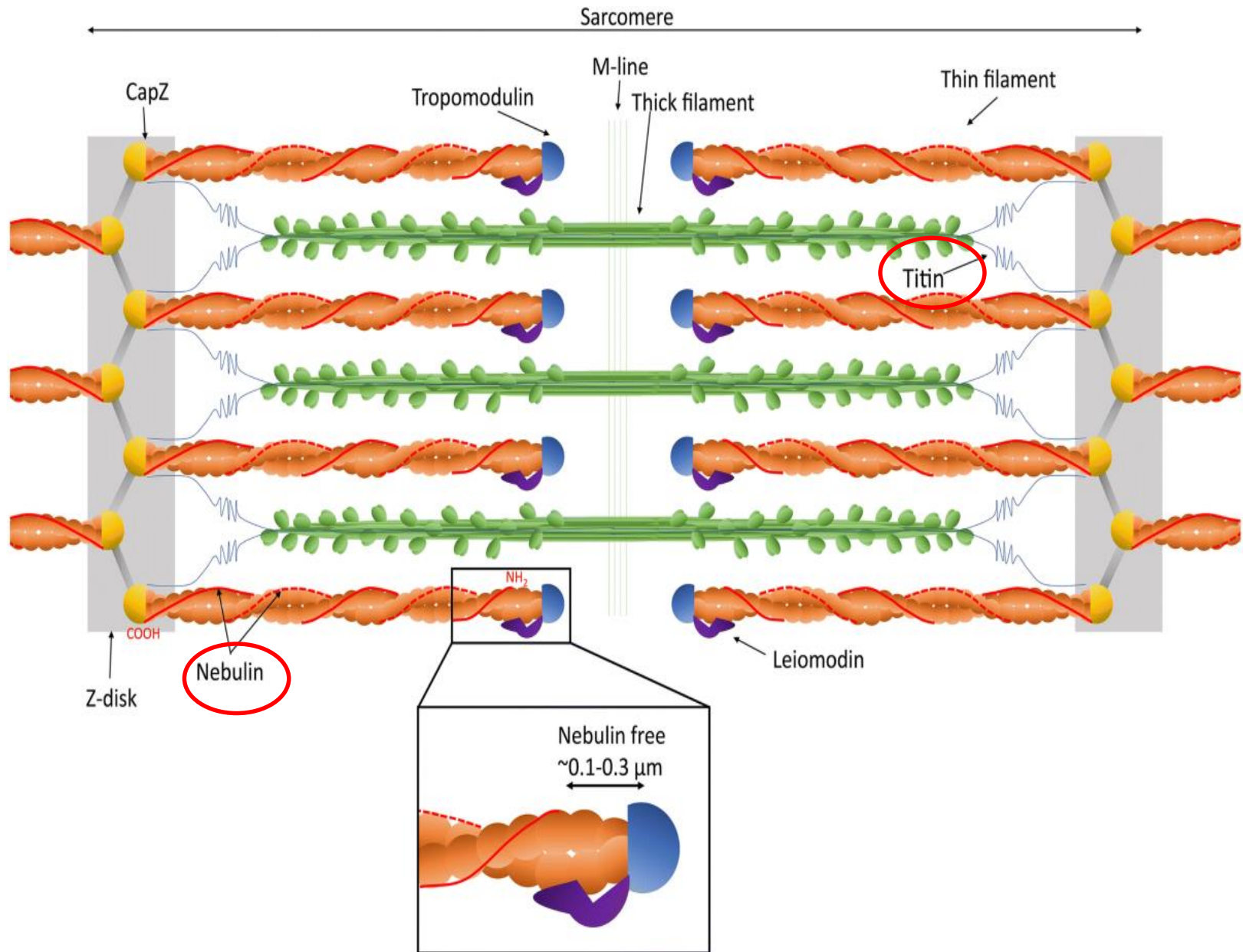


b Thin filament

- 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 Ca^{2+} ; and **TnI**, which regulates the actin-myosin interaction. Troponin complexes attach at specific sites regularly spaced along each tropomyosin molecule.



b Thin filament



- An important accessory protein in I bands is **titin**, the largest protein in the body, with scaffolding and elastic properties, which supports the thick myofilaments and connects them to the Z disc. It is spanning from the Z-disc to the M-line within the sarcomere
- Another very large accessory protein, **nebulin** which binds each thin myofilament laterally, helps anchor them to α -actinin, and specifies the length of the actin polymers during myogenesis.

- Bisecting the H zone is the M line containing a myosin-binding protein **myomesin** that holds the thick filaments in place.
- Despite the many proteins present in sarcomeres, myosin and actin together represent over half of the total protein in striated muscle.

Sarcoplasmic Reticulum & Transverse Tubule System

- Sarcoplasmic reticulum, is specialized for 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 aligned A- and I-band boundaries of sarcomeres.
- Adjacent to each side of every T tubule are expanded terminal cisterns 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.

