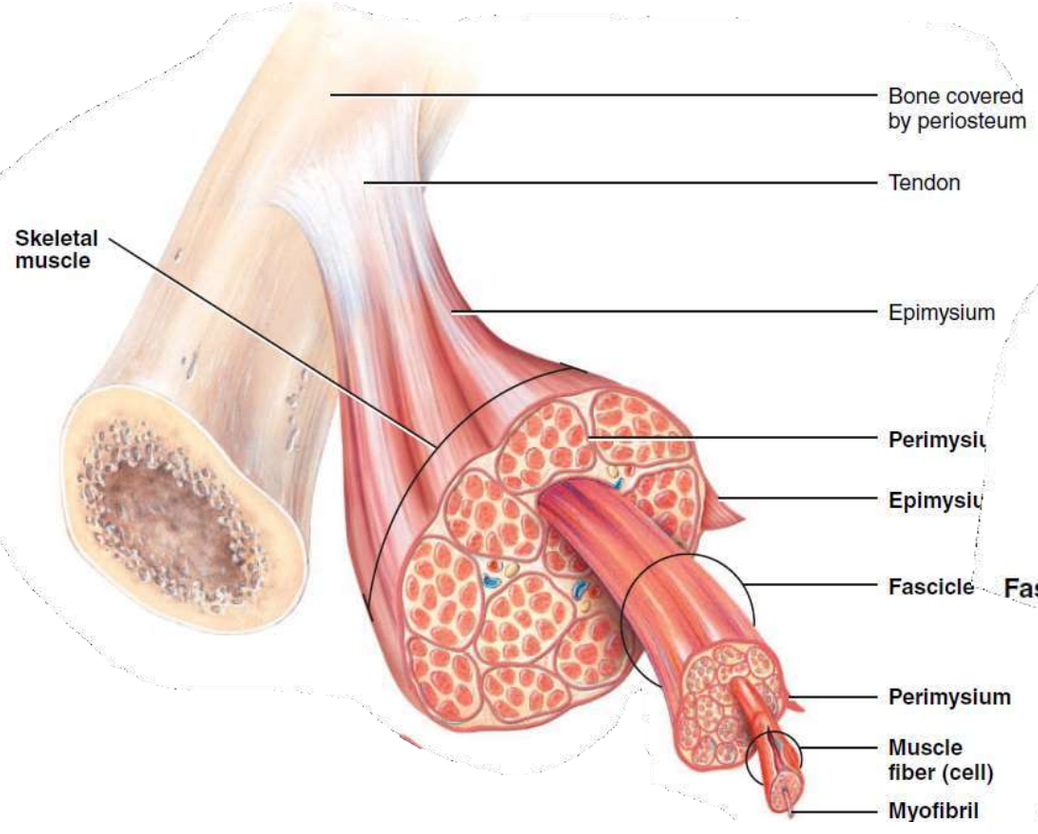
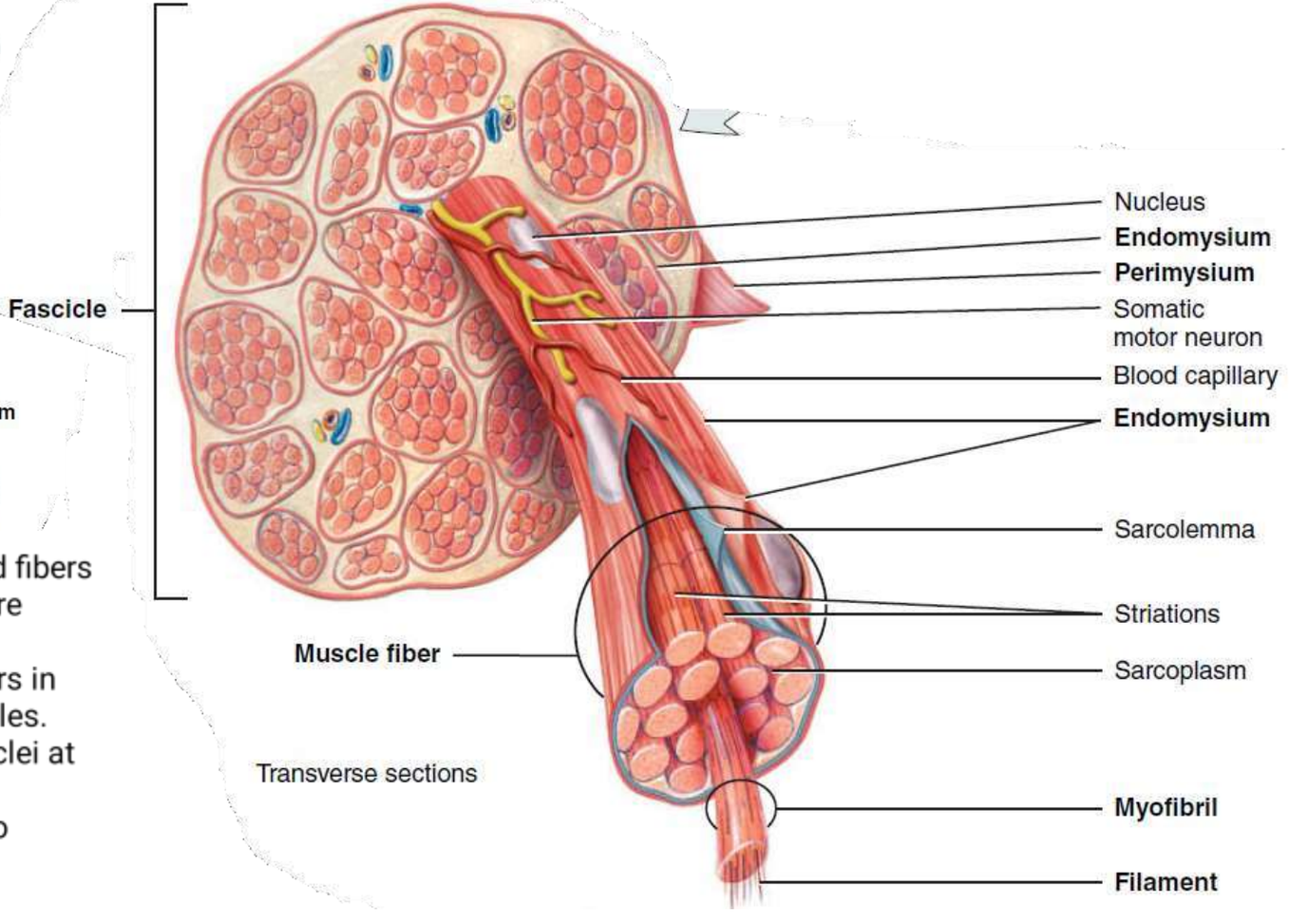
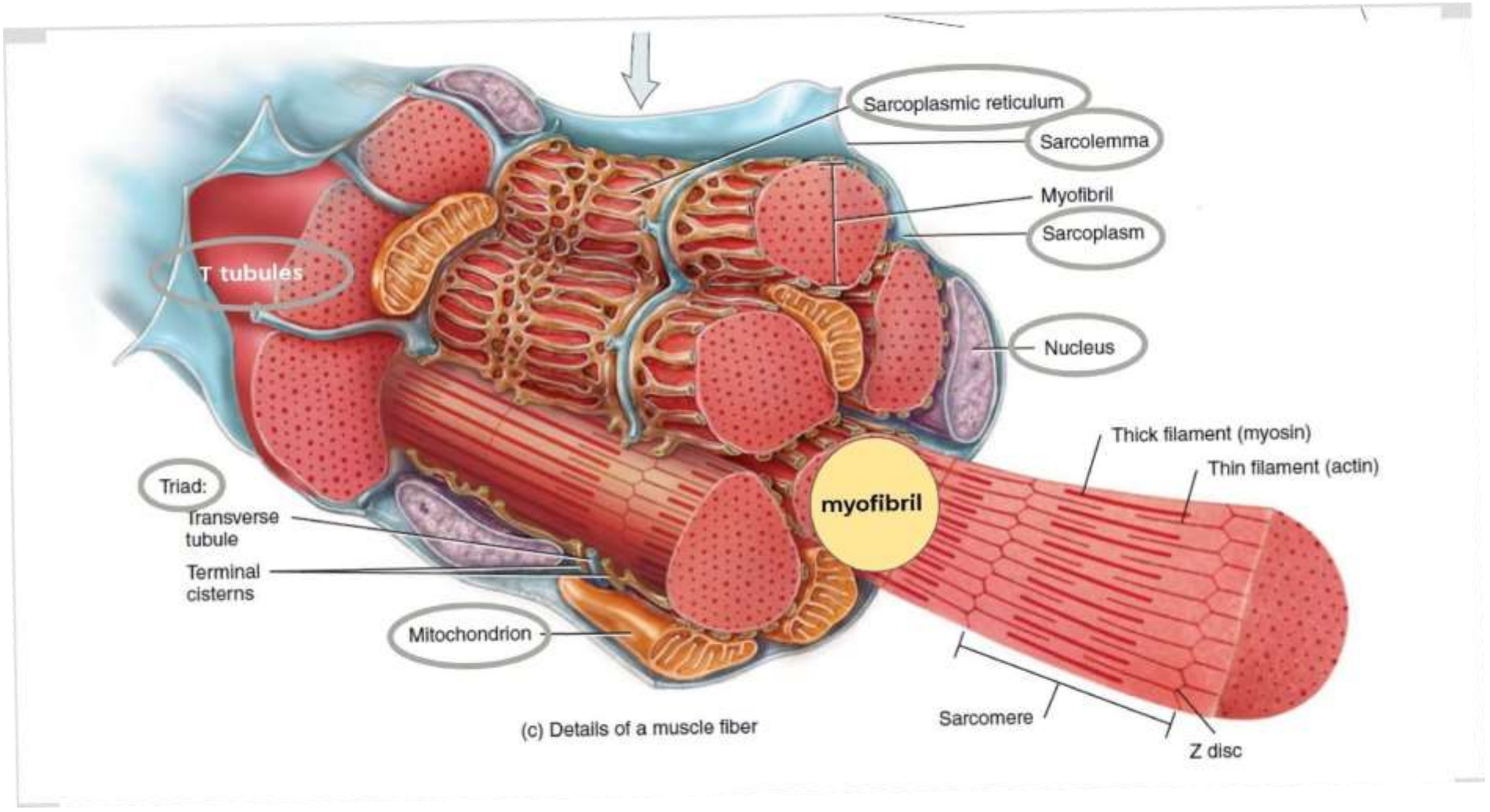




NOTE : Skeletal muscle tissue consists of long, cylindrical, striated fibers (striations are alternating light and dark bands within fibers that are visible under a light microscope).
Skeletal muscle fibers vary greatly in length, from a few centimeters in short muscles to 30–40 cm (about 12–16 in.) in the longest muscles.
A muscle fiber is a roughly cylindrical, multinucleated cell with nuclei at the periphery.
Skeletal muscle is considered voluntary because it can be made to contract or relax by conscious control.
Location: Usually attached to bones by tendons.
Function: Motion, posture, heat production, protection.



NOTE : The sarcolemma consists of a true cell membrane, called the plasma membrane, and an outer coat made up of a thin layer of polysaccharide material that contains numerous thin collagen fibrils. At each end of the muscle fiber, this surface layer of the sarcolemma fuses with a tendon fiber. The tendon fibers, in turn, collect into bundles to form the muscle tendons that then connect the muscles to the bones.

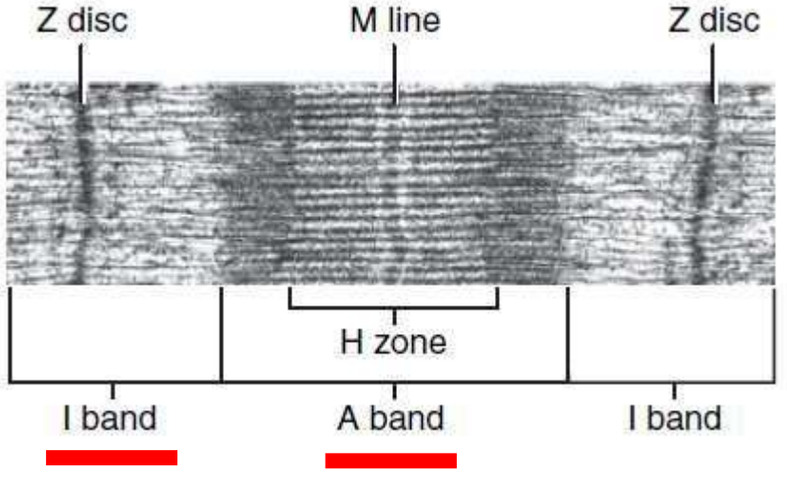
The spaces between the myofibrils are filled with intracellular fluid called sarcoplasm, containing large quantities of potassium, magnesium, and phosphate, plus multiple protein enzymes.

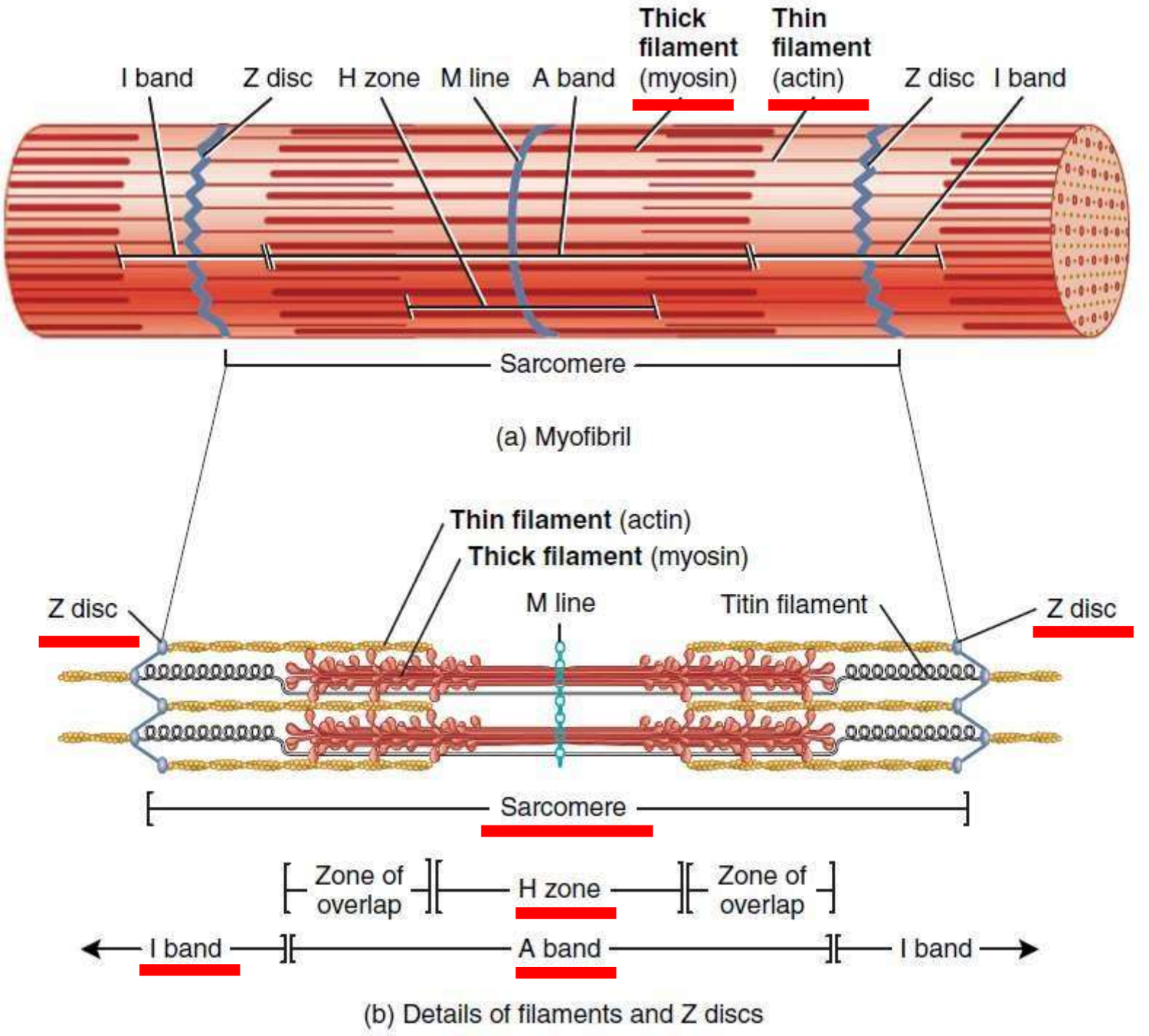
There is tremendous numbers of mitochondria that lie parallel to the myofibrils. These mitochondria supply the contracting myofibrils with large amounts of energy in the form of adenosine triphosphate (ATP) formed by the mitochondria.

Sarcoplasmic reticulum has a special organization that is extremely important in regulating calcium storage, release, reuptake and therefore muscle contraction

**Each muscle fiber contains several hundred to several thousand myofibrils.

myofibril


Z disc
M line
Z disc
H zone
I band
A band
I band

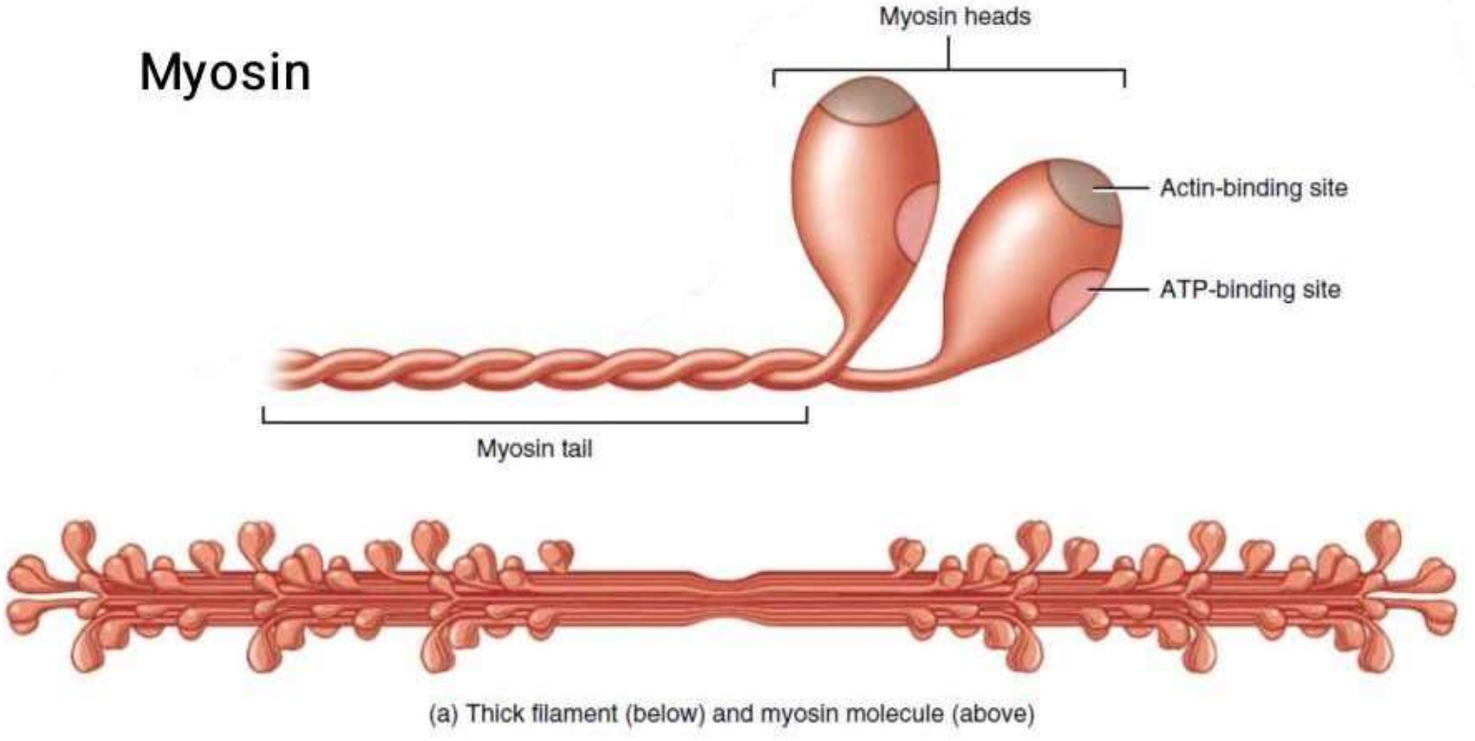

Thick filament (myosin)
Thin filament (actin)
I band
Z disc
H zone
M line
A band
Z disc
I band
Sarcomere
(a) Myofibril
Thin filament (actin)
Thick filament (myosin)
Z disc
M line
Titin filament
Z disc
Sarcomere
Zone of overlap
H zone
Zone of overlap
I band
A band
I band
(b) Details of filaments and Z discs

Note for previous slide

NOTe:Each muscle fiber contains several hundred to several thousand myofibrils.
** Each myofibril is composed of about 1500 adjacent myosin filaments and 3000 actin filaments, which are large polymerized protein molecules that are responsible for the muscle contraction.
** The light bands contain only actin filaments and are called I bands because they are isotropic to polarized light.
** The dark bands contain myosin filaments, as well as the ends of the actin filaments, where they overlap the myosin, and are called A bands because they are anisotropic to polarized light
** sarcomere, which is the functional unit of skeletal muscle. A functional unit of any organ is the smallest component that can perform all functions of that organ.

Contractile Proteins

Myosin



(a) Thick filament (below) and myosin molecule (above)

NOTE :Each thick filament has several hundred myosin molecules packed together in a specific arrangement.

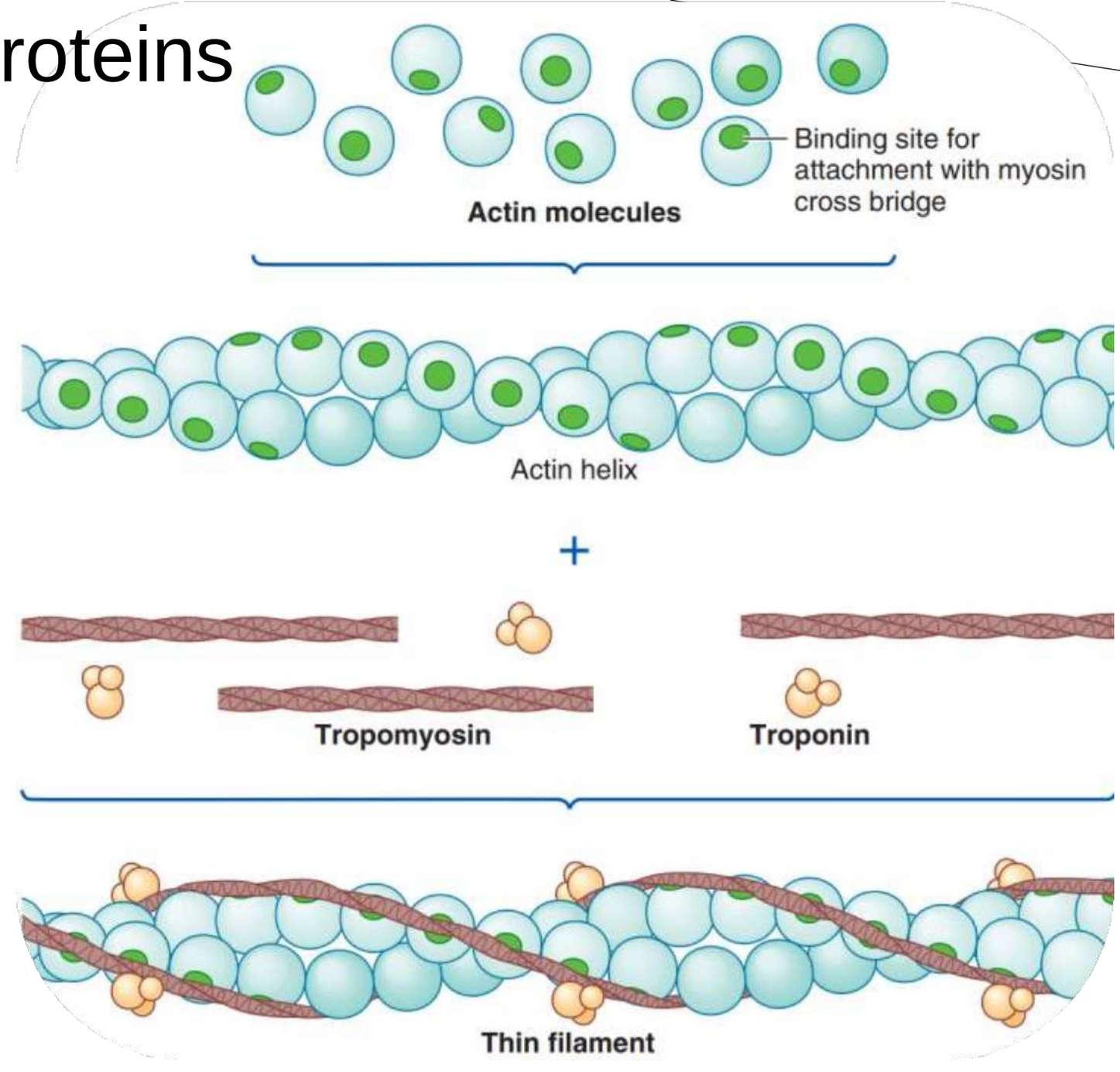
** A myosin molecule is a protein consisting of two identical subunits (head and tail).

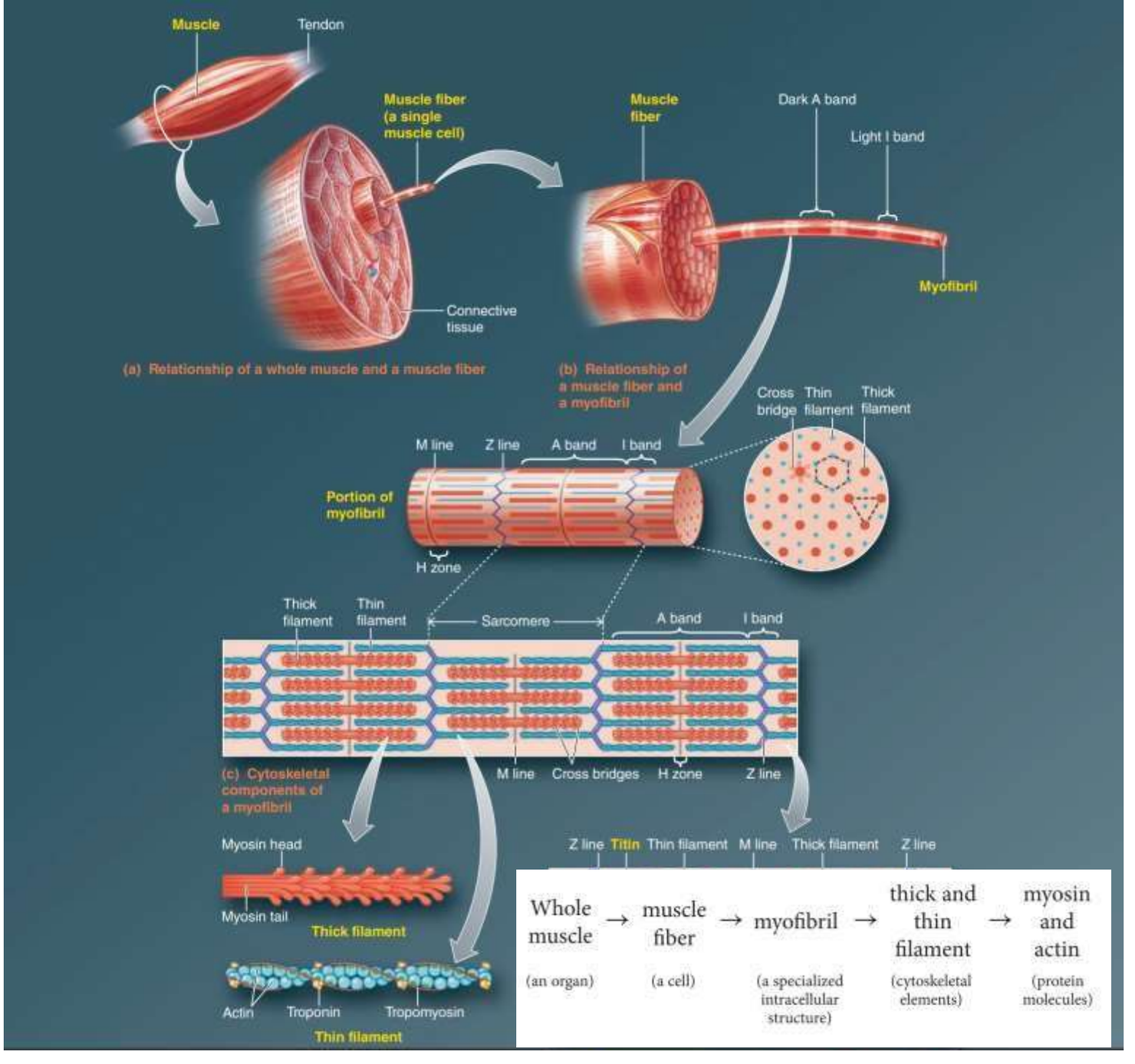
** The two myosin heads of each myosin molecule act independently, with only one head attaching to actin at a given time.

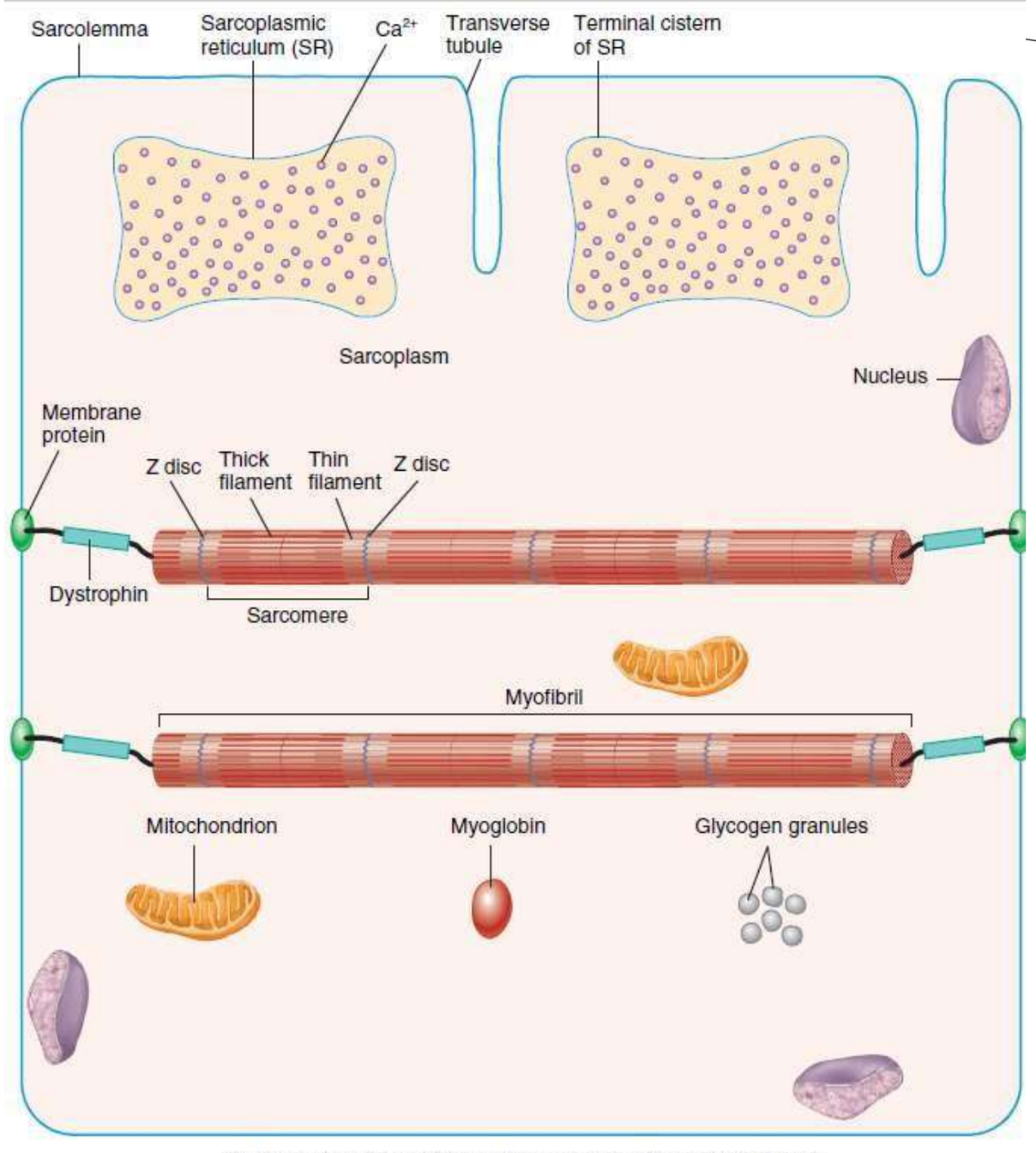
Contractile Proteins

Actin

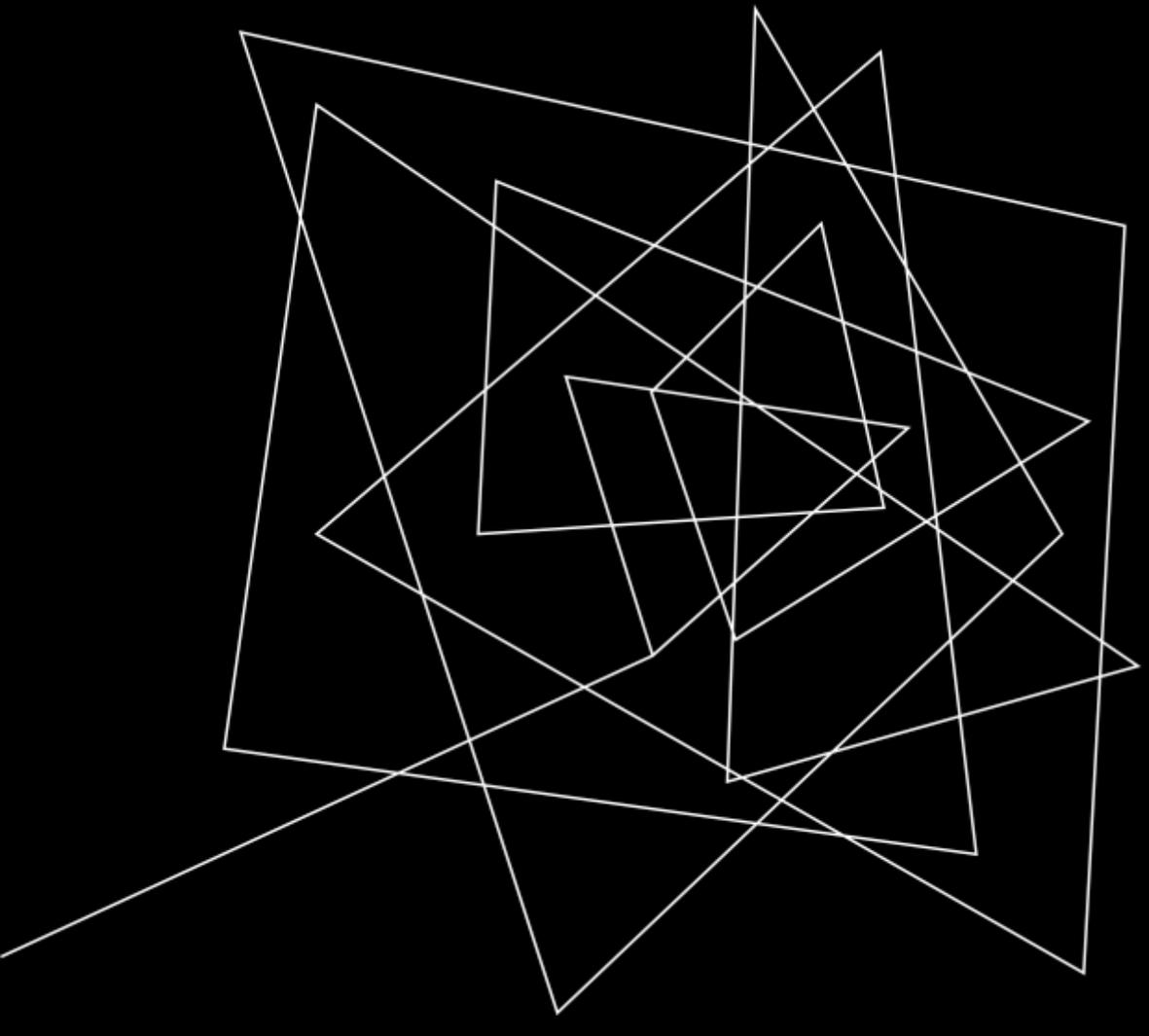
NOTE :Thin filaments consist of three proteins: actin, tropomyosin, and troponin.




Muscle
Tendon
Muscle fiber (a single muscle cell)
Muscle fiber
Dark A band
Light I band
Myofibril
Connective tissue
(a) Relationship of a whole muscle and a muscle fiber
(b) Relationship of a muscle fiber and a myofibril
Cross bridge
Thin filament
Thick filament
M line
Z line
A band
I band
Portion of myofibril
H zone
Thick filament
Thin filament
Sarcomere
A band
I band
(c) Cytoskeletal components of a myofibril
M line
Cross bridges
H zone
Z line
Myosin head
Myosin tail
Thick filament
Actin
Troponin
Tropomyosin
Thin filament
Z line
Titin
Thin filament
M line
Thick filament
Z line
Whole muscle (an organ) → muscle fiber (a cell) → myofibril (a specialized intracellular structure) → thick and thin filament (cytoskeletal elements) → myosin and actin (protein molecules)



(d) Simplistic representation of the components of a muscle fiber

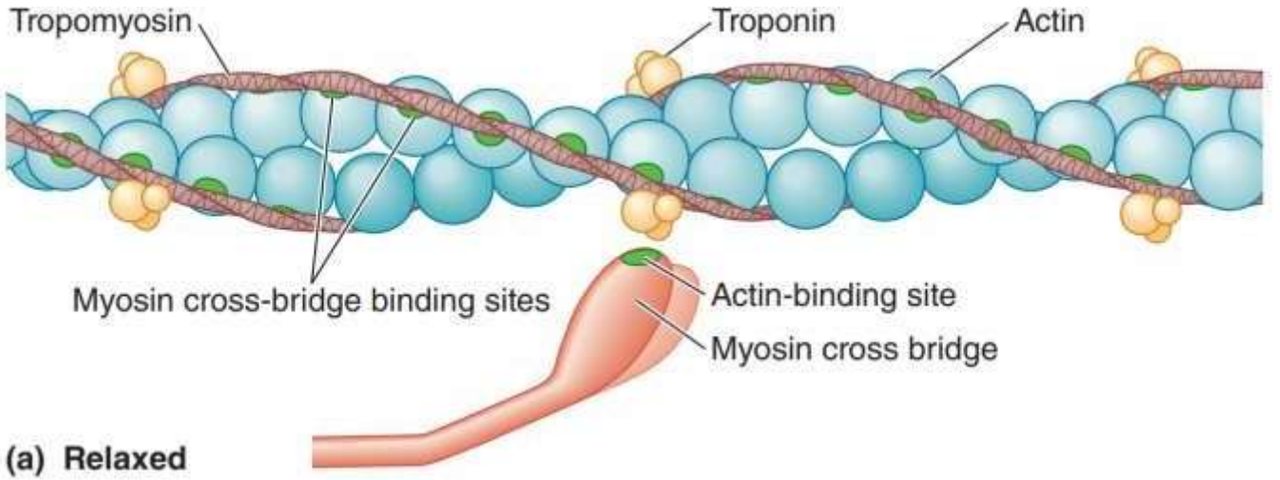


SKELETAL MUSCLE

Molecular Basis of Skeletal Muscle Contraction

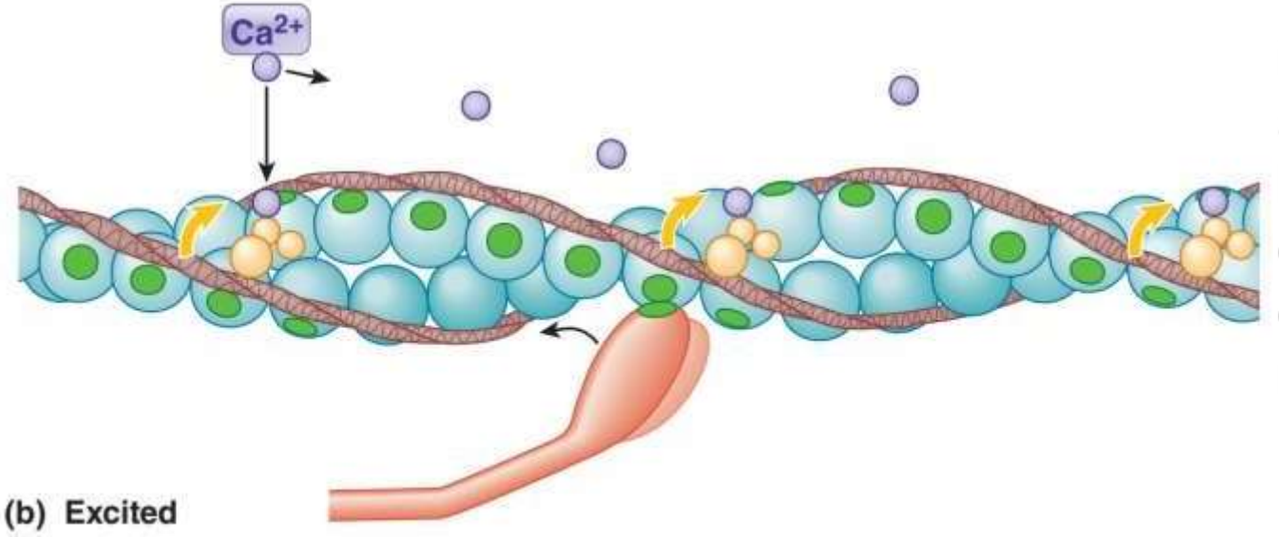
sliding filaments

Cross-bridging



(a) Relaxed

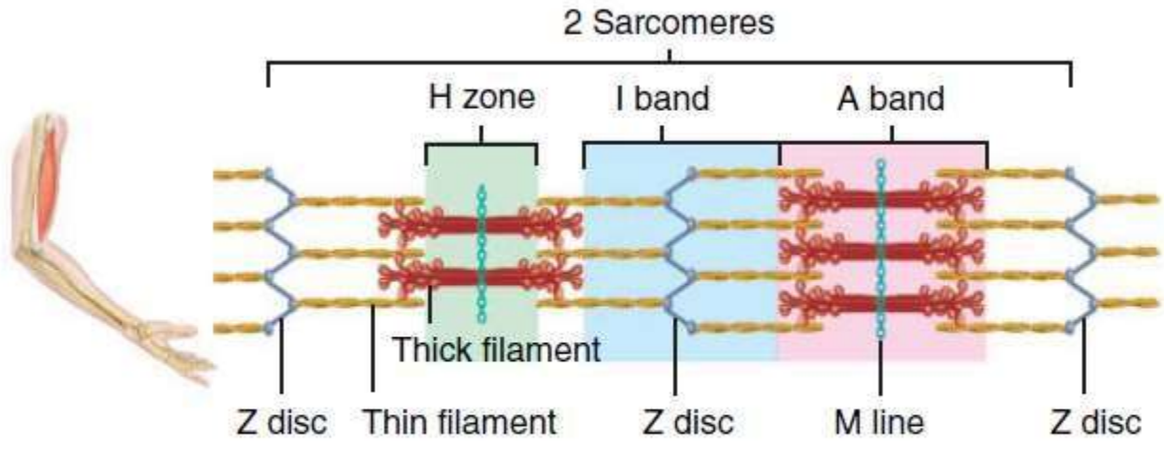
1. No excitation.
2. No cross-bridge binding because cross-bridge binding site on actin is physically covered by troponin–tropomyosin complex.
3. Muscle fiber is relaxed.



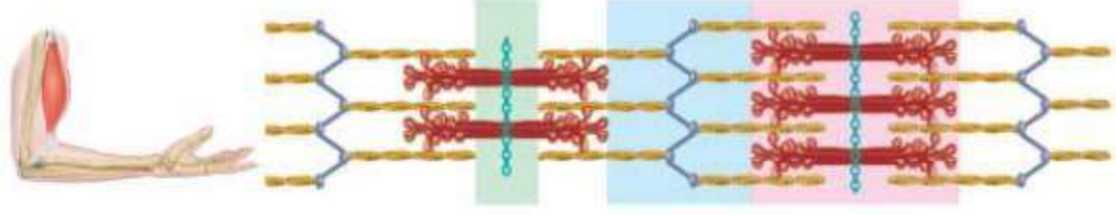
(b) Excited

NOTE : Cross-bridge interaction between actin and myosin brings about muscle contraction by means of the sliding filament mechanism.

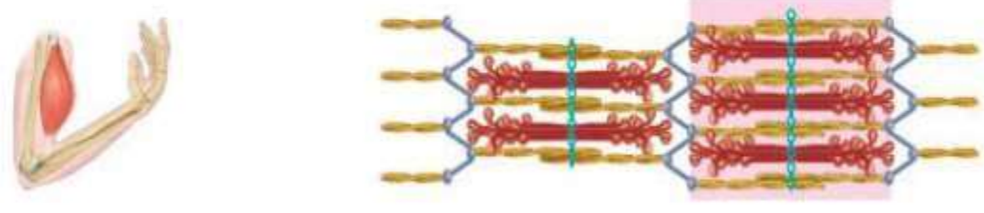
The Sliding Filament Mechanism



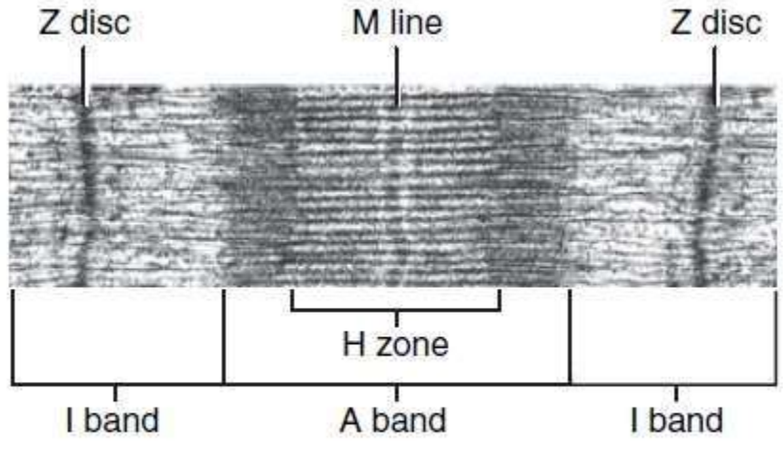
(a) Relaxed muscle

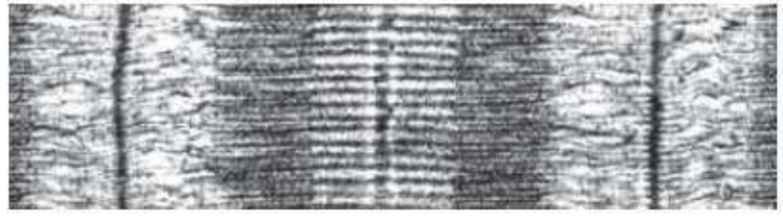


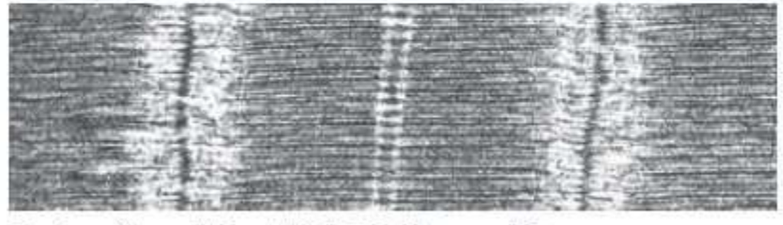
(b) Partially contracted muscle



(c) Maximally contracted muscle







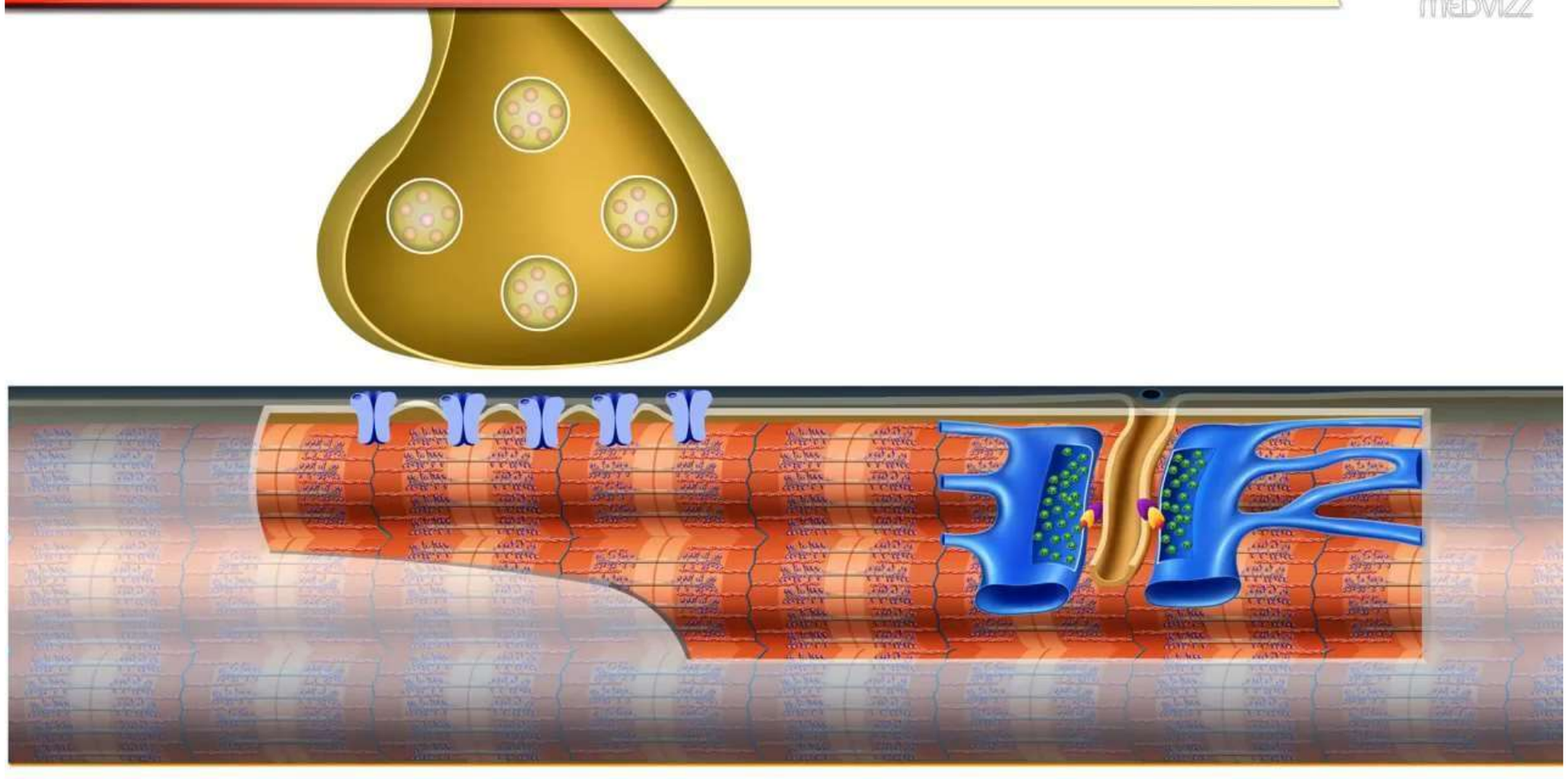
Courtesy Hiroyouki Sasaki, Yale E.Goldman and Clara Franzini-Armstrong

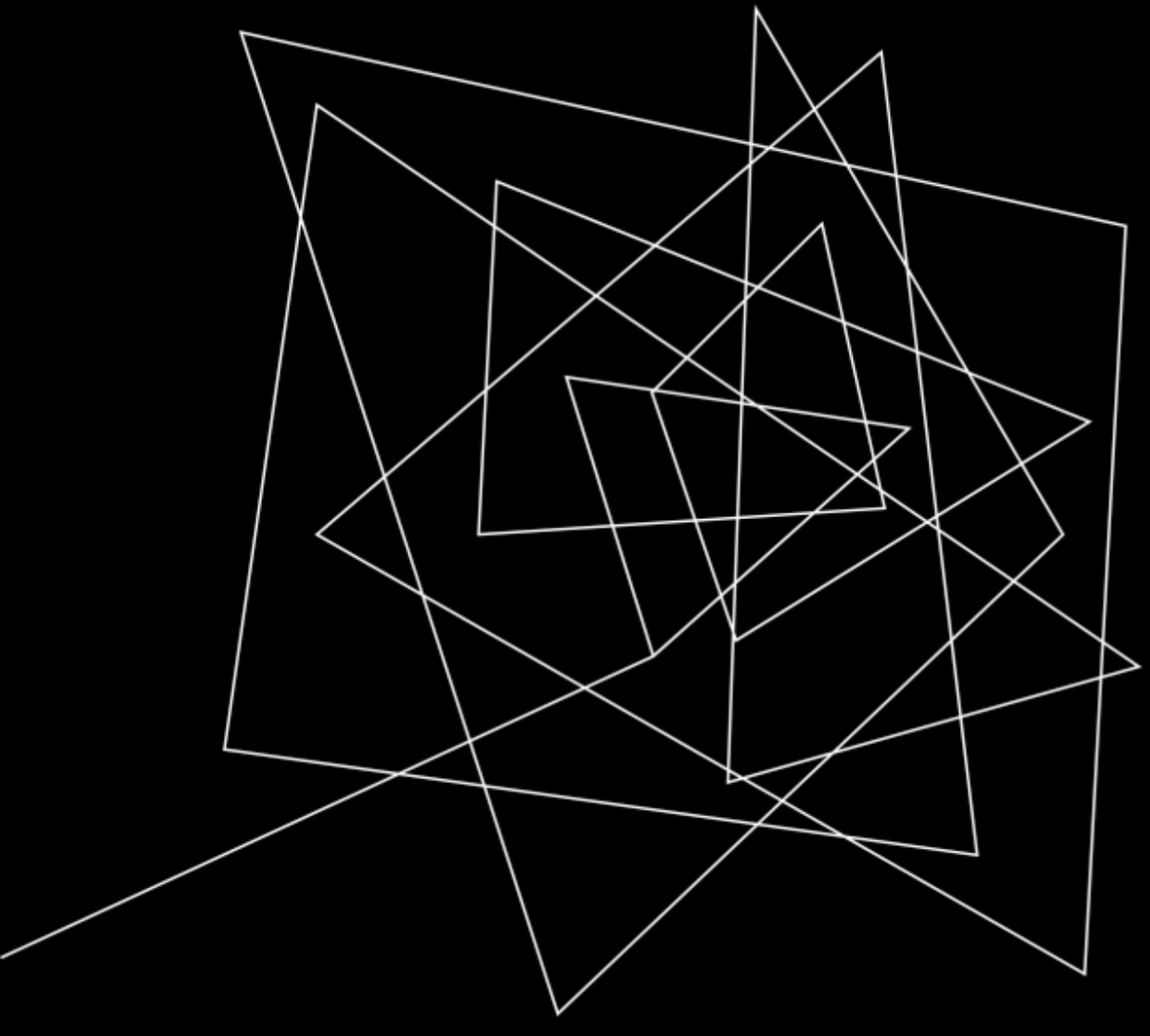
Note for previous slide

Muscle contraction occurs because myosin heads attach to and “walk” along the thin filaments at both ends of a sarcomere, progressively pulling the thin filaments toward the M line.
**As a result, the thin filaments slide inward and meet at the center of a sarcomere. They
may even move so far inward that their ends overlap.
**As the thin filaments slide inward, the I band and H zone narrow and eventually
disappear altogether when the muscle is maximally contracted
**Since the thin filaments on each side of the sarcomere are attached to Z discs, when the thin filaments
slide inward, the Z discs come closer together, and the sarcomere shortens.
**Shortening of the sarcomeres causes shortening of the whole
muscle fiber, which in turn leads to shortening of the entire muscle.
**Note that neither the thick nor the thin filaments decrease in length to shorten the sarcomere. Instead, contraction is accomplished by the thin filaments from the opposite sides of each sarcomere sliding closer together between the thick filaments.

Skeletal Muscle Contraction

Excitation Contraction Coupling

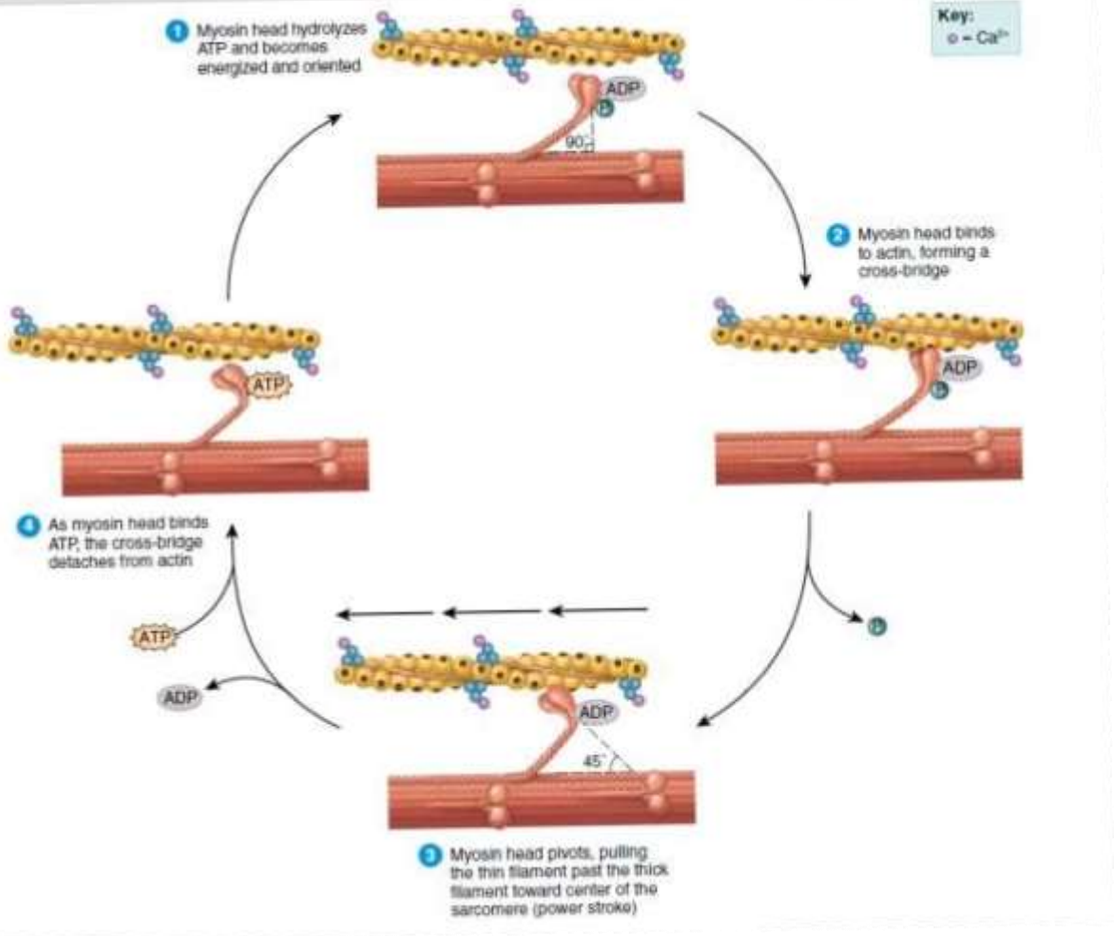




SKELETAL MUSCLE

Contraction _ contraction cycle

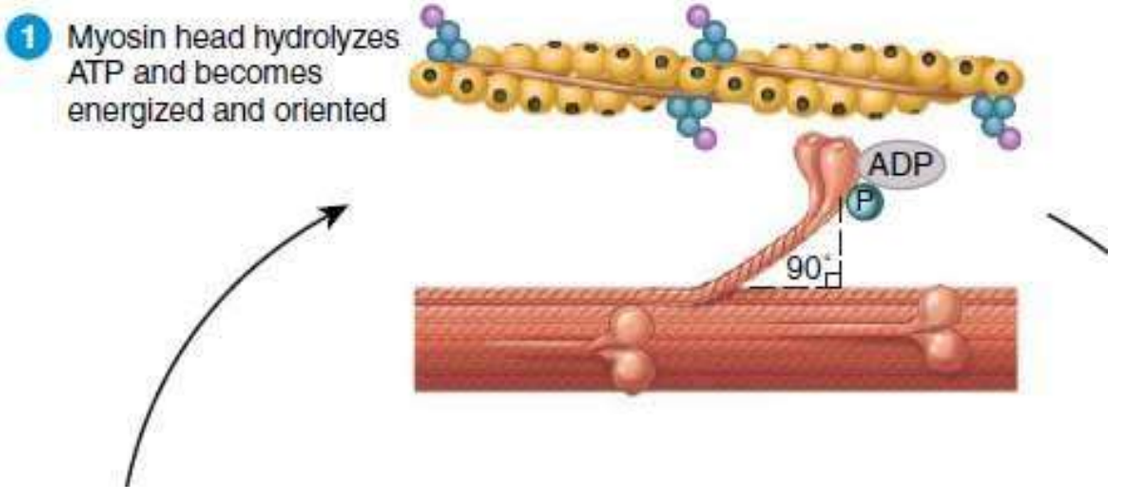
THE CONTRACTION CYCLE



NOTE: At the onset of contraction, the sarcoplasmic reticulum releases calcium ions (Ca2+) into the sarcoplasm. There, they bind to troponin. Troponin then moves tropomyosin away from the myosin-binding sites on actin. Once the binding sites are “free,” the contraction cycle—the repeating sequence of events that causes the filaments to slide—begins.

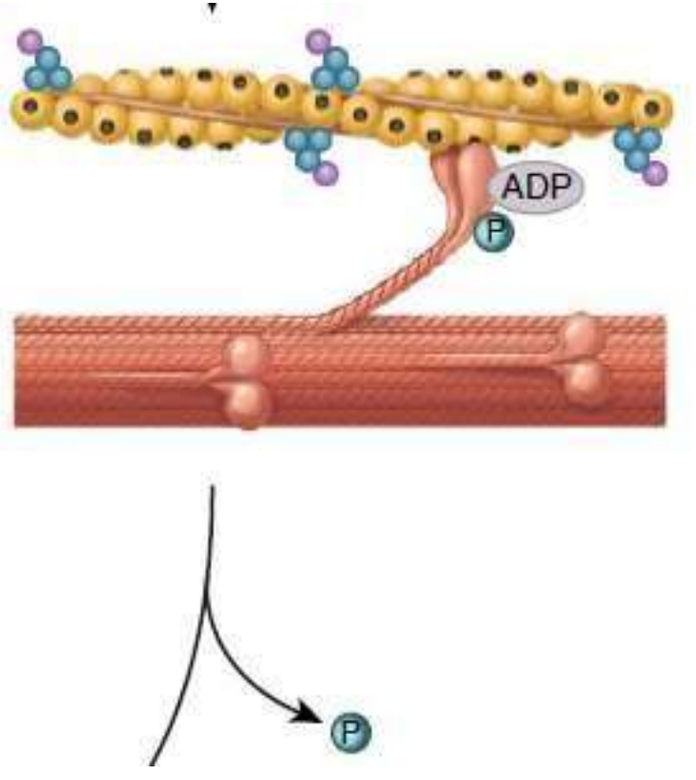
STEP 1: ATP HYDROLYSIS.

- The energy generated from ATP hydrolysis reaction is stored in the myosin head.
- The energized myosin head is perpendicular (at a 90° angle) relative to the thick and thin filaments and has the proper orientation to bind to an actin molecule.
- Notice that ADP and a phosphate group are still attached to the myosin head.



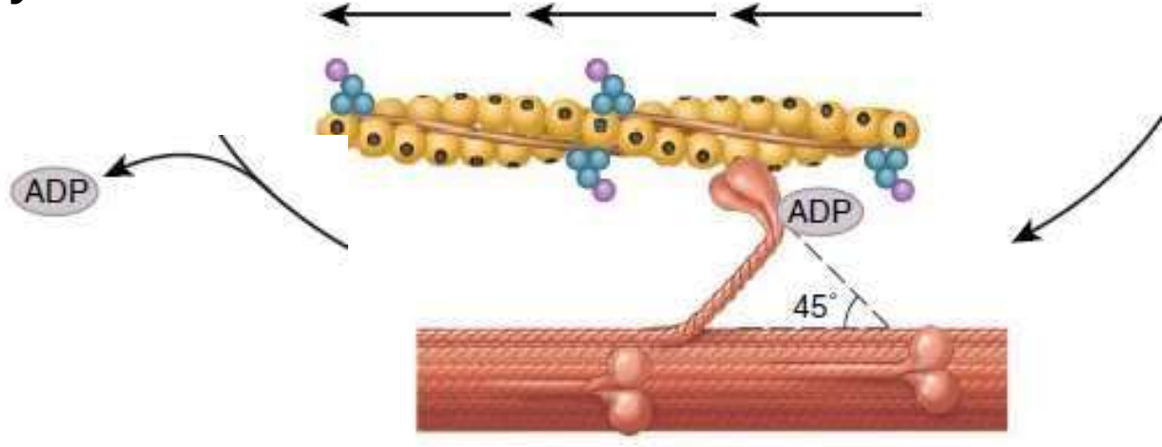
STEP 2: ATTACHMENT OF MYOSIN TO ACTIN

- The energized myosin head attaches to the myosin-binding site on actin and releases the phosphate group.
- When a myosin head attaches to actin during the contraction cycle, the myosin head is referred to as a **cross-bri**



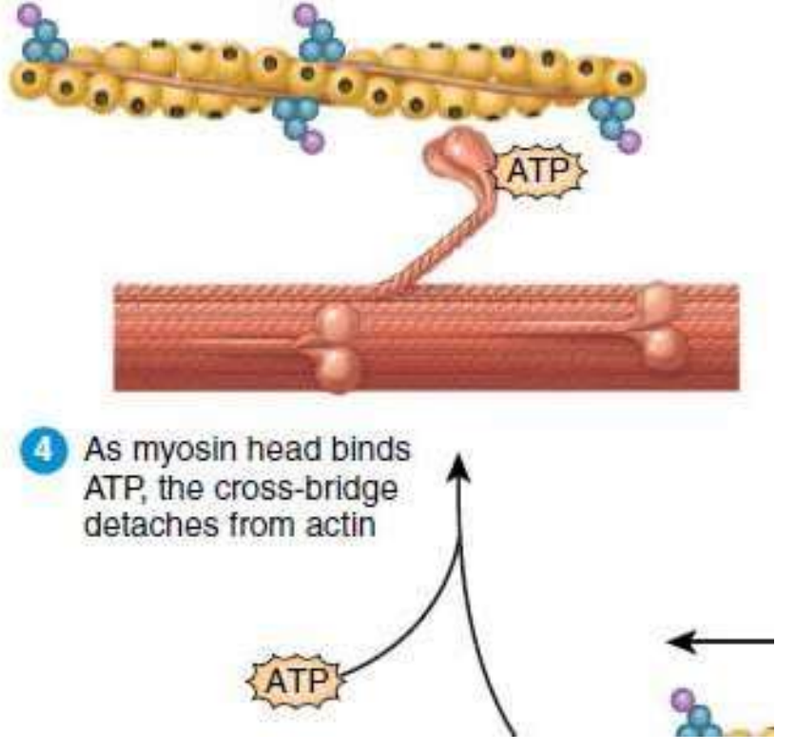
STEP 3: POWER STROKE

- After a cross-bridge forms, the myosin head pivots, changing its position from a 90° angle to a 45° angle.
- As the myosin head changes to its new position, it pulls the thin filament past the thick filament toward the center of the sarcomere, generating tension (force).
- This event is known as the **power stroke**.
- Once the power stroke occurs, ADP is released from the myosin he[illegible]



STEP 4: DETACHMENT OF MYOSIN FROM ACTIN

- At the end of the power stroke, the cross-bridge remains firmly attached to actin until it binds another molecule of ATP.
- As ATP binds to the ATP binding site on the myosin head, the myosin head detaches from actin

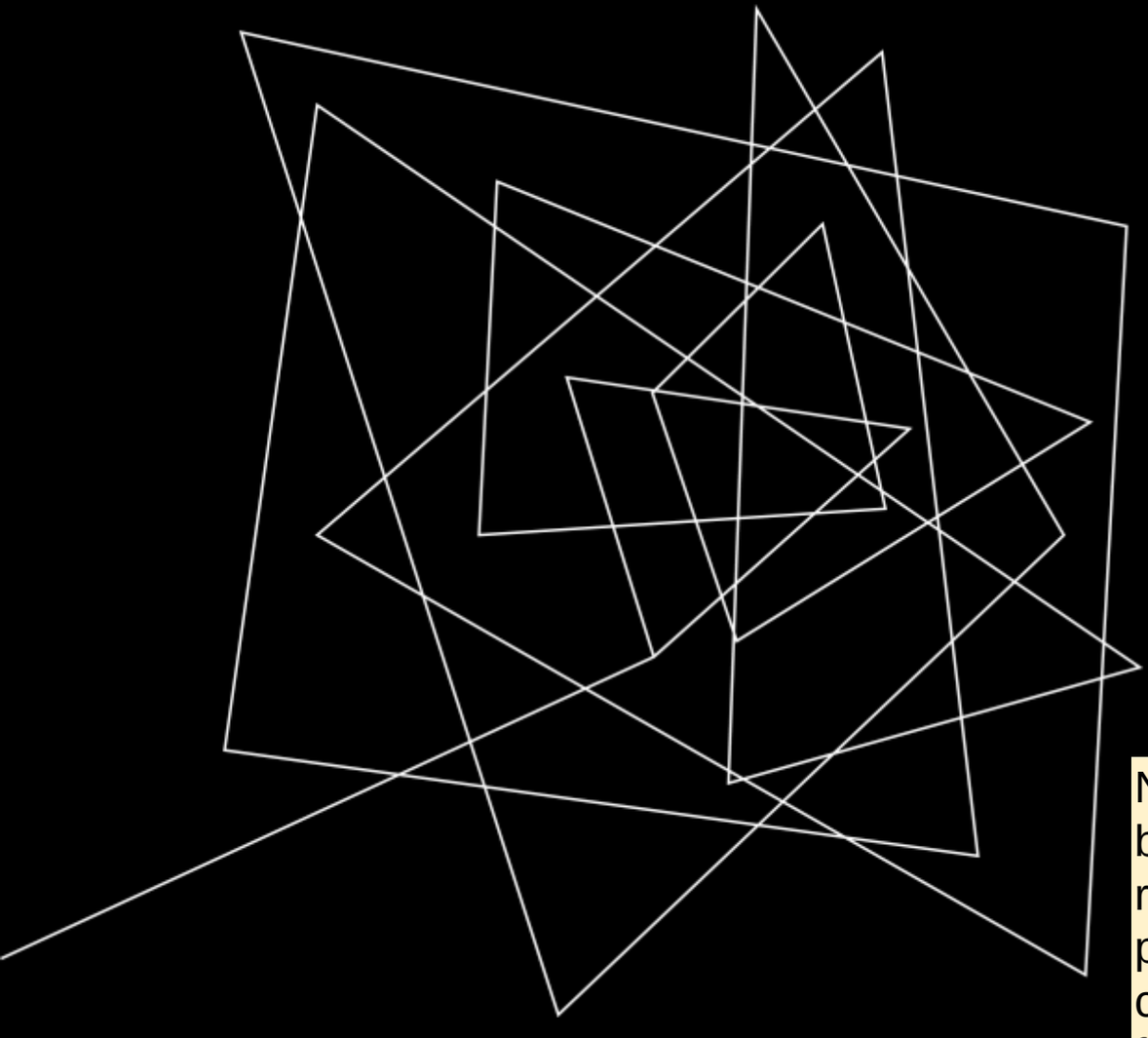


NOTE:

the contraction cycle repeats as the. myosi ATPase hydrolyzes. The newly bound molecule of ATP,and. continues as long as ATP as ATP is available and the ca2+ level near the. thin filament is sufficiently high.

Rigor Mortis (Rigidity of death)

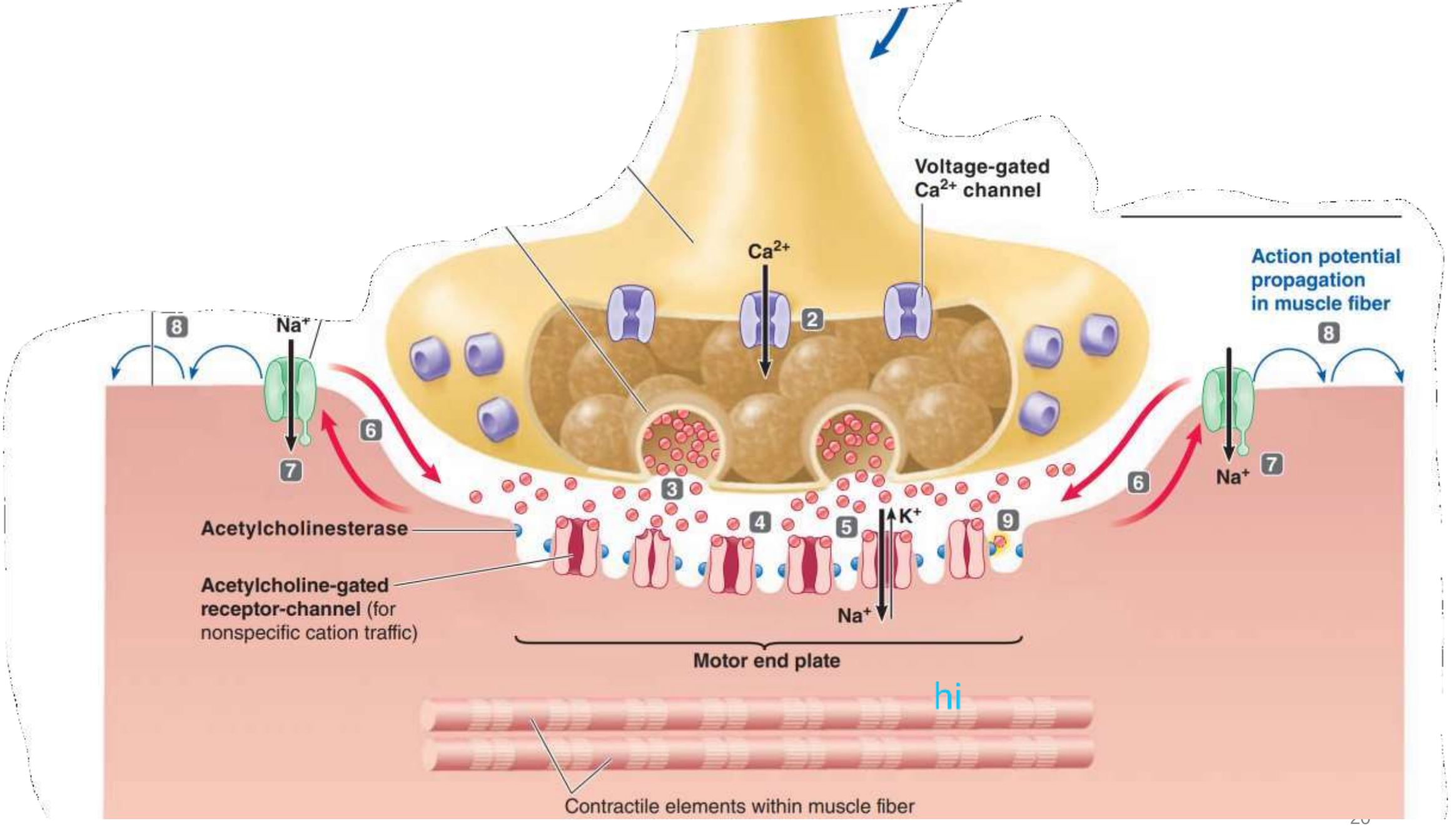
- A condition in which muscles are in a state of rigidity.
- Begins 3–4 hours after death and lasts about 24 hours.
- Explanation : after death, cellular membranes become leaky. Calcium ions leak out of the sarcoplasmic reticulum into the sarcoplasm and allow myosin heads to bind to actin.
- ATP synthesis ceases shortly after breathing stops, however, so the cross-bridges cannot detach from actin.
- It disappears as proteolytic enzymes from lysosomes digest the cross-bridges.

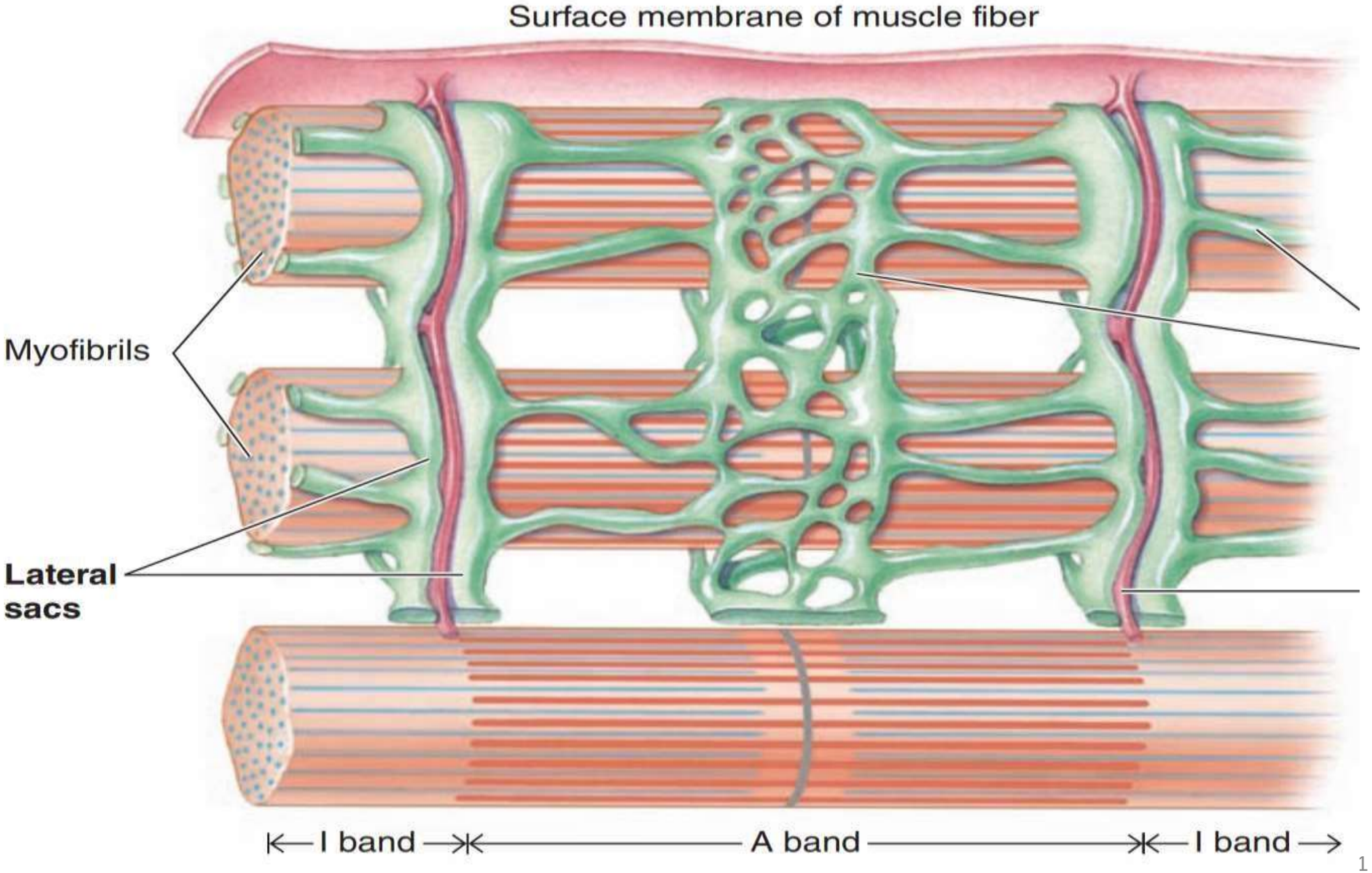


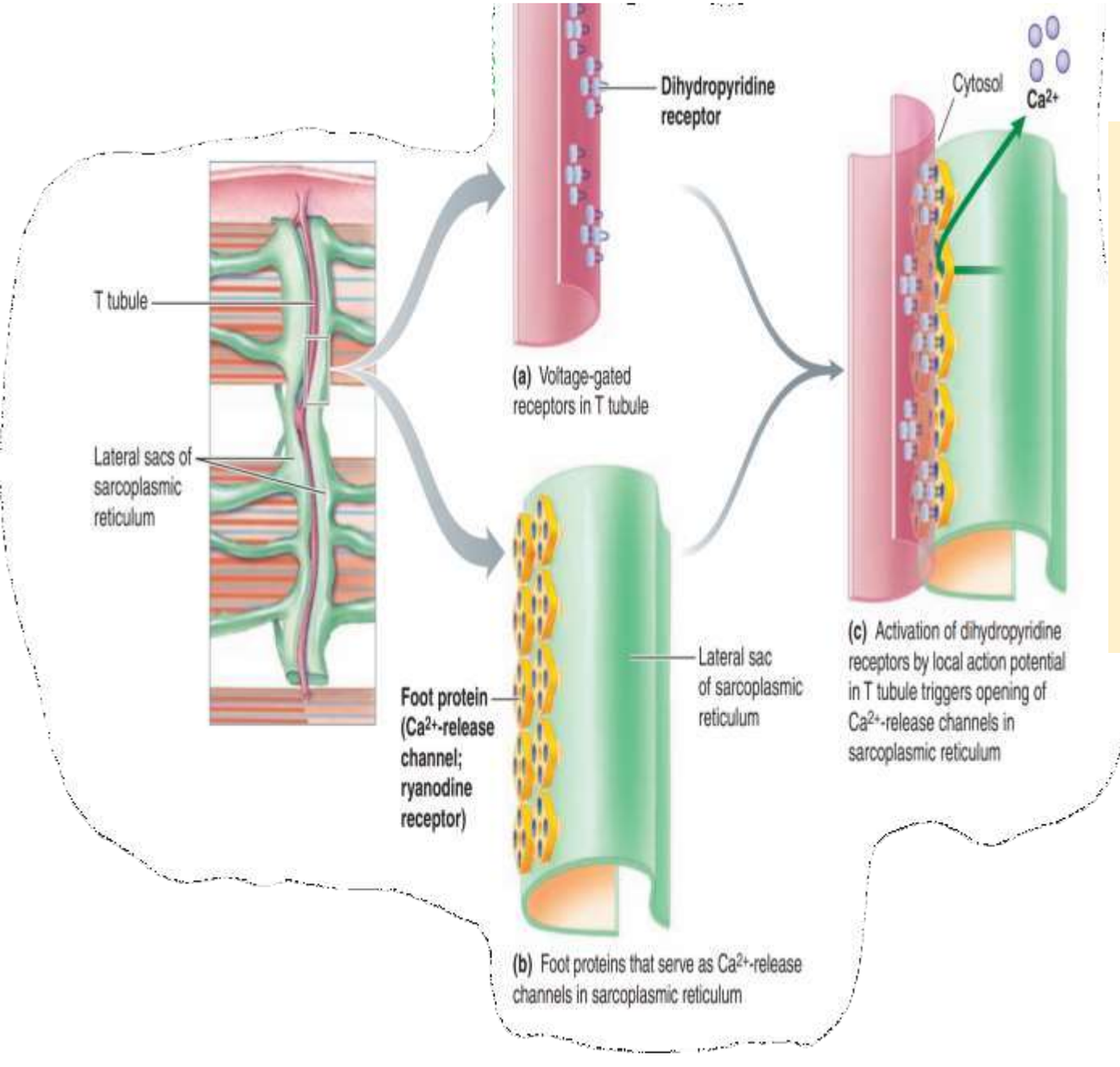
SKELETAL MUSCLE

Excitation–contraction coupling

NOTE: How does muscle excitation switch on this cross-bridge cycling? The term excitation–contraction coupling refers to the series of events linking muscle excitation (the presence of an action potential in a muscle fiber) to muscle contraction (cross-bridge activity that causes the thin filaments to slide closer together to produce sarcomere shortening).


Voltage-gated
Ca^{2+} channel
Ca^{2+}
2
Action potential
propagation
in muscle fiber
8
Na^+
8
6
7
3
4
5
K^+
9
6
Na^+
7
Acetylcholinesterase
Acetylcholine-gated
receptor-channel (for
nonspecific cation traffic)
Na^+
Motor end plate
hi
Contractile elements within muscle fiber

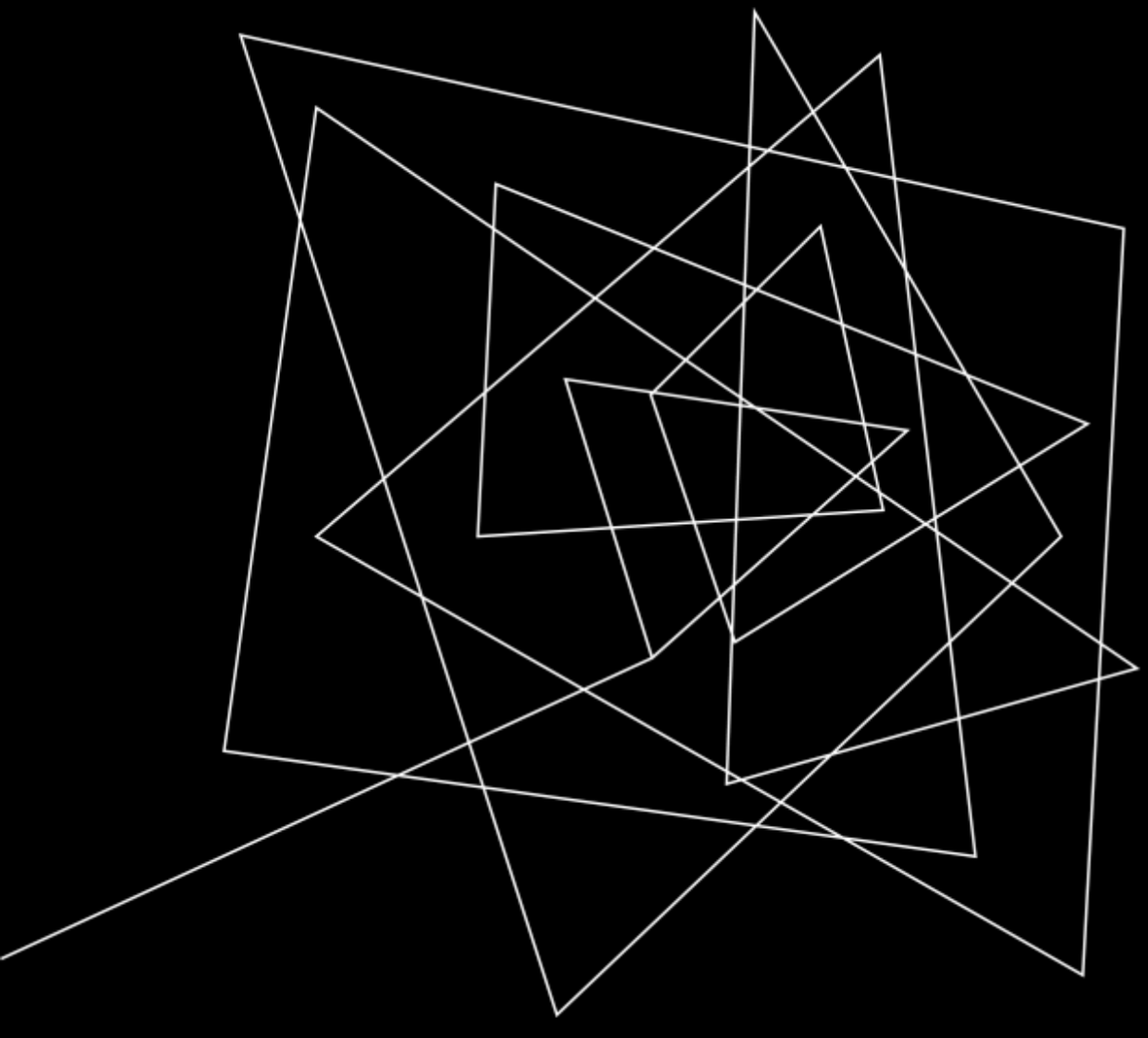

Surface membrane of muscle fiber
Myofibrils
Lateral sacs
I band
A band
I band



NOTE: T tubule membrane proteins known as dihydropyridine receptors serve as voltage sensors.

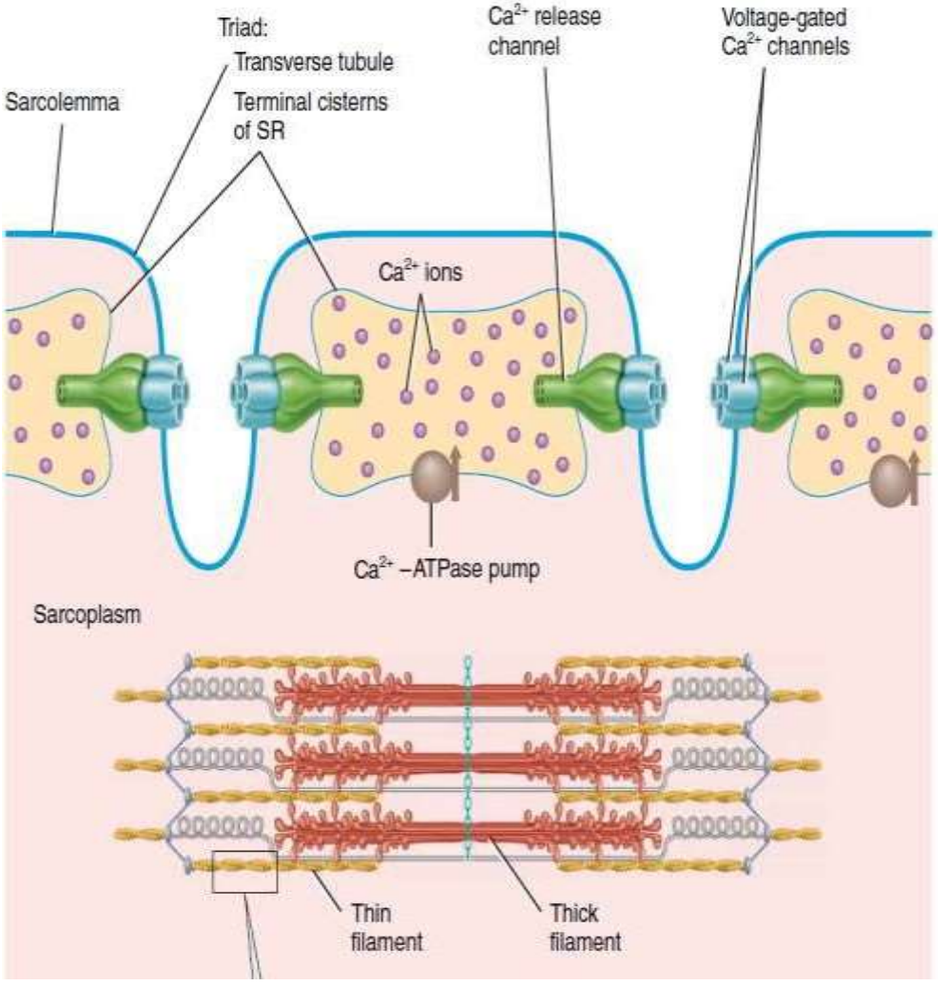
Local depolarization of the T tubules activates the dihydropyridine receptors, which in turn trigger the opening of directly abutting foot proteins (Ca-release channels or ryanodine receptors) in the adjacent lateral sacs.

When these Ca2 release channels are opened in the presence of a local action potential in the adjacent T tubule, Ca2 is released into the cytosol from the terminal cisternae.



SKELETAL MUSCLE

Relaxation



NOTE: The terminal cisternal membrane of the sarcoplasmic reticulum also contains **Ca2+-ATPase pumps** that use ATP to constantly
transport Ca2+ from the sarcoplasm into the SR . As long as muscle action potentials continue to propagate
along the T tubules, the Ca2+ release channels remain open and Ca2+ flows into the sarcoplasm faster than it is transported back into the SR by the Ca2+-ATPase pumps. After the last action potential has propagated throughout the T tubules, the Ca2+ release channels close. As the Ca2+-ATPase pumps move Ca2+ back
into the SR, the Ca2+ level in the sarcoplasm rapidly decreases.