Skeletal Muscle – Structure and Function

Human body: Has >400 voluntary sk. m., ~40-50% of total body wt.
It has 3 major functions: 1) Force generation for movement (most obvious function)
2) Force generation for postural support
3) Heat production during cold stress
Attached to bones: By tough connective tissue - tendons.

- One end attached to a bone that doesn't move (origin)
- Opposite end is fixed to a bone (insertion) that is moved in muscular contraction

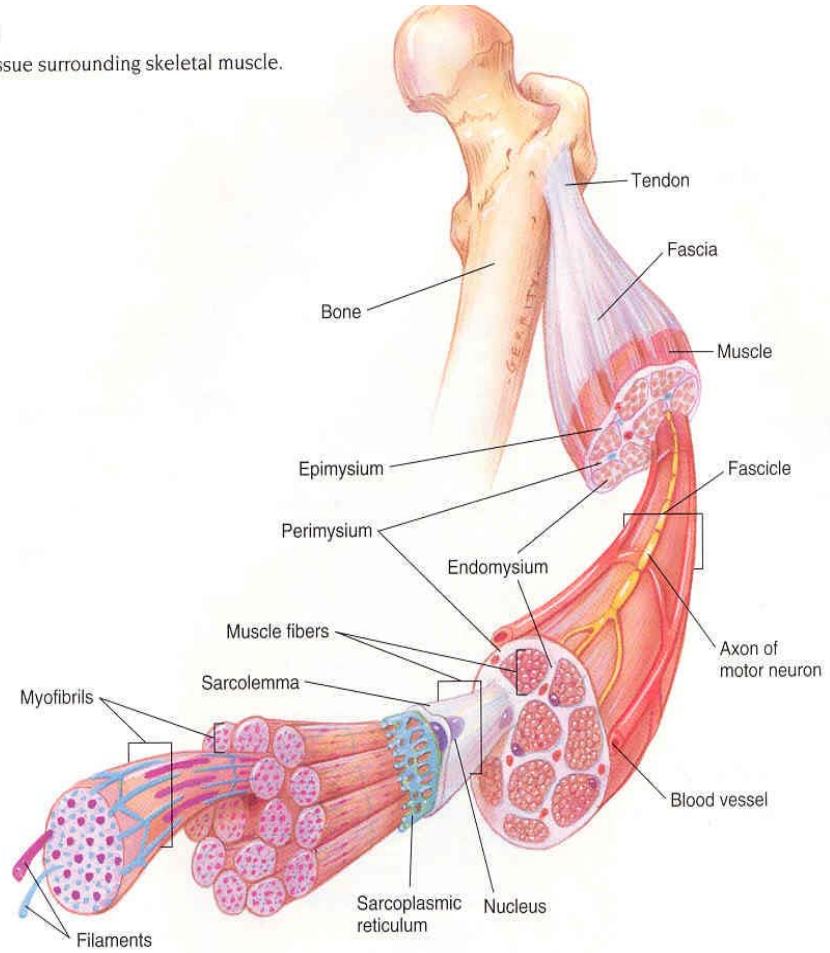
Different movements are possible: depending on type of joint & muscles

- Muscles that ↓joint angles = Flexors
- Muscles that ↑joint angles = Extensors.

Structure

Different tissues: Muscle, nerve, blood & dif connective tissues.
Muscles are separated: They're held in position by layers of connective tissue (Fascia)
3 other layers (connective tissue)
Epimysium: Tissue around each sk m, between its fascia & m. cells
Perimysium: Surrounds each bundle of fibers (fasciculi)
Endomysium: Each fiber in fasciculus surrounded by this layer
Despite the shape, m. cells have same organelles like other cells, & they're multinucleated.

Figure 8.1
Connective tissue surrounding skeletal muscle.



Unique microscopy

Striated: Alternating light & dark bands across the fiber
Thin, elongated cylinder: usually extends the length of the muscle
Cell membrane = Sarcolemma
Inside: Sarcoplasm, with cellular proteins, organelles, myofibrils.
Myofibrils: Threadlike structures with contractile proteins:

- Thick filaments composed of protein myosin
- Thin filaments composed of protein actin
- Arrangement of these 2 filaments gives skeletal muscle its striated look
- On the actin molecules there're 2 other proteins - troponin & tropomyosin. They're small part of the muscle, but play major role in regulation of the contractile process
- Can be further subdivided to individual segments (sarcomeres)

Sarcomeres:

Divided from each other by a thin sheet of connective tissue = Z lines.
Myosin filaments- mainly in dark part of sarcomere (A band)
Actin filaments- mainly in lighter region (I band).
Actin overlap myosin filaments & also seen in A band.
In sarcomere's center there is part of myosin filament with no overlap of actin (H zone)
In sarcoplasm: Sarcoplasmic reticulum (SR) is a network of mem. channels that surround each myofibril & run parallel with it. Act as storage sites for calcium (major role in m. contraction)

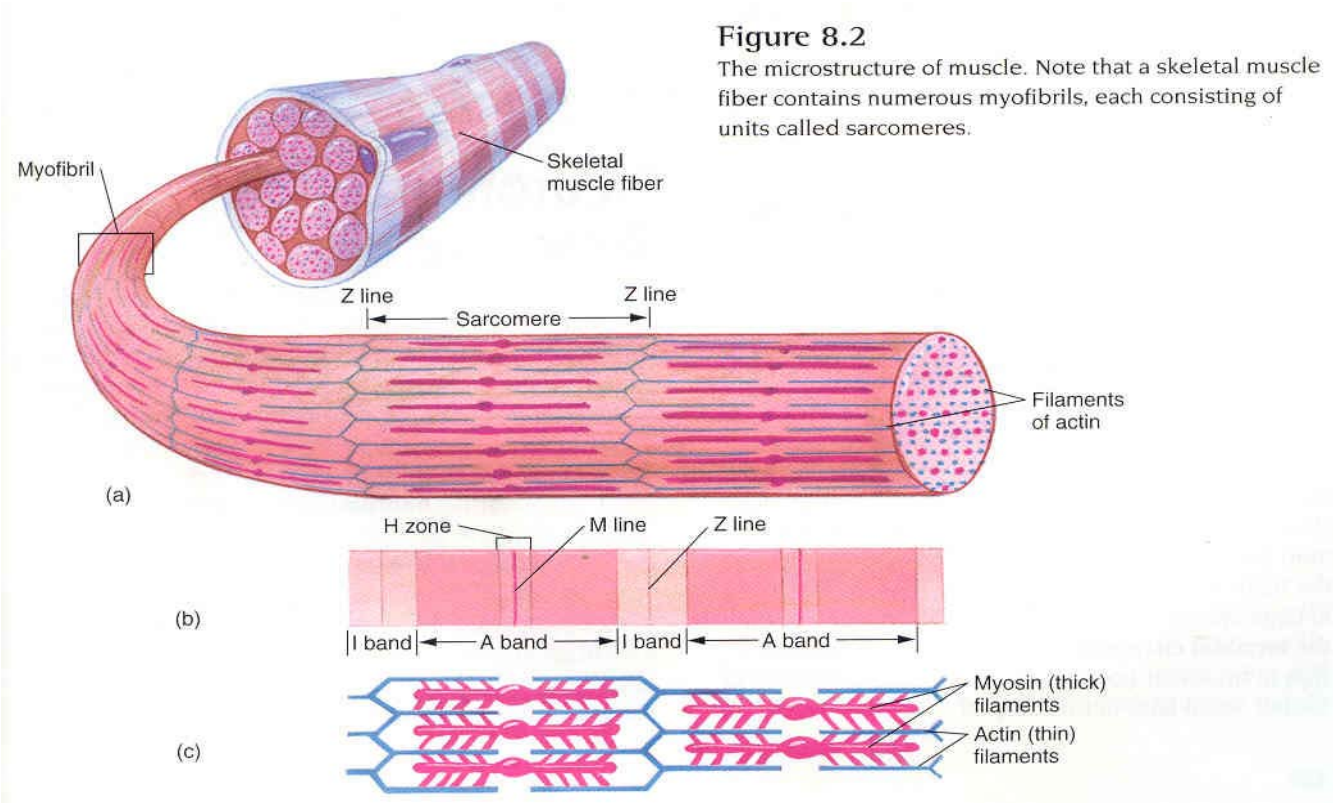
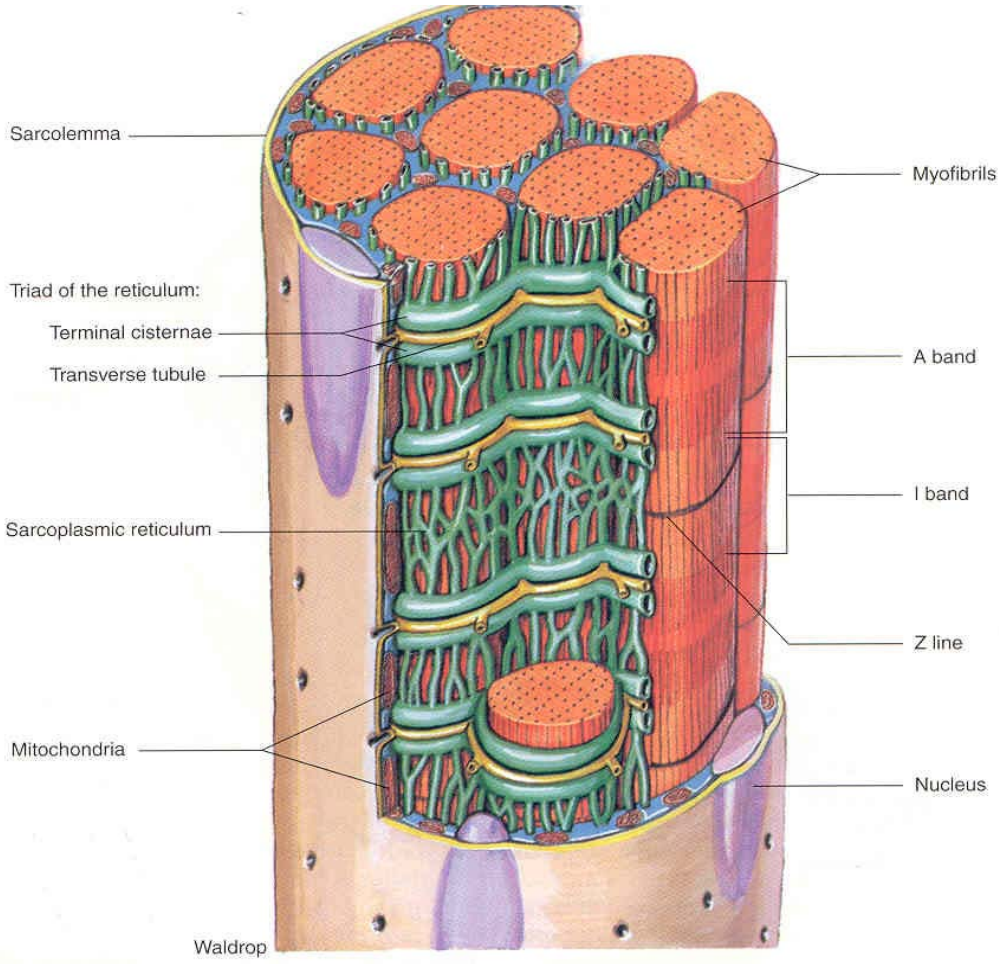


Figure 8.2
The microstructure of muscle. Note that a skeletal muscle fiber contains numerous myofibrils, each consisting of units called sarcomeres.

Transverse tubules

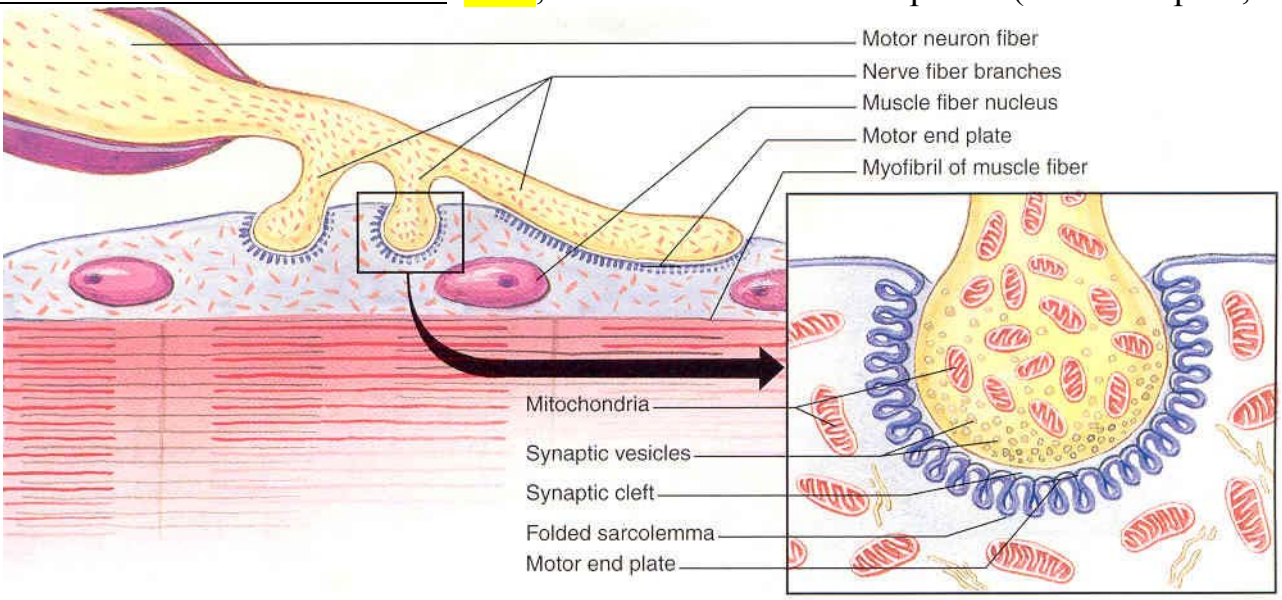
Set of membrane channels, from the sarcolemma inside, pass between 2 enlarged bags of SR = Terminal Cisternae, forming triad of reticulum
(TT + 2•TC)



Neuromuscular Junction (NMJ)

Each m. cell: Connected to nerve fiber branch (axon terminal) from nerve cell. These Motor neurons (MN) extend out of spinal cord, & with m. fibers they innervate, they're motor units

Site where MN & muscle cell meet: NMJ, where sarcolema forms a pocket (motor end plate, **MEP)**

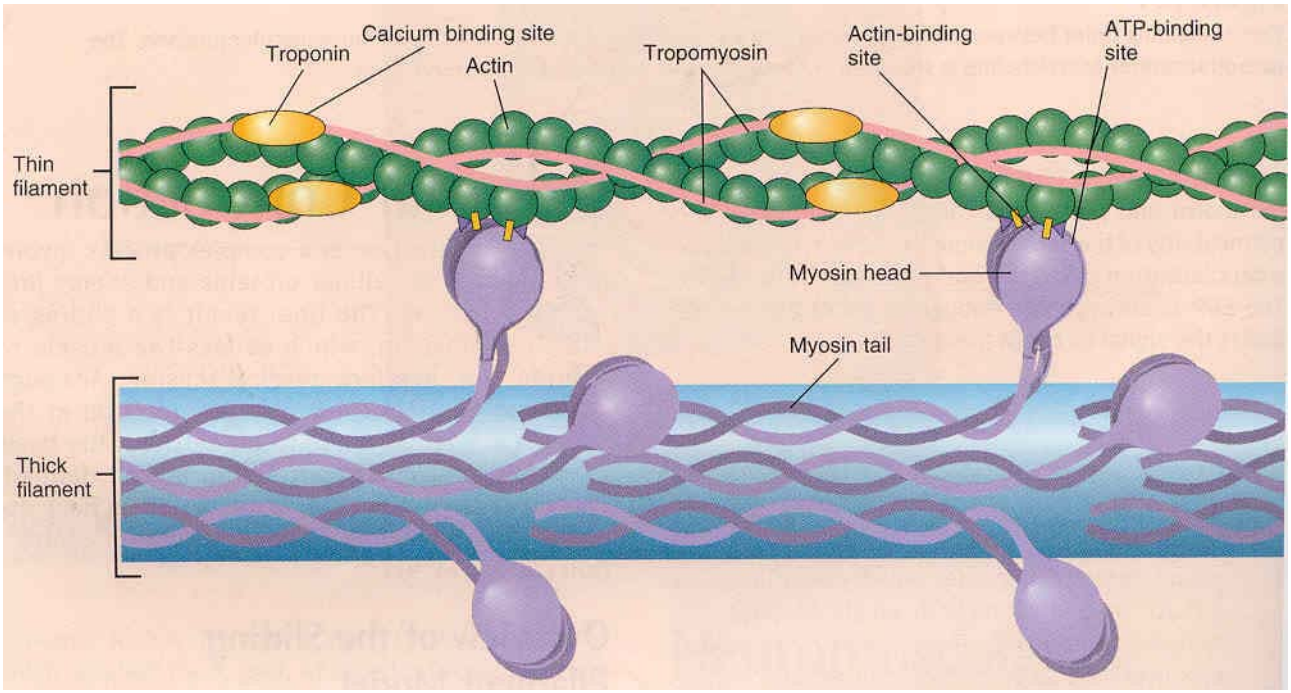


End of MN (axon terminal): separated form MEP by the NM cleft

- It ↑permeability of sarcolemma to Na^{+} ➔ Depolarization (End Plate Potential (EPP)

Contractile Process - Summary of Events

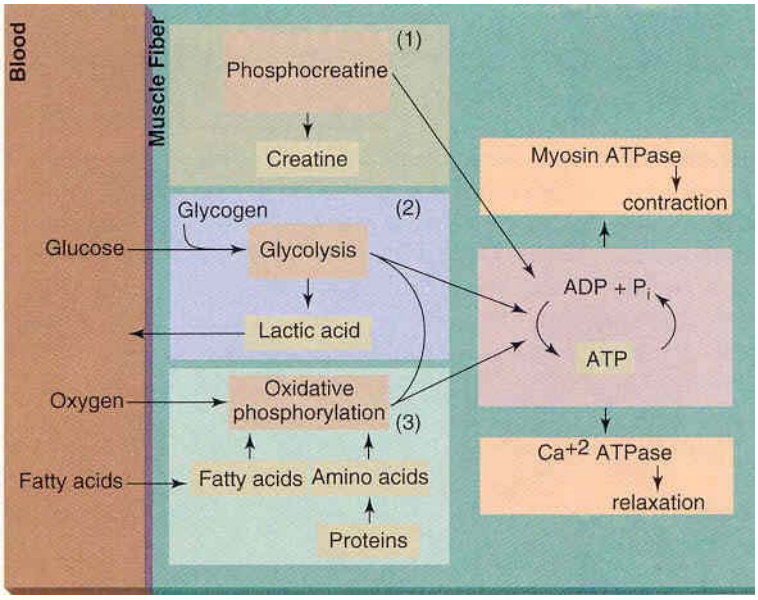
1. When AP reaches axon terminal, it releases Ach that cross the synaptic cleft & binds to its receptor
2. Accumulated Ach binding to MEP, produces EPP big enough to exceed threshold & leads to AP that are conducted down the transverse tubules, deep into the muscle fiber
3. When AP reaches TC, Ca^{+2} is released to sarcoplasm & binds to troponin. That causes a shift in position of tropomyosin to uncover "active sites" on actin.
4. The "cocked" myosin cross-bridge attaches to active site on actin & pulls it over the myosin
5. Attaching "fresh" ATP to myosin cross-bridges allows the cross-bridge to detach from actin
6. ATP is broken to ADP + Pi + E, & released E that is used to "cock" the myosin cross-bridges
7. This cycle is repeated as long as Ca^{+2} is present. When AP stops, SR removes Ca^{+2} from sarcoplasm & tropomyosin moves to its inhibitory position - covering active sites on actin.



Excitation-contraction coupling = Sequence where AP reaches m. membrane & leads to muscle shortening by cross-bridges activity.

E of Contraction: ATP hydrolysis by myosin ATPase (myosin head) energizes myosin cross-bridges, allowing the release of these heads & further pulling of actin over myosin, to shorten the muscle.

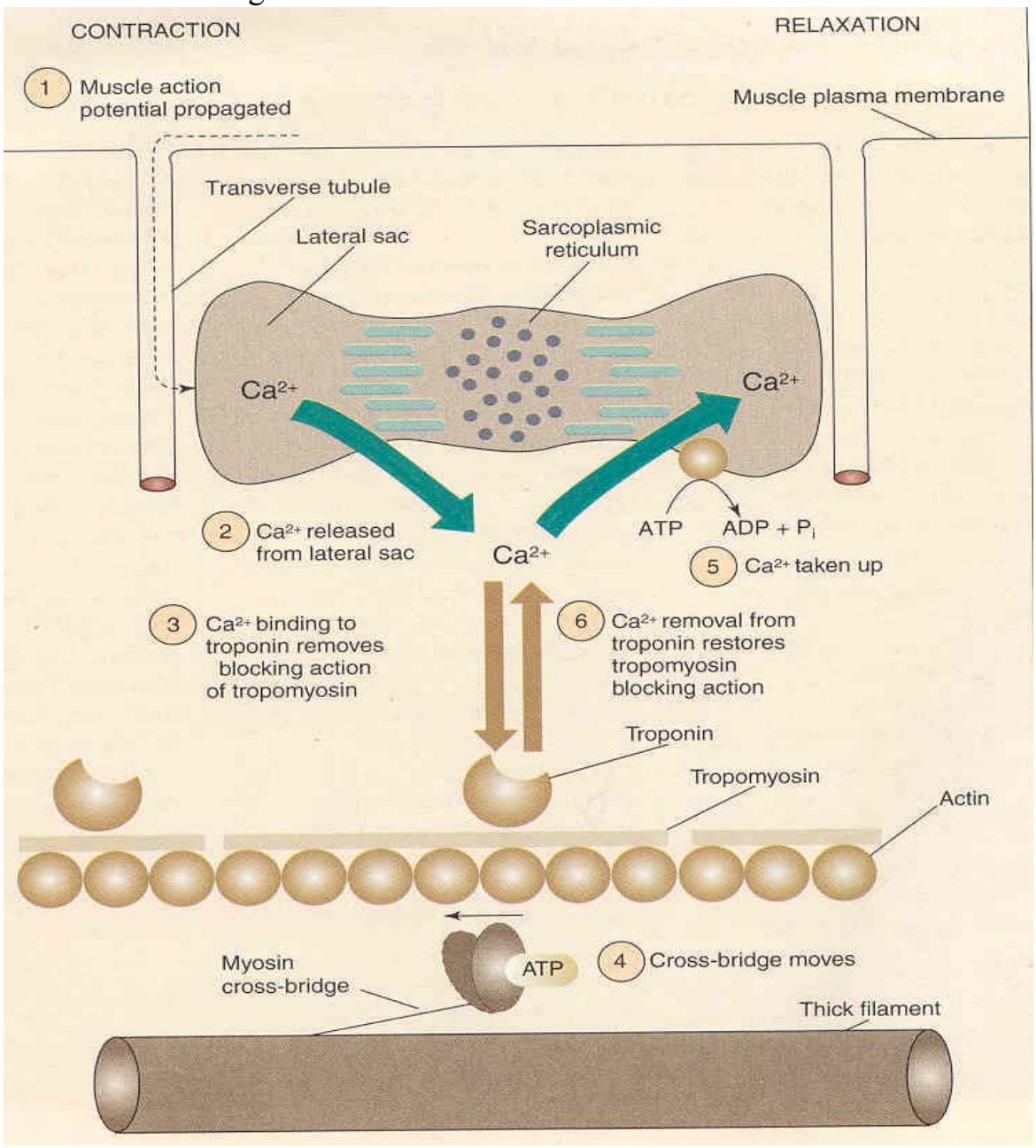
Fig 7: 3 sources of ATP in contraction

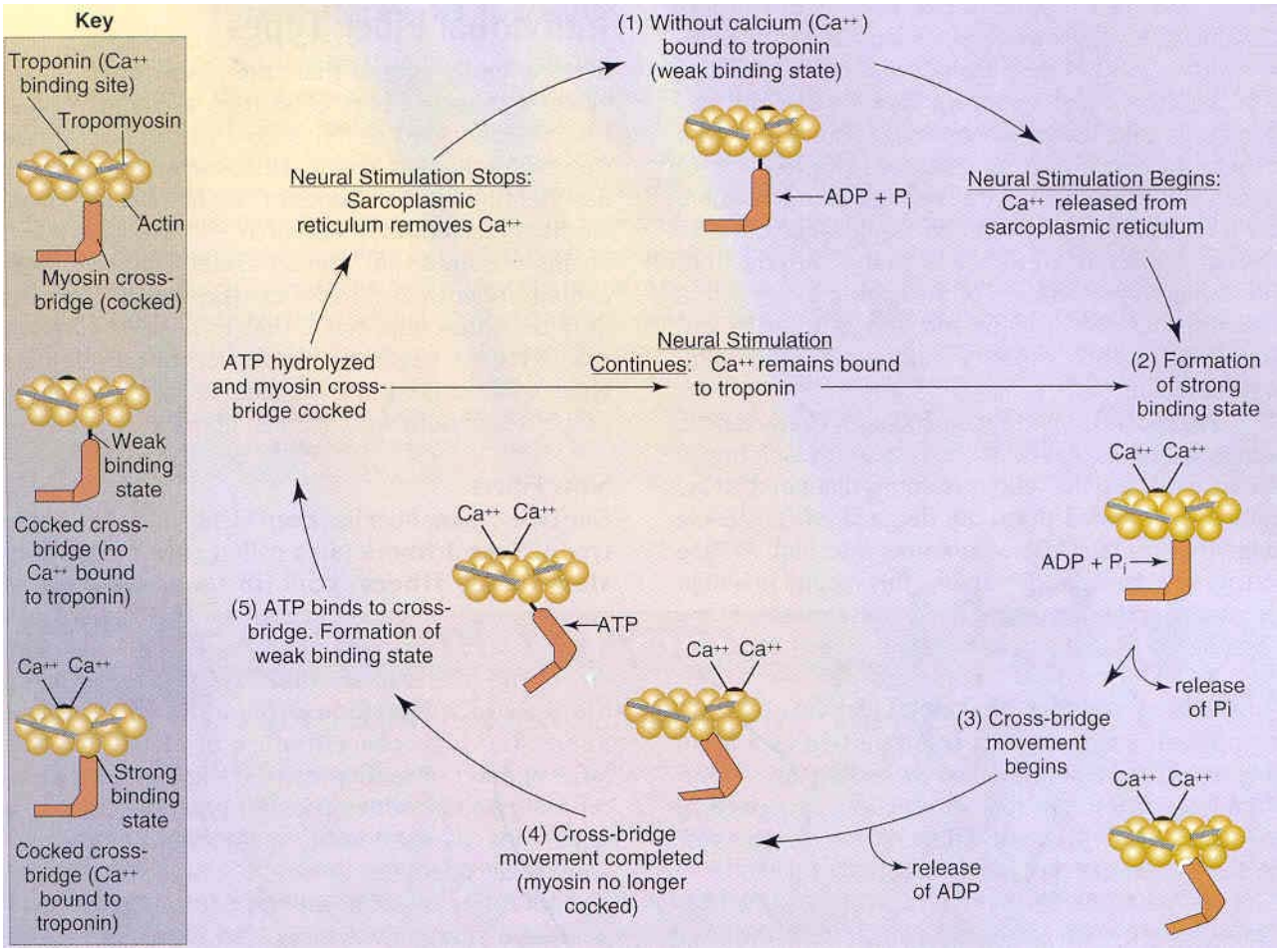


Stopping the Contraction

Signal: Lack of AP at the NMJ

E-dep. Ca^{+2} pump (in SR): move it back to SR. Ca^{+2} is removed from troponin, allowing tropomyosin to move & cover binding sites.





Muscle Fatigue

Short-term, high intensity or prolonged sub-max ex can induce ↓muscle force production
This fatigue is defined as ↓max force production ➔↓ ability to work

Cause of fatigue: Varies & dep on type of ex.

- Fatigue D/T high intensity ex (400 m' sprint)- D/T accumulated Inorganic P & H^+ that interact with contractile proteins & ↓muscle force
- Fatigue D/T prolonged ex may involve failure of excitation-contraction coupling, by ↓release Ca^{+2} of SR ➔ Fewer cross-bridges in strong binding state (force generation) & ↓m. force production