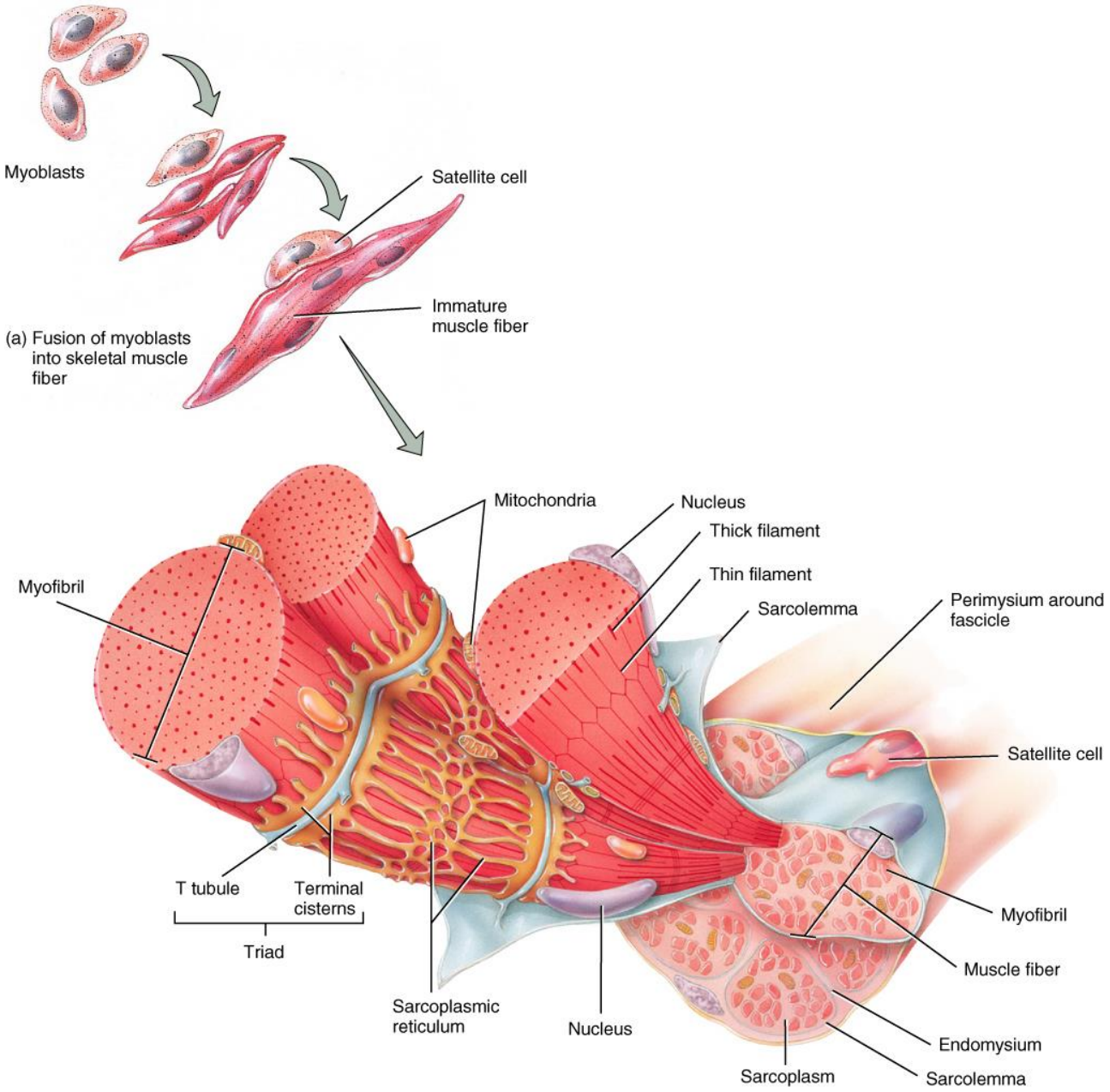
Muscle Physiology
Ref: Guyton, chapters: 6,7,8

Types of Muscle

Fig. 10.03



10.03

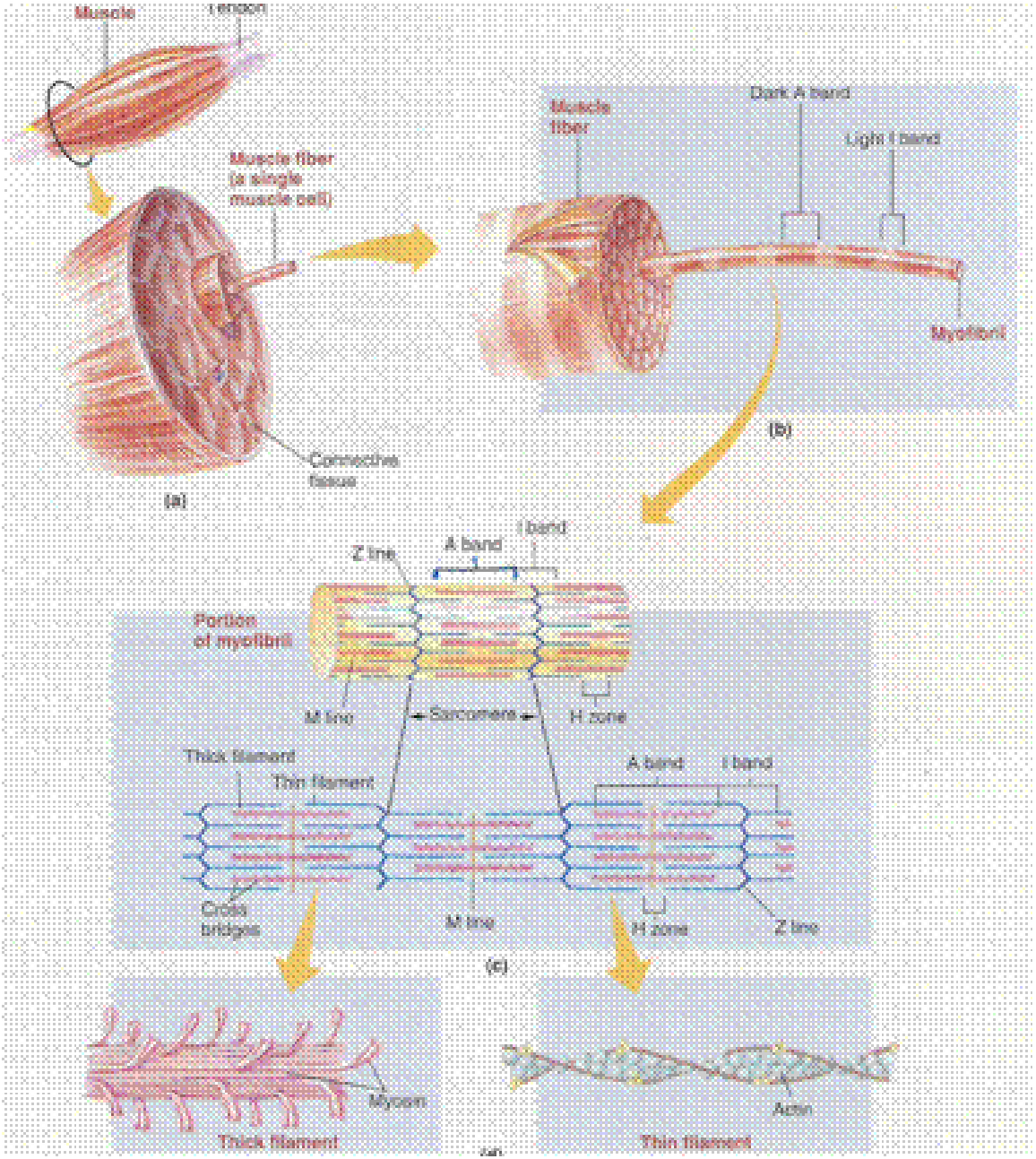


Figure 2. The components of a muscle.

Taken from Sherwood, 2004.

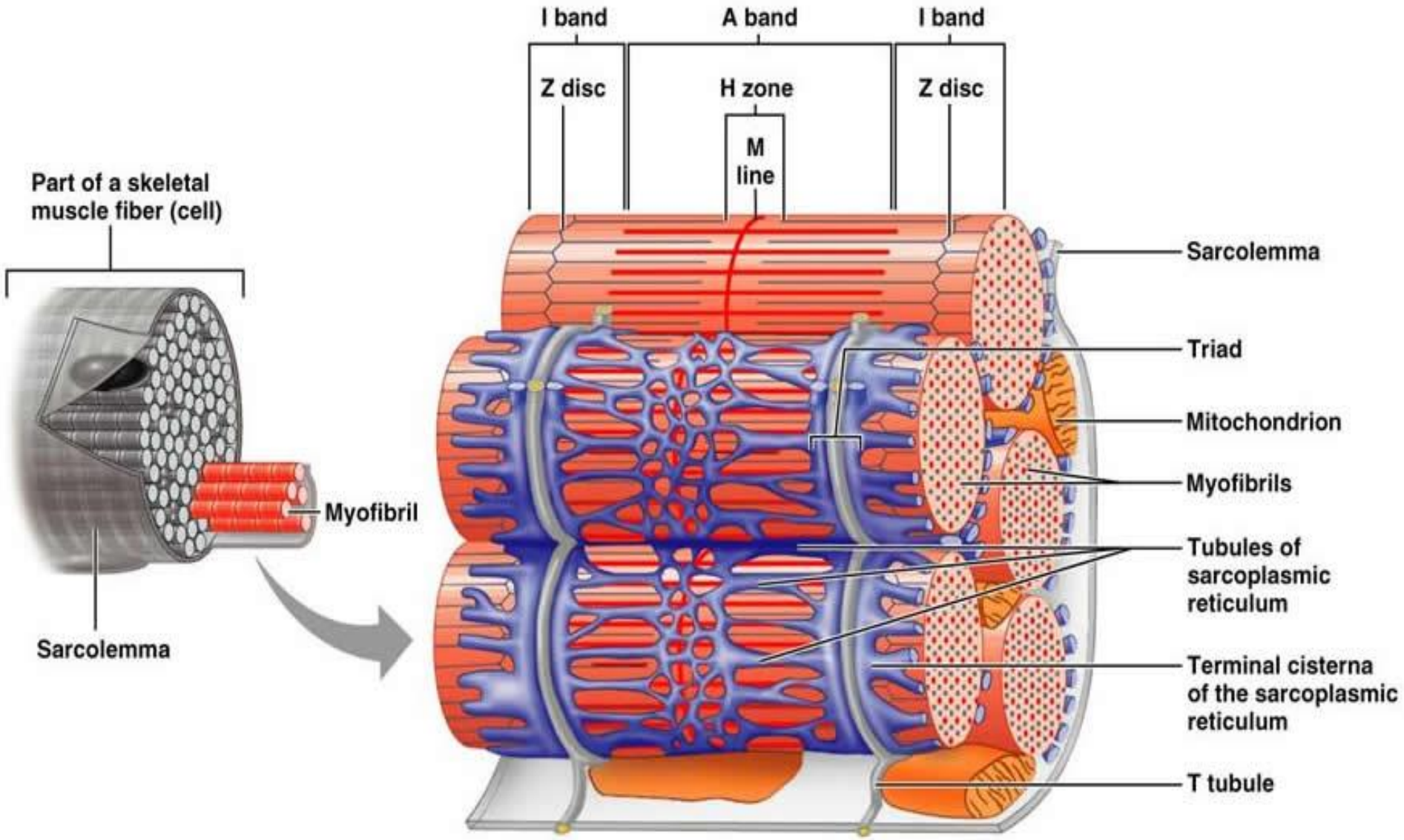
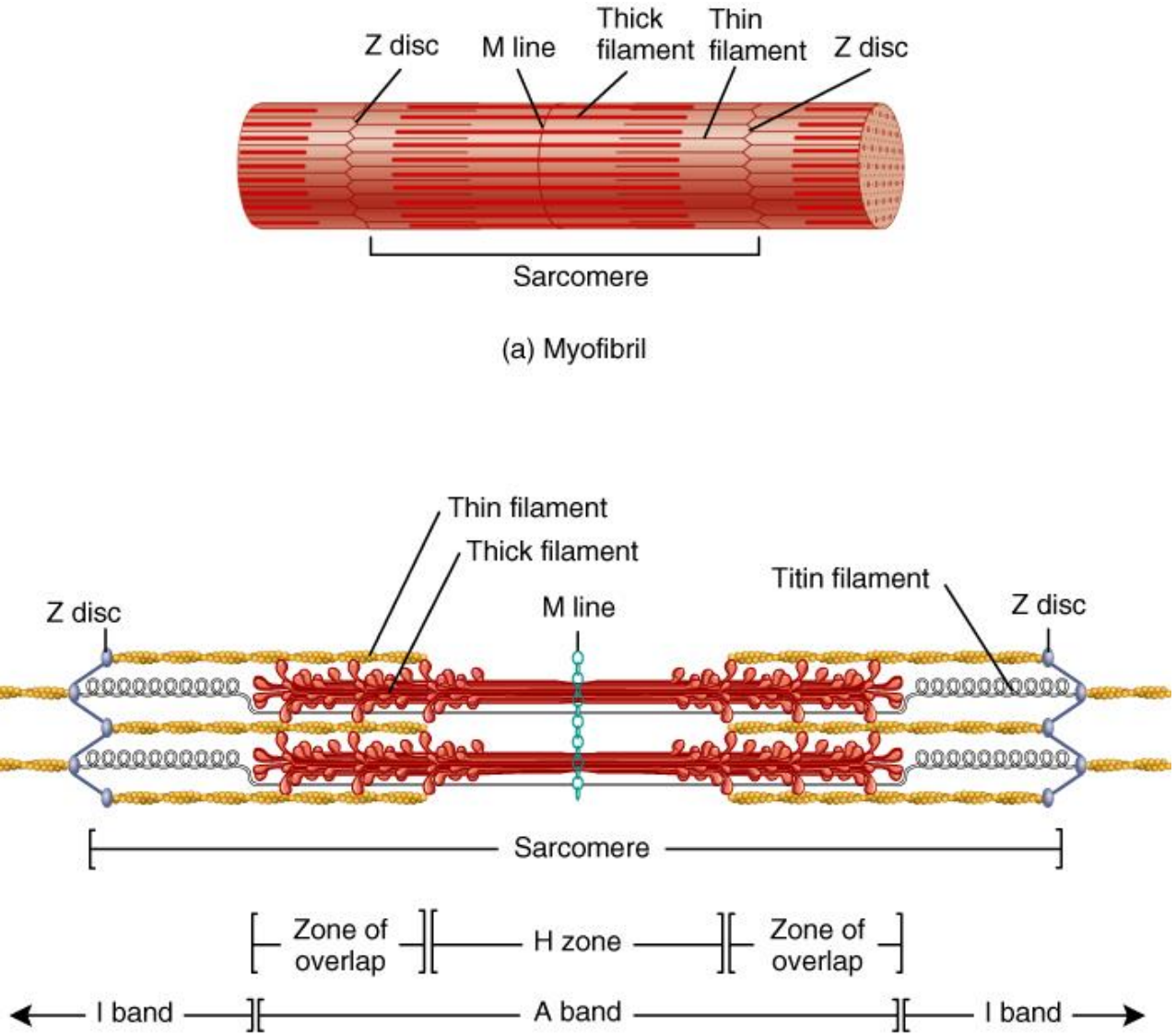
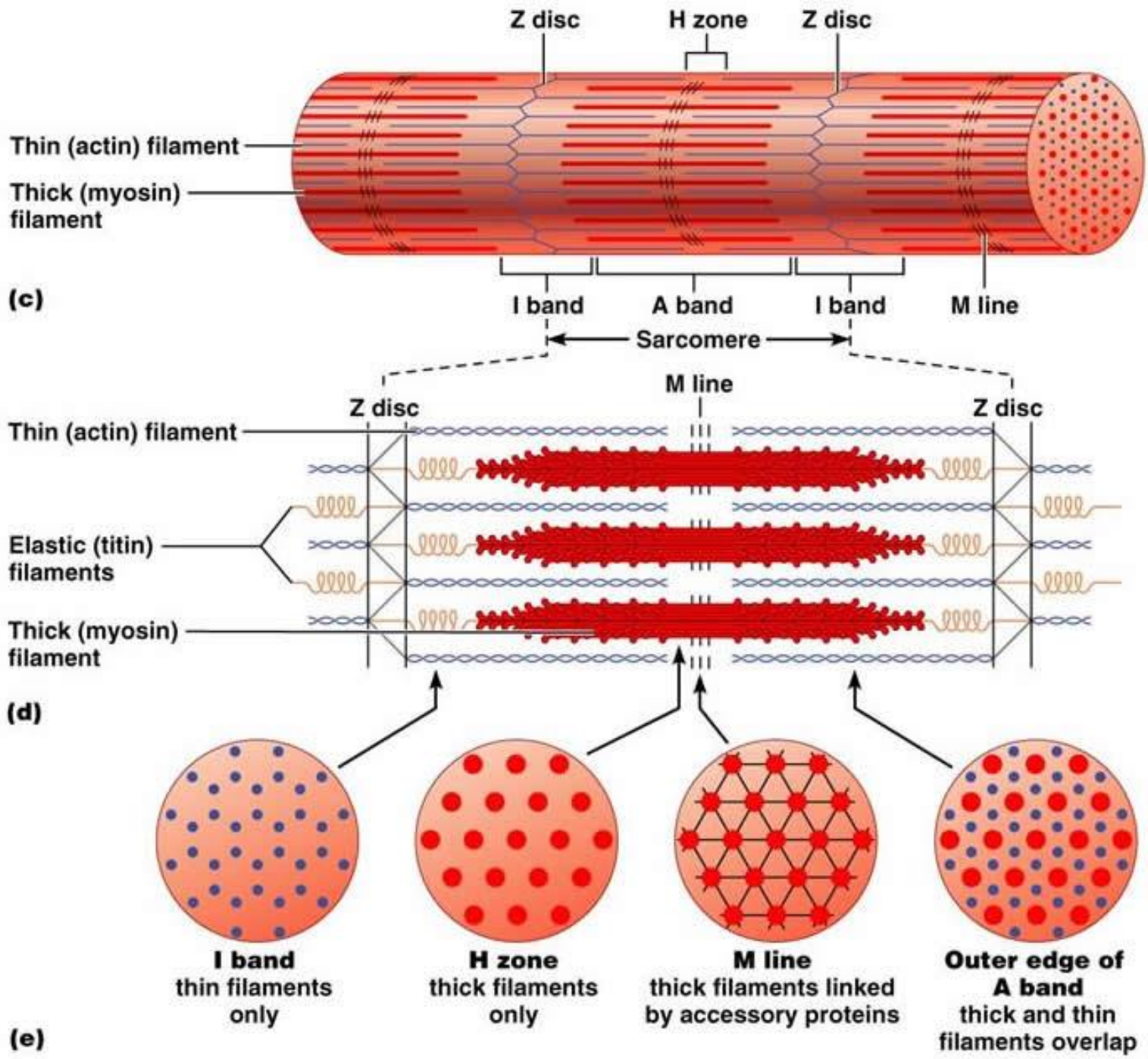

I band
A band
I band
Z disc
H zone
Z disc
M line
Part of a skeletal muscle fiber (cell)
Sarcolemma
Triad
Mitochondrion
Myofibrils
Myofibril
Tubules of sarcoplasmic reticulum
Terminal cisterna of the sarcoplasmic reticulum
Sarcolemma
T tubule

Fig. 10.04



10.04


Z disc
H zone
Z disc
Thin (actin) filament
Thick (myosin) filament
(c)
I band
A band
I band
M line
Sarcomere
M line
Z disc
Z disc
Thin (actin) filament
Elastic (titin) filaments
Thick (myosin) filament
(d)
I band
thin filaments only
H zone
thick filaments only
M line
thick filaments linked by accessory proteins
Outer edge of A band
thick and thin filaments overlap
(e)

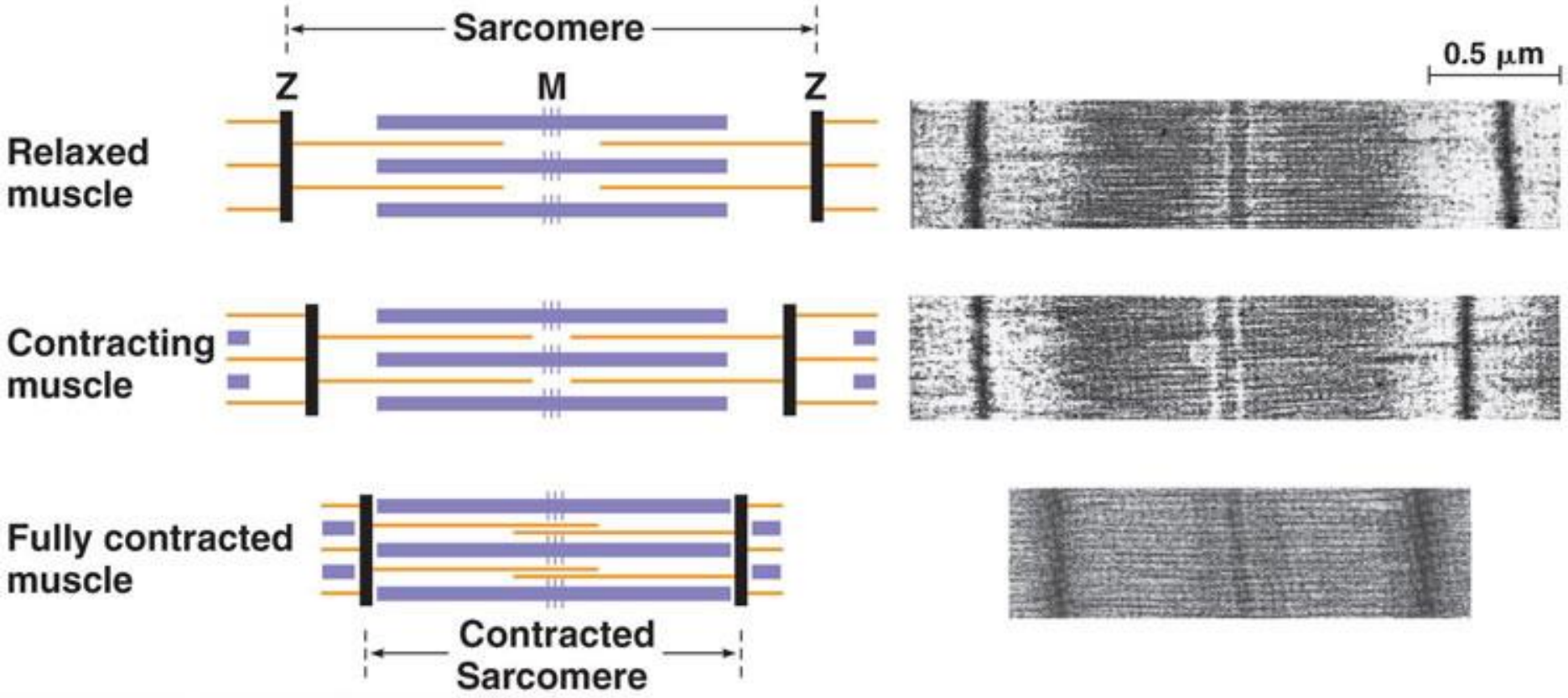
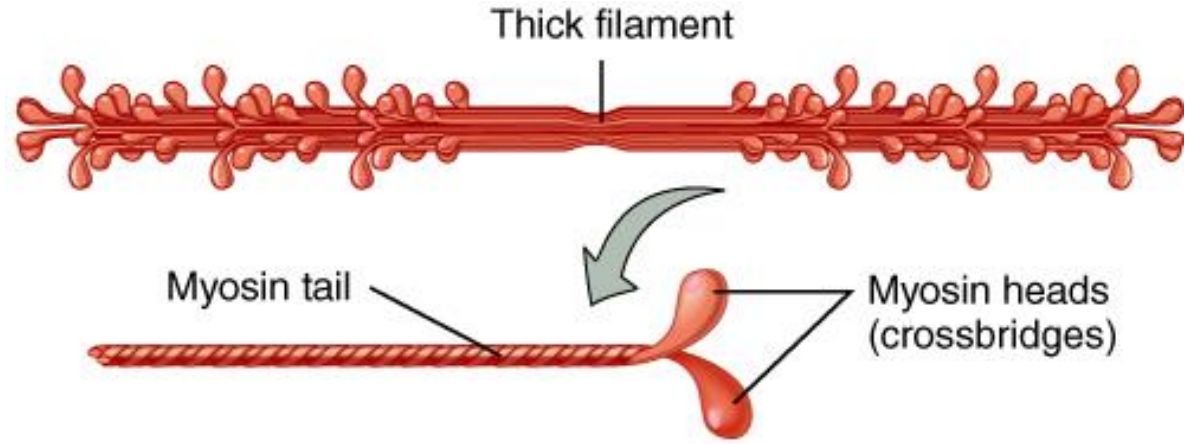
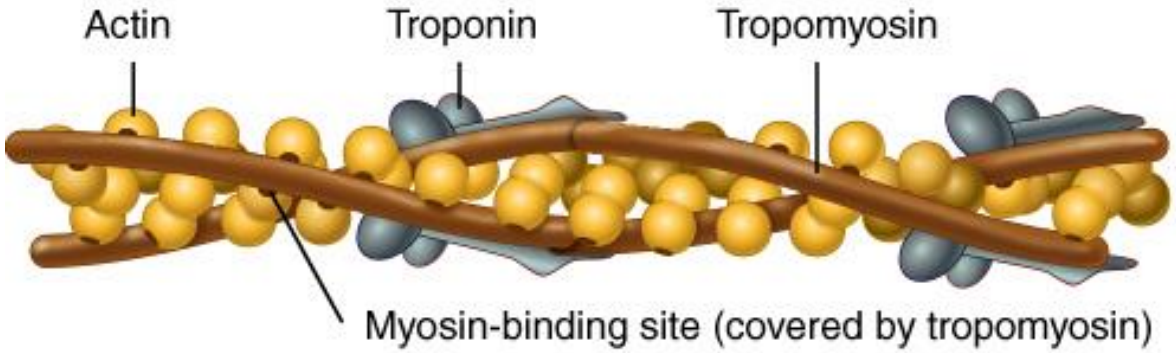


Fig. 10.06



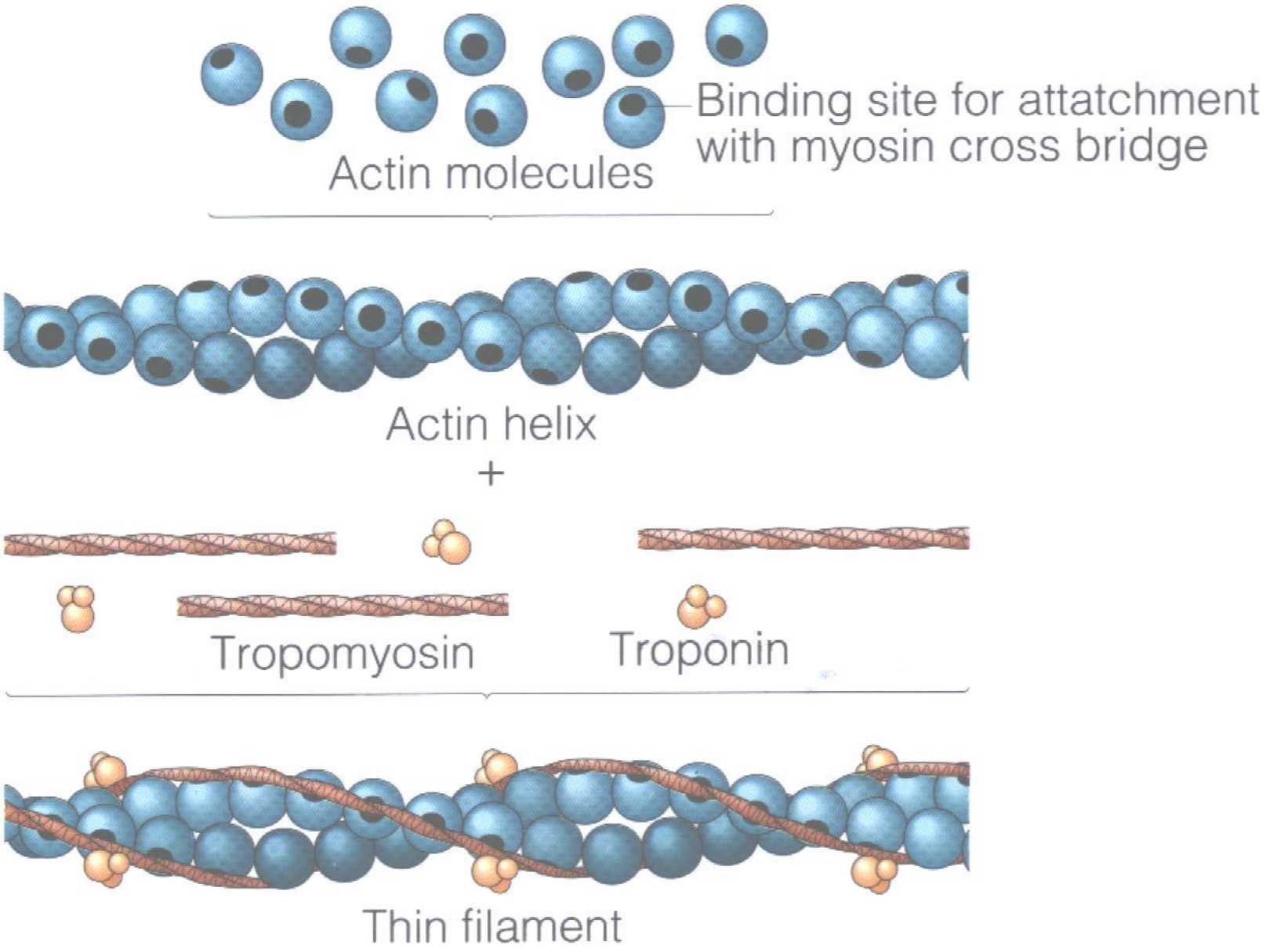
(a) One thick filament (above) and a myosin molecule (below)



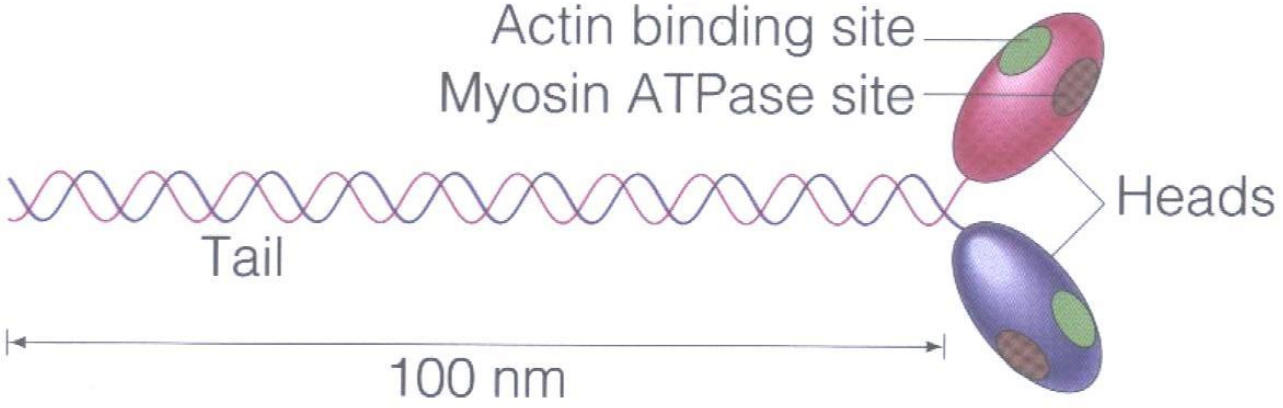
(b) Portion of a thin filament

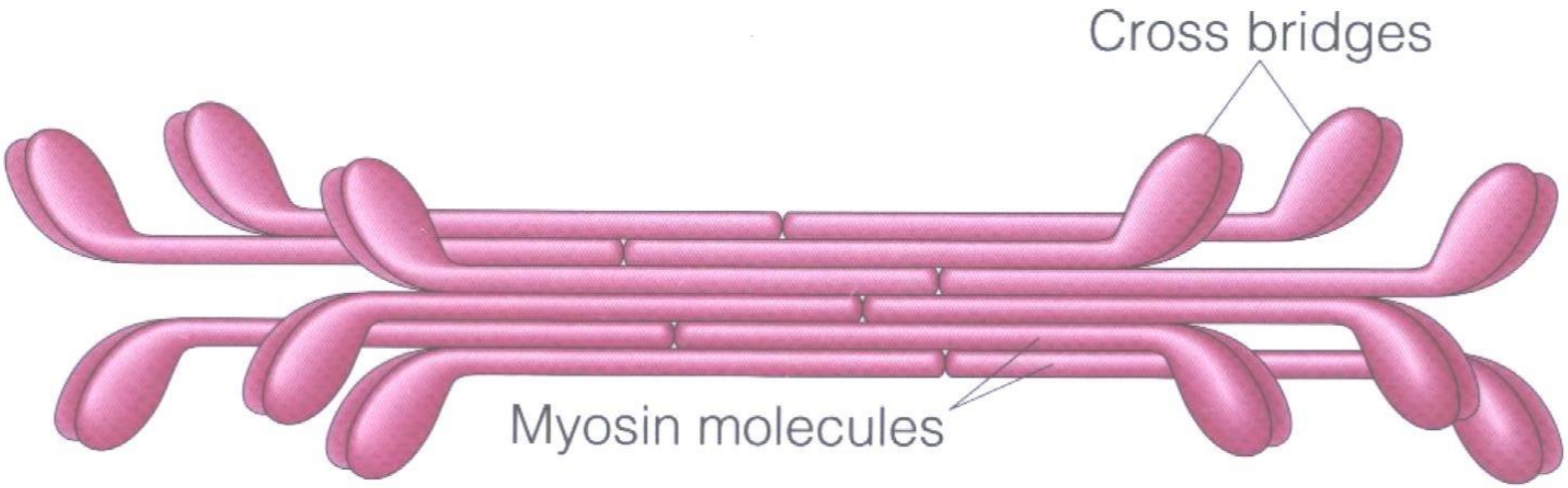
10.06

Composition of Thin Filaments



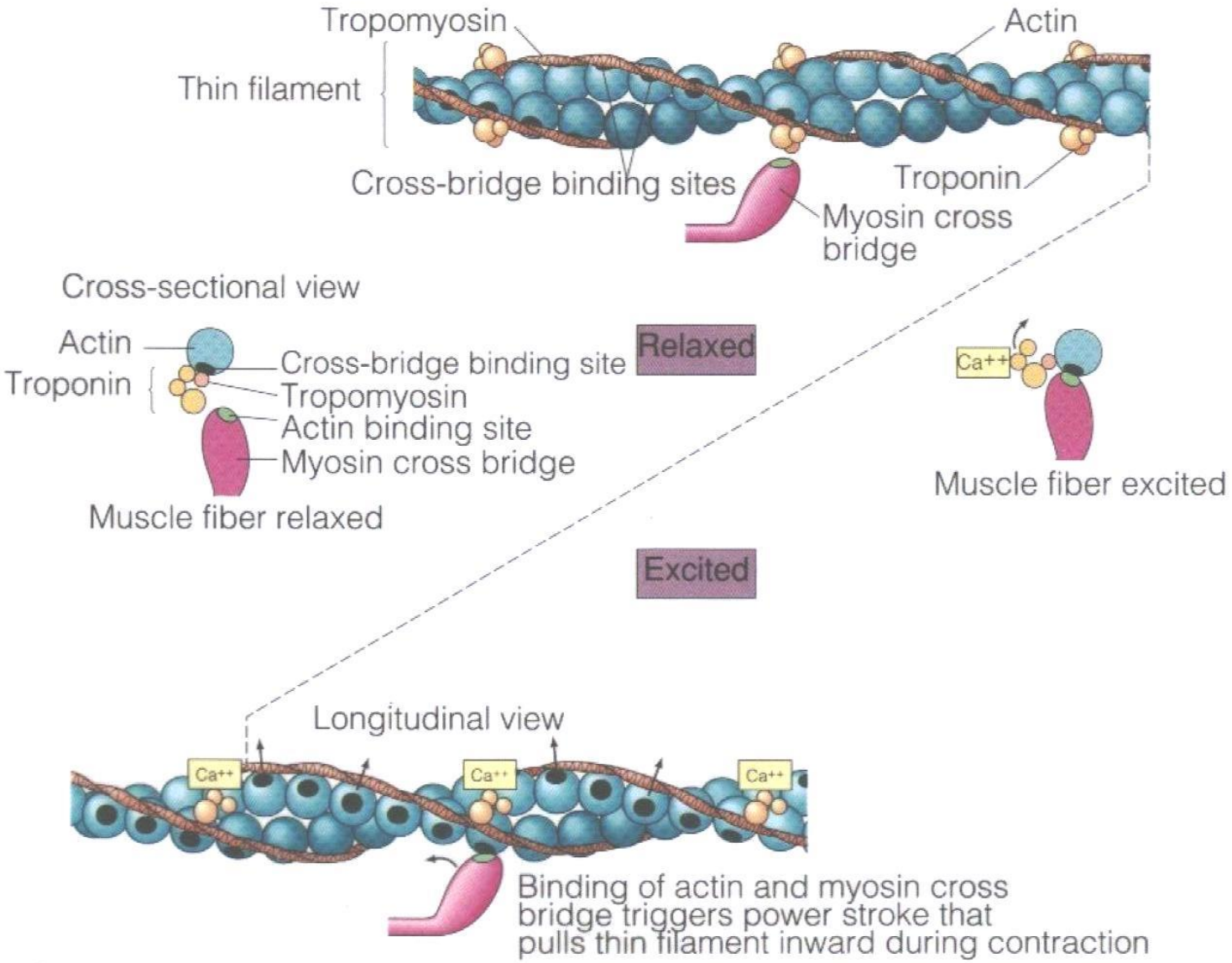
Structure of Myosin Molecules and Their Organization within a Thick Filament





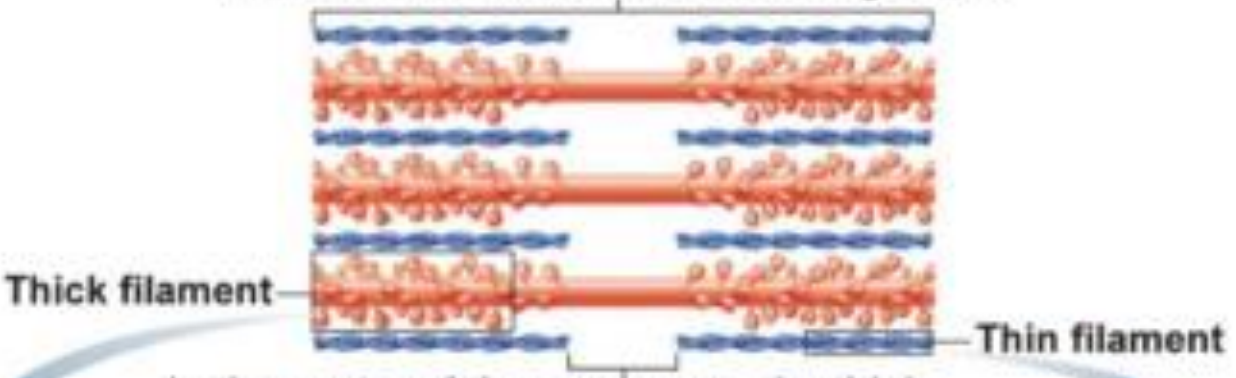
Acetate 60 (Figure 8-5)

Schematic Representation of Role of Calcuim in Turning on Cross Bridges



Acetate 62 (Figure 8-7)

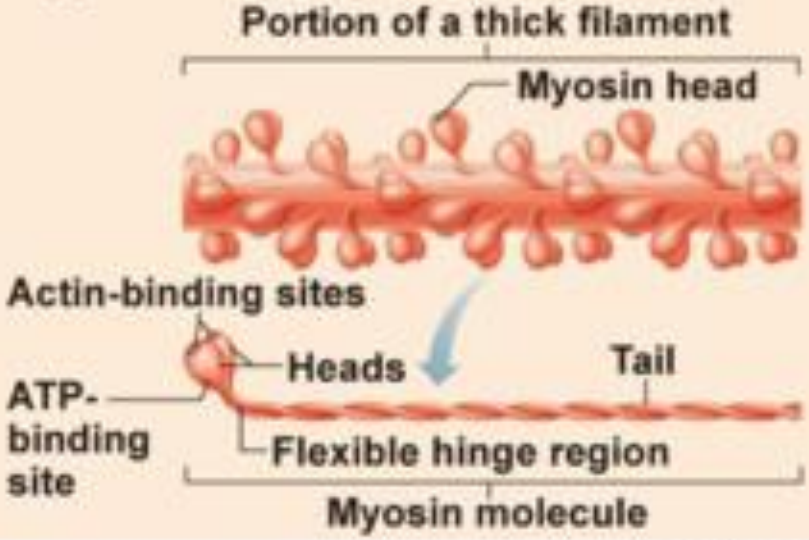
Longitudinal section of filaments within one sarcomere of a myofibril



In the center of the sarcomere, the thick filaments lack myosin heads. Myosin heads are present only in areas of myosin-actin overlap.

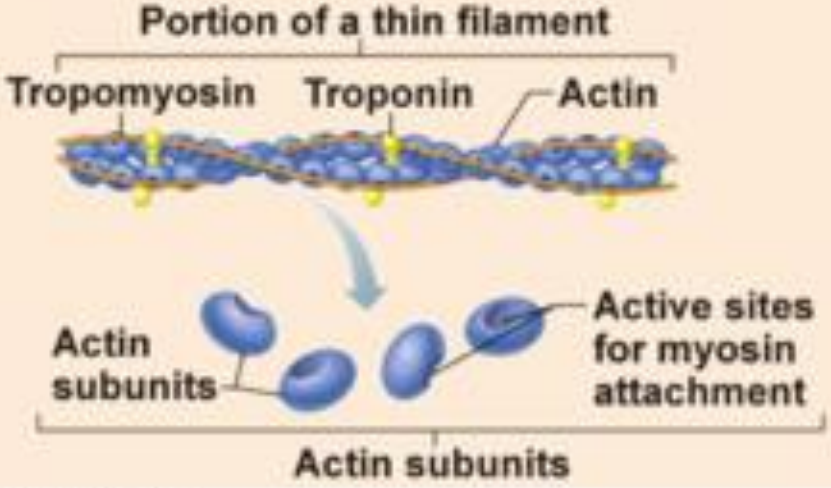
Thick filament

Each thick filament consists of many myosin molecules whose heads protrude at opposite ends of the filament.



Thin filament

A thin filament consists of two strands of actin subunits twisted into a helix plus two types of regulatory proteins (troponin and tropomyosin).



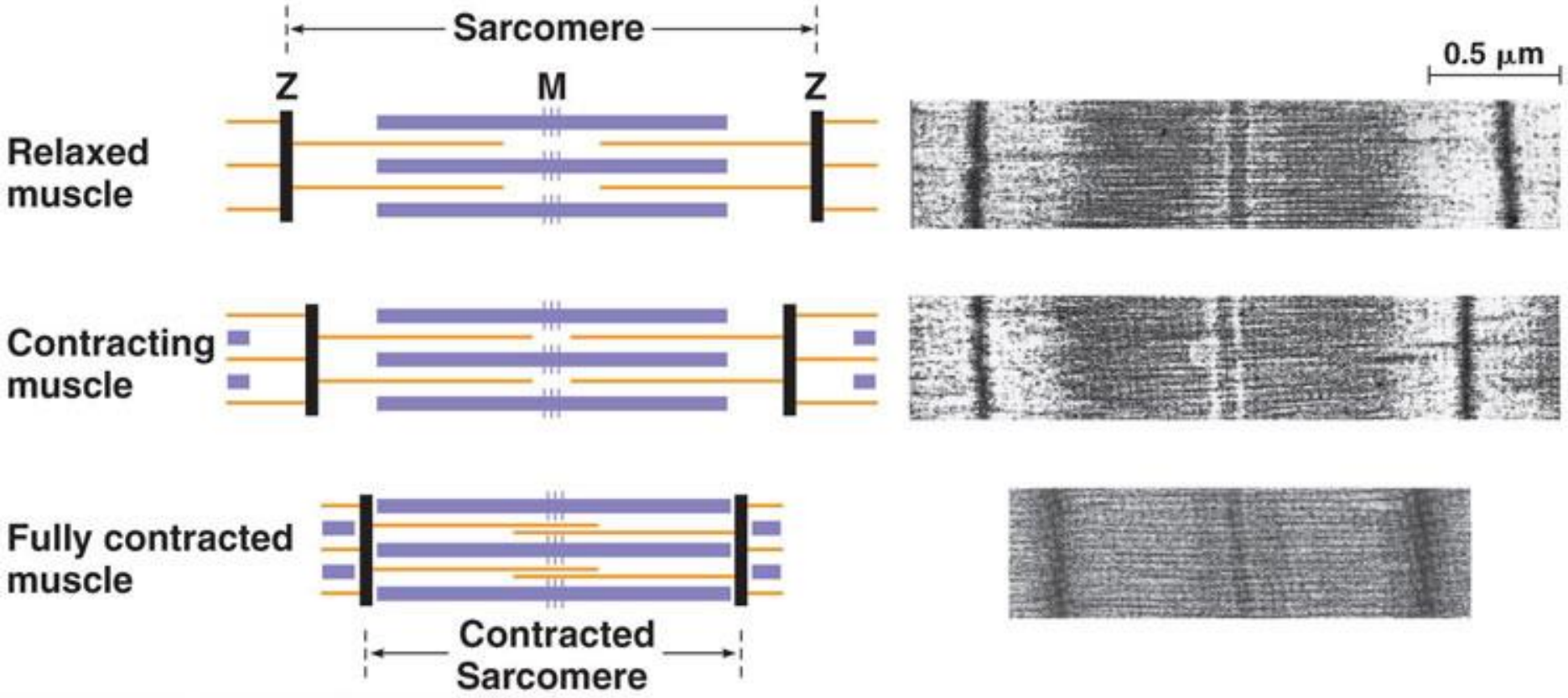
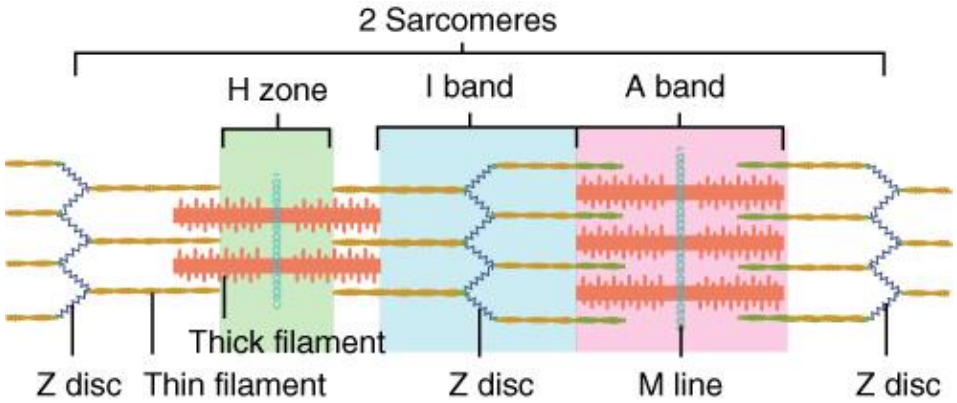
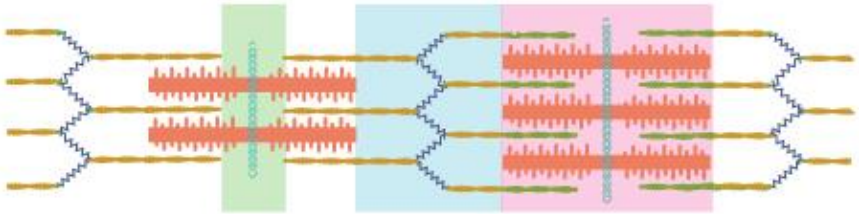


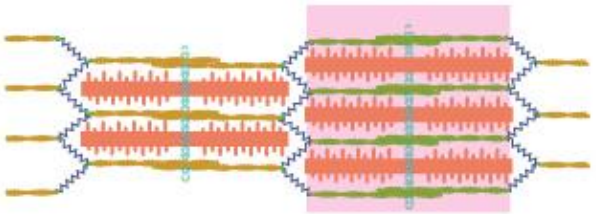
Fig. 10.07



(a) Relaxed muscle



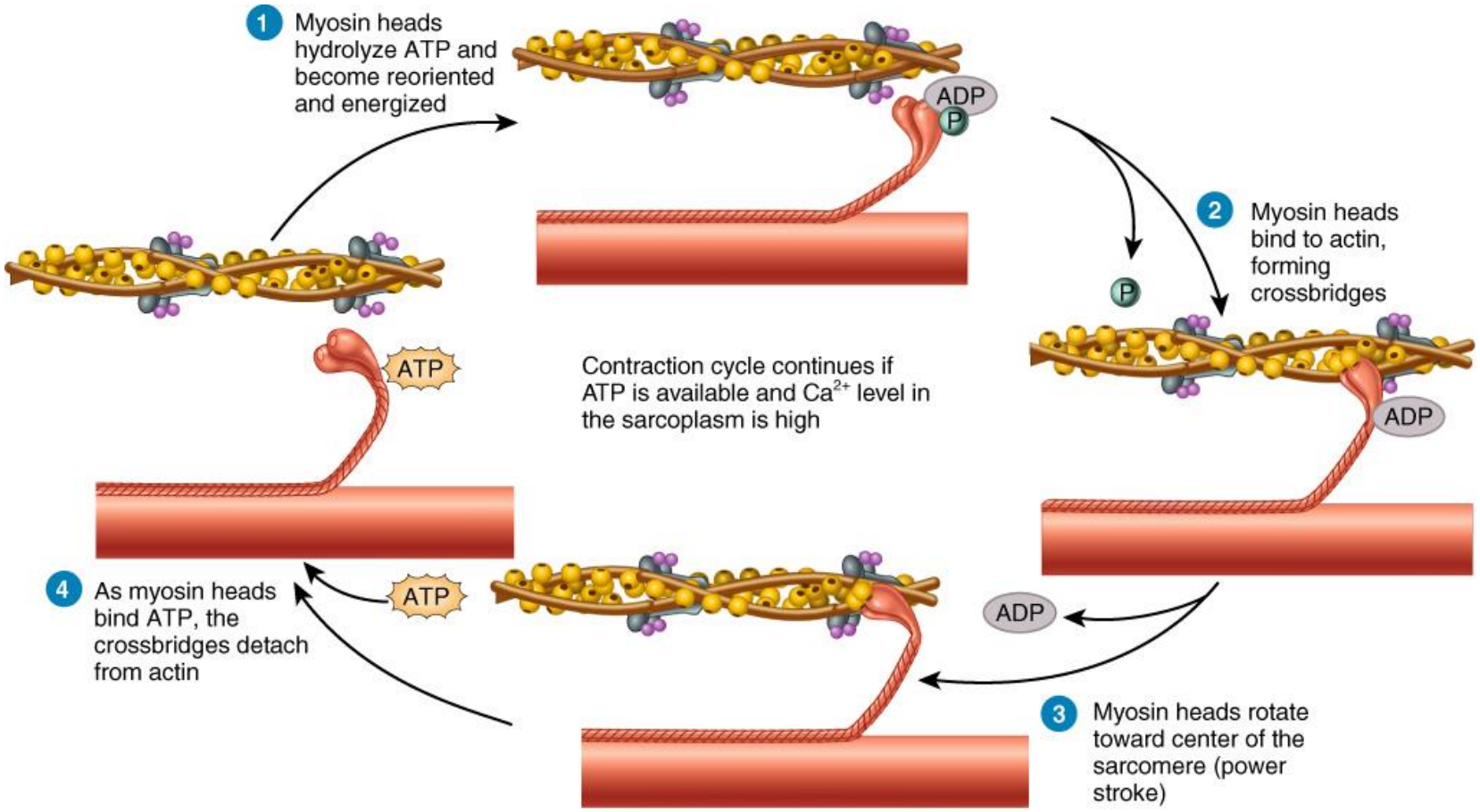
(b) Partially contracted muscle



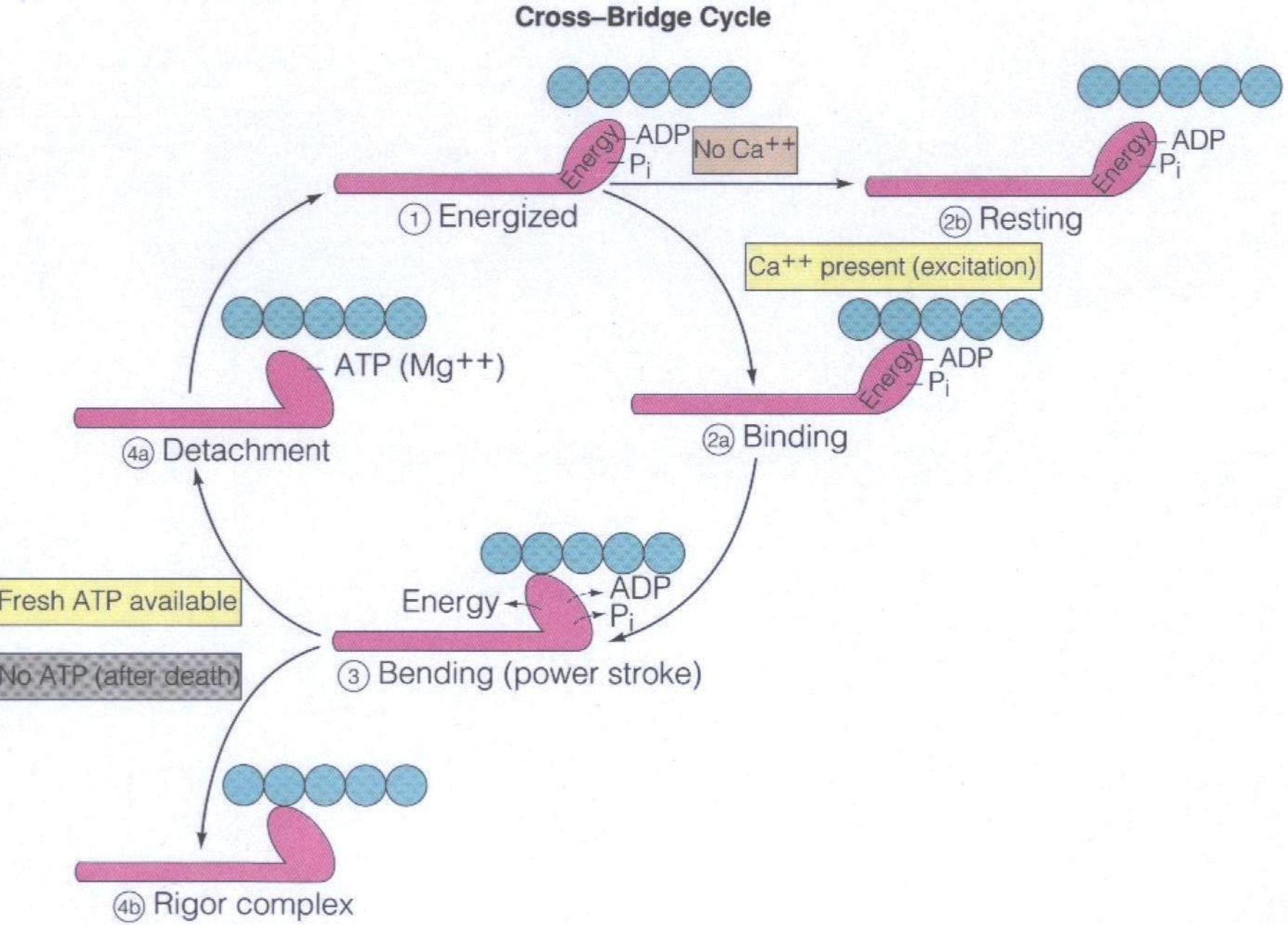
(c) Maximally contracted muscle

10.07

Fig. 10.08



10.08

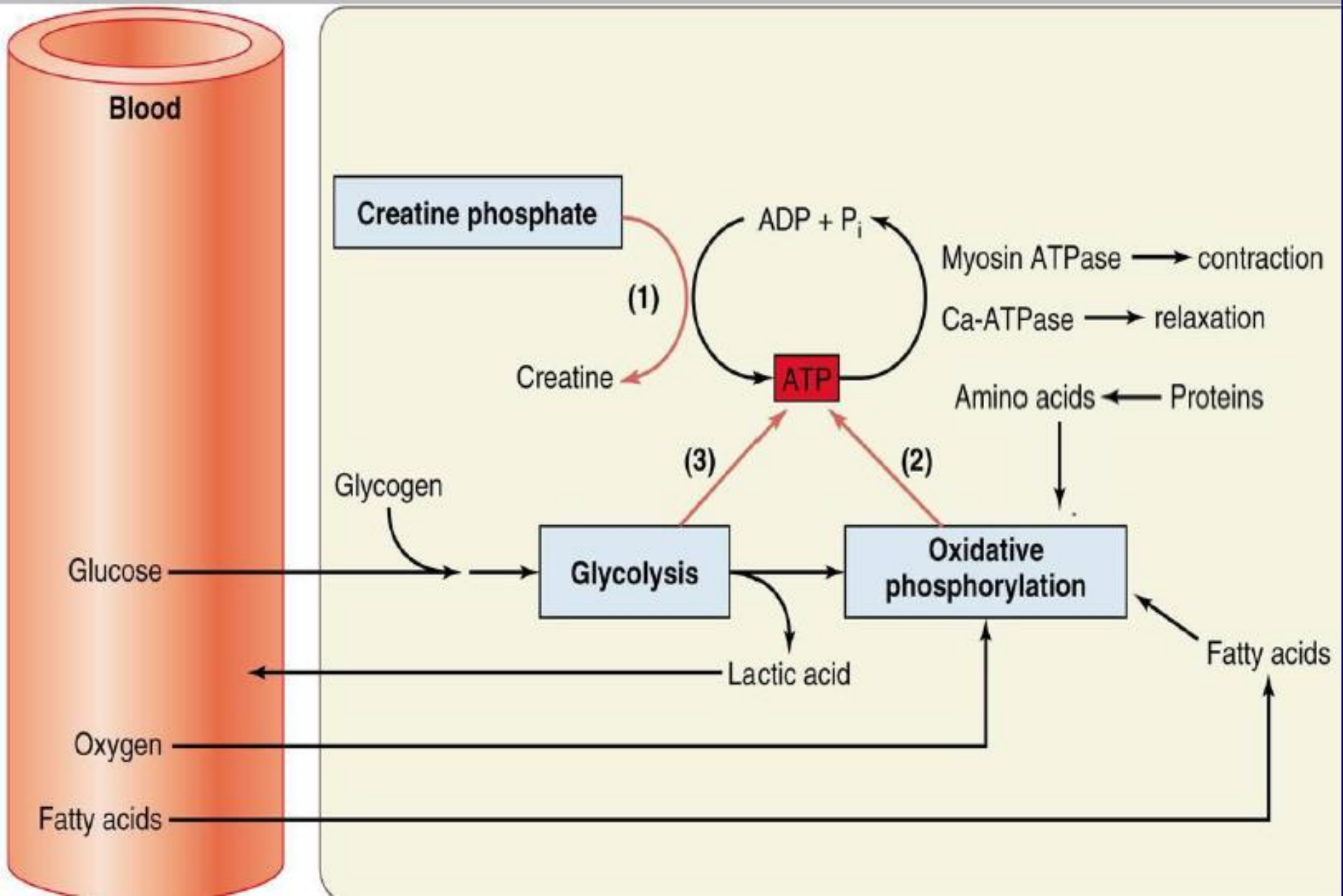

Cross–Bridge Cycle
Energy
ADP
P_i
No Ca^{++}
1 Energized
2b Resting
Ca^{++} present (excitation)
ATP (Mg^{++})
4a Detachment
2a Binding
Fresh ATP available
No ATP (after death)
3 Bending (power stroke)
4b Rigor complex

Summary of Muscle Contraction

https://www.youtube.com/watch?v=6YvdLWgT5mg

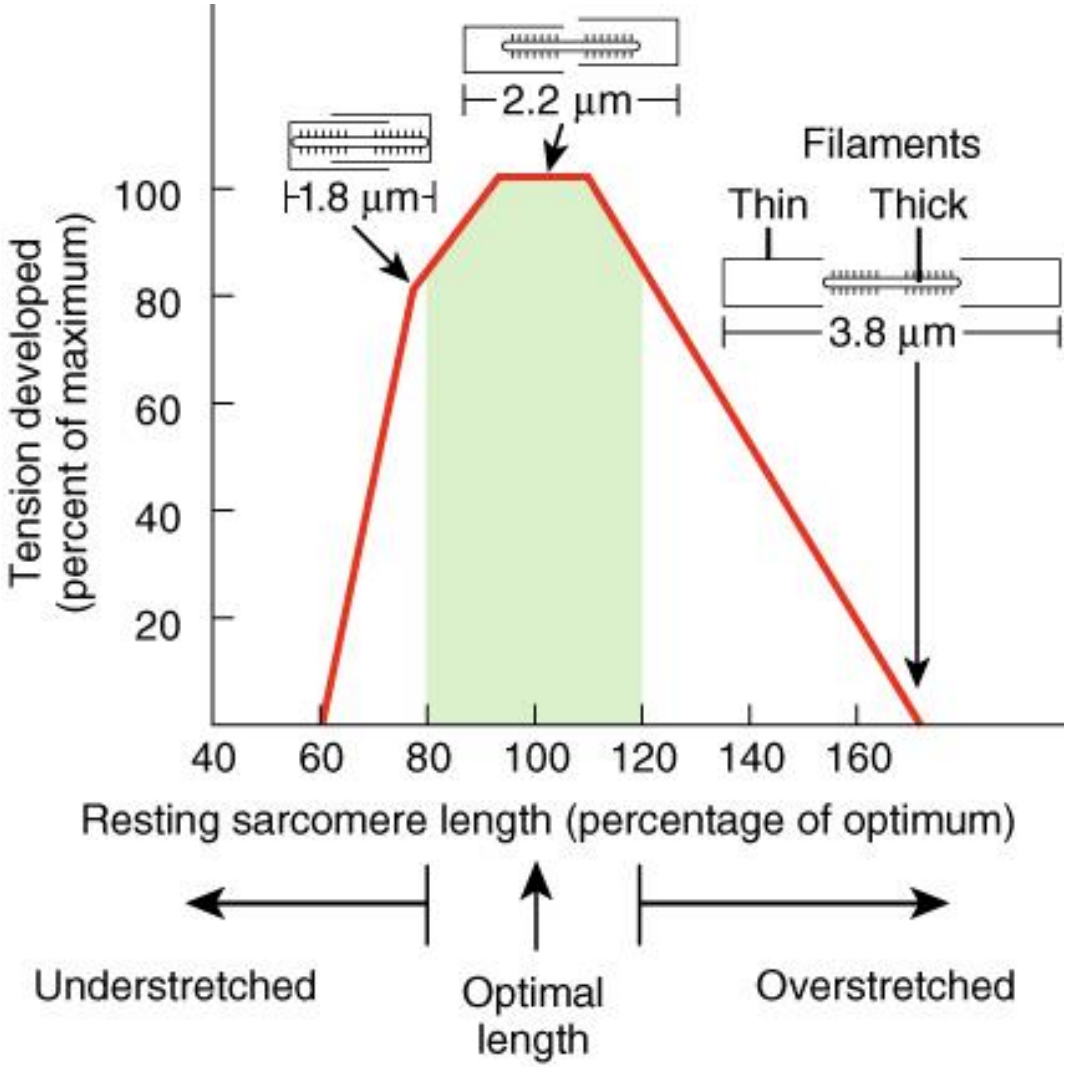
Muscle Energy

Sources of energy for muscle contraction



Muscle Mechanics

Fig. 10.10



10.10

Length-Tension Curve of a Muscle

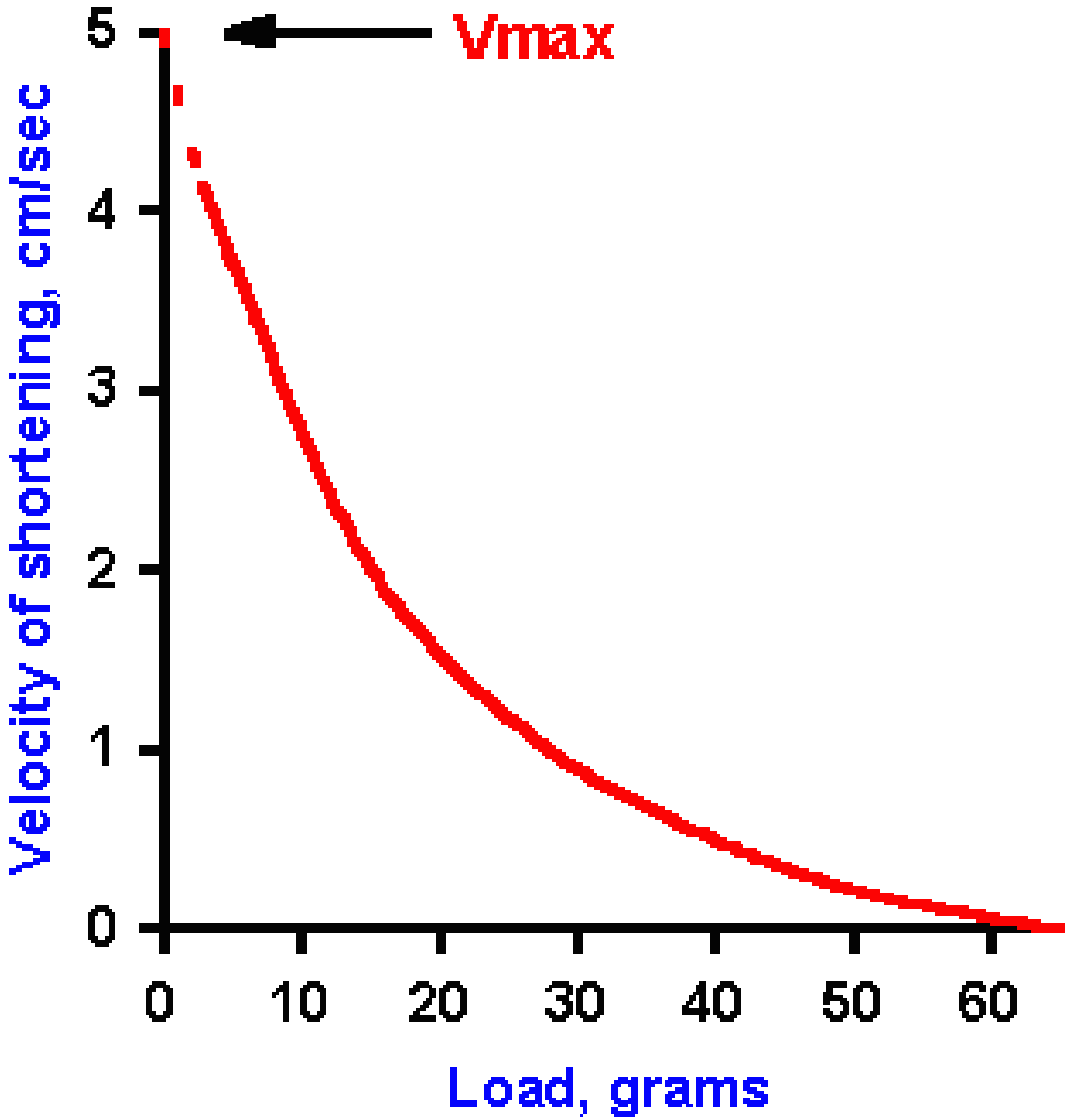
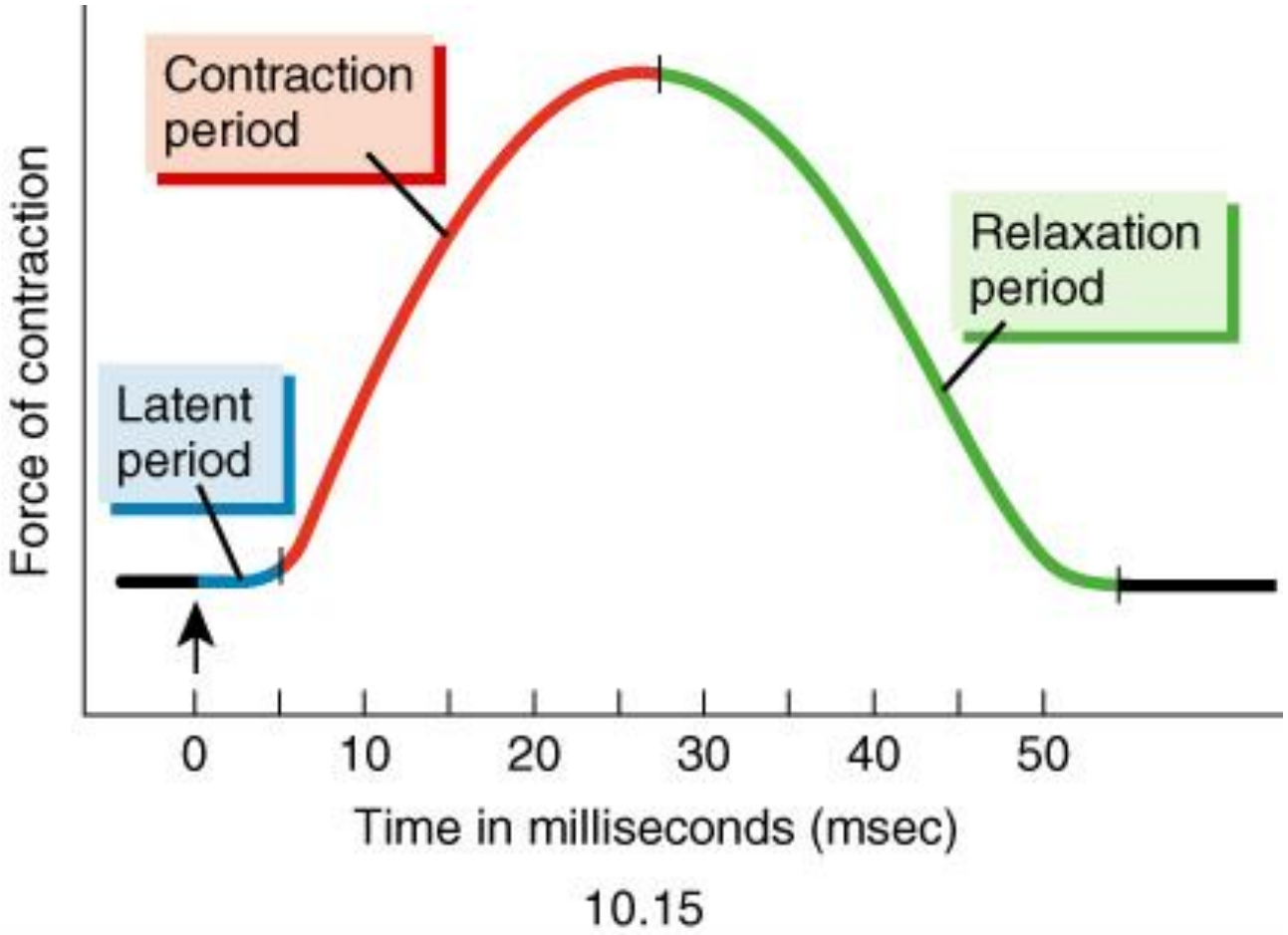
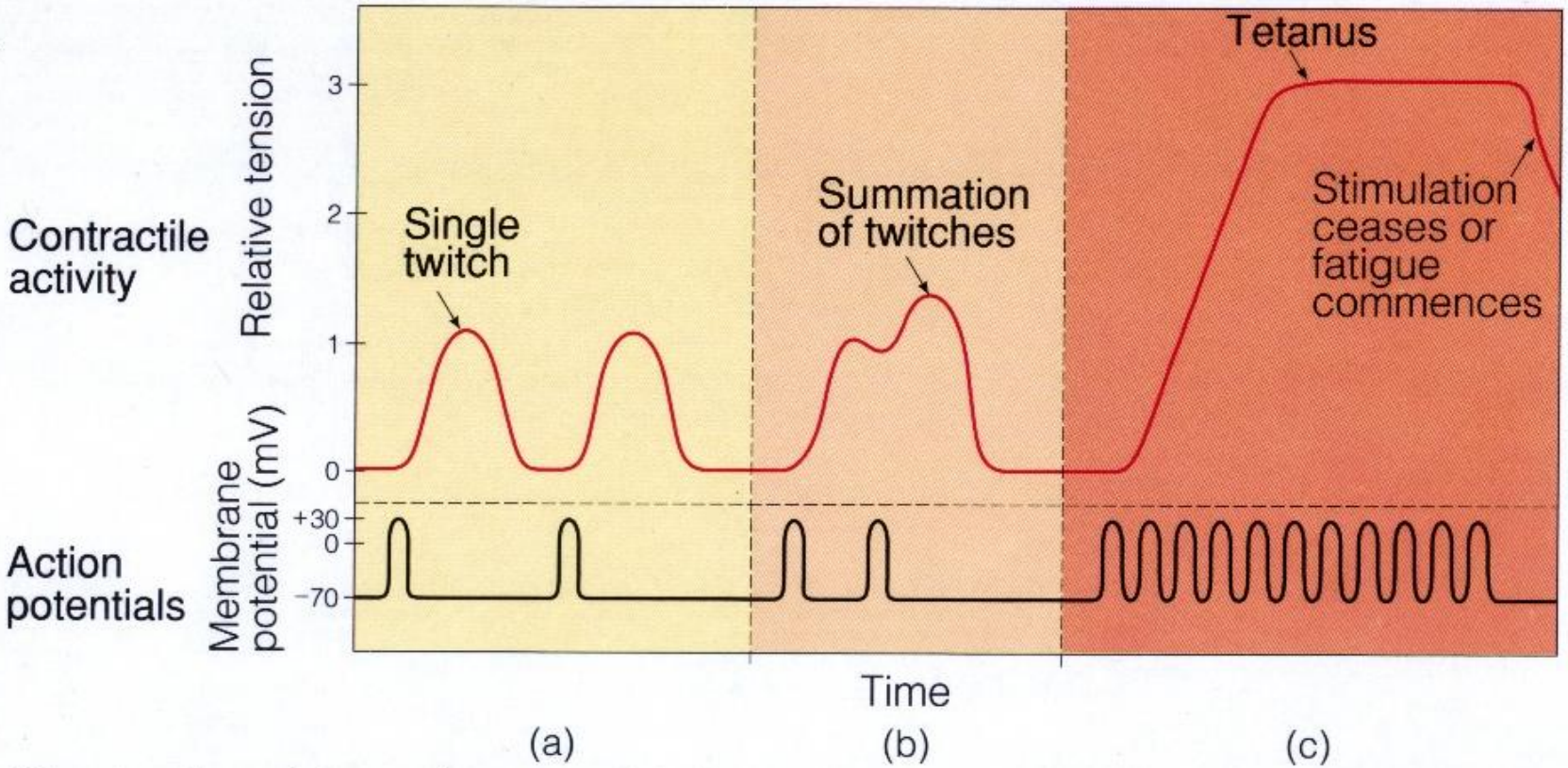

Vmax
Velocity of shortening, cm/sec
5
4
3
2
1
0
0
10
20
30
40
50
60
Load, grams

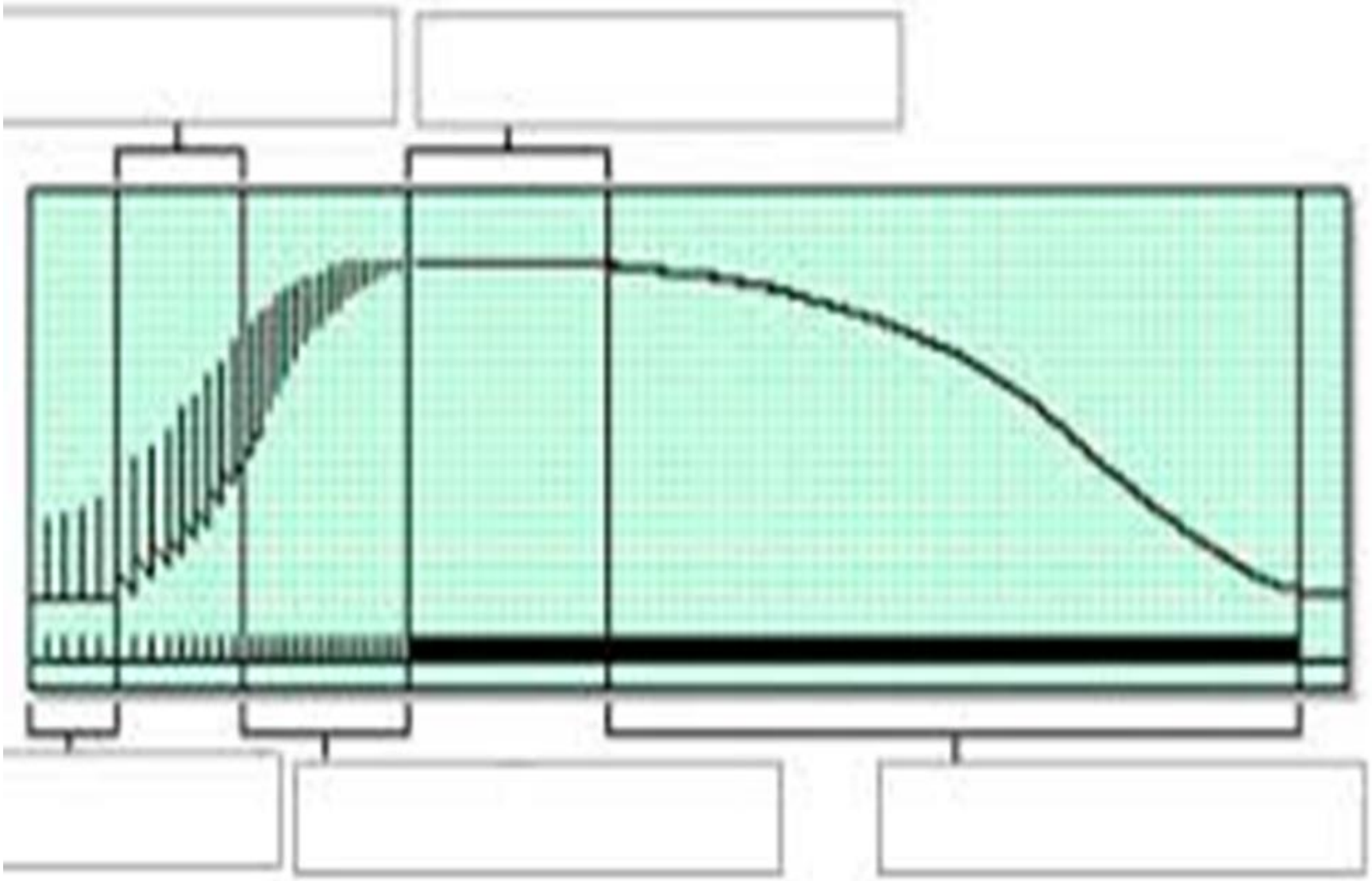
Fig. 10.15


Contraction period
Relaxation period
Latent period
Force of contraction
0
10
20
30
40
50
Time in milliseconds (msec)
10.15

Summation and Tetanus



The duration of the action potentials is not drawn to scale but is exaggerated.



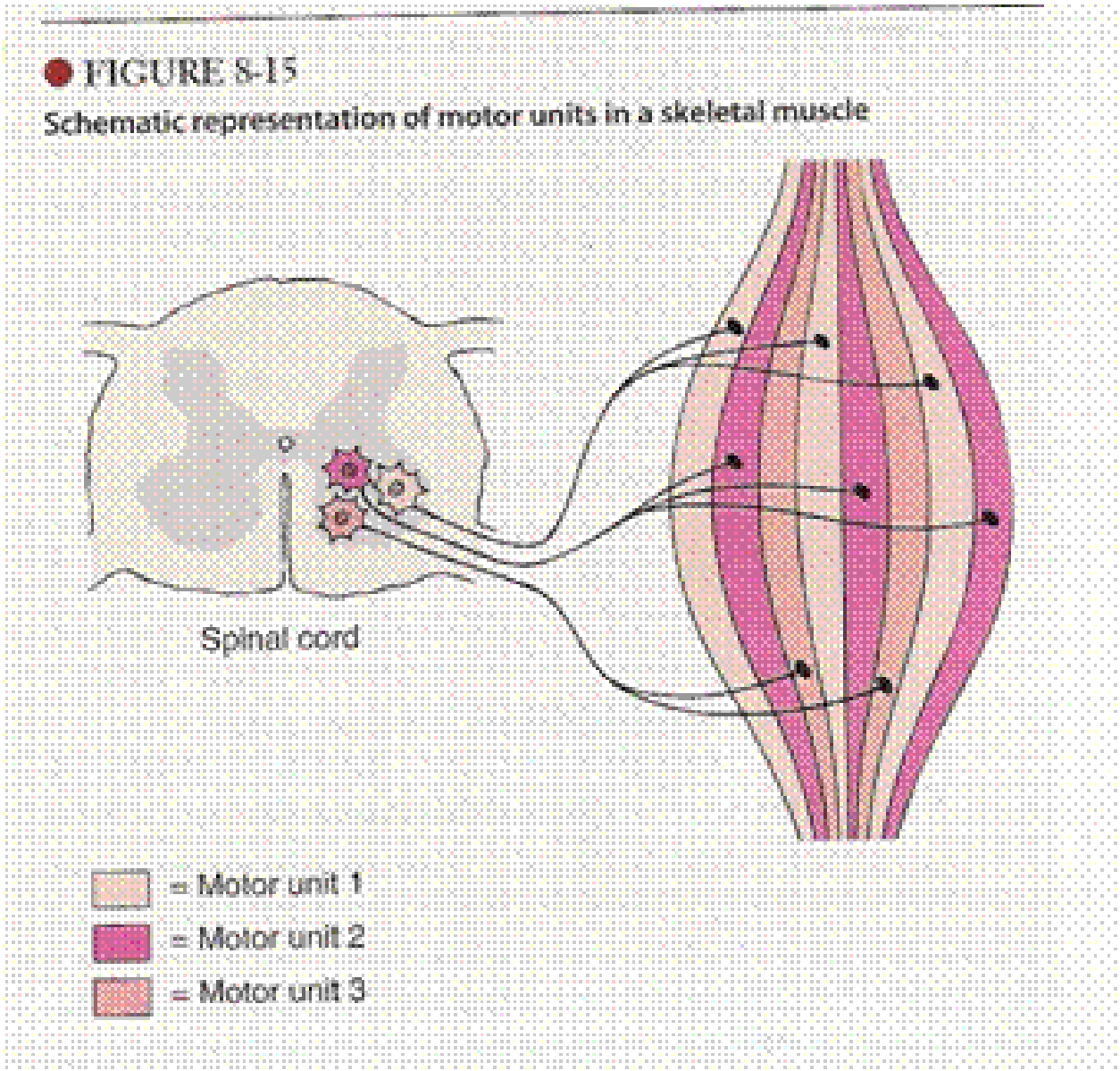
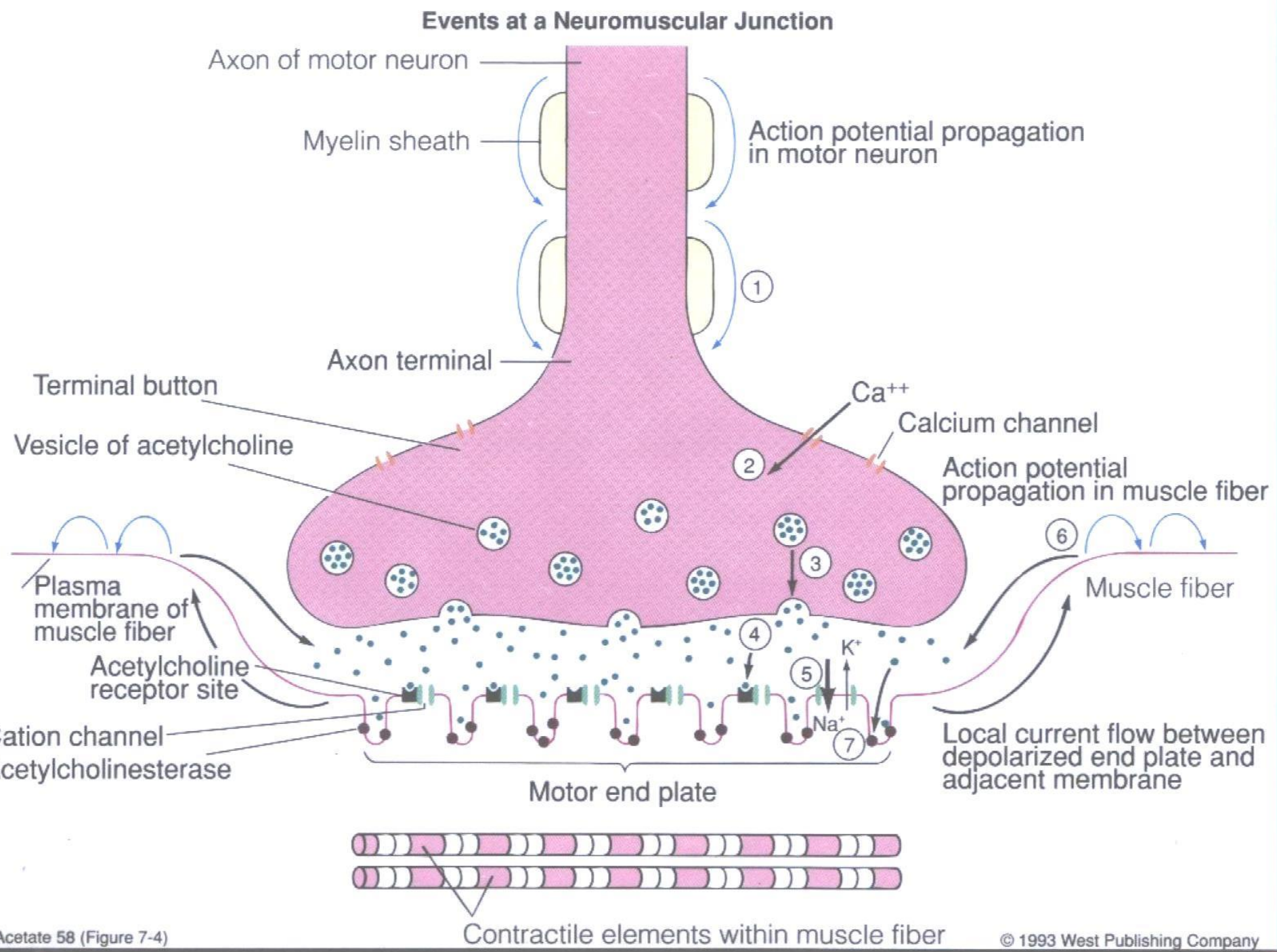


Figure 4. One motor unit can control multiple muscle cells.

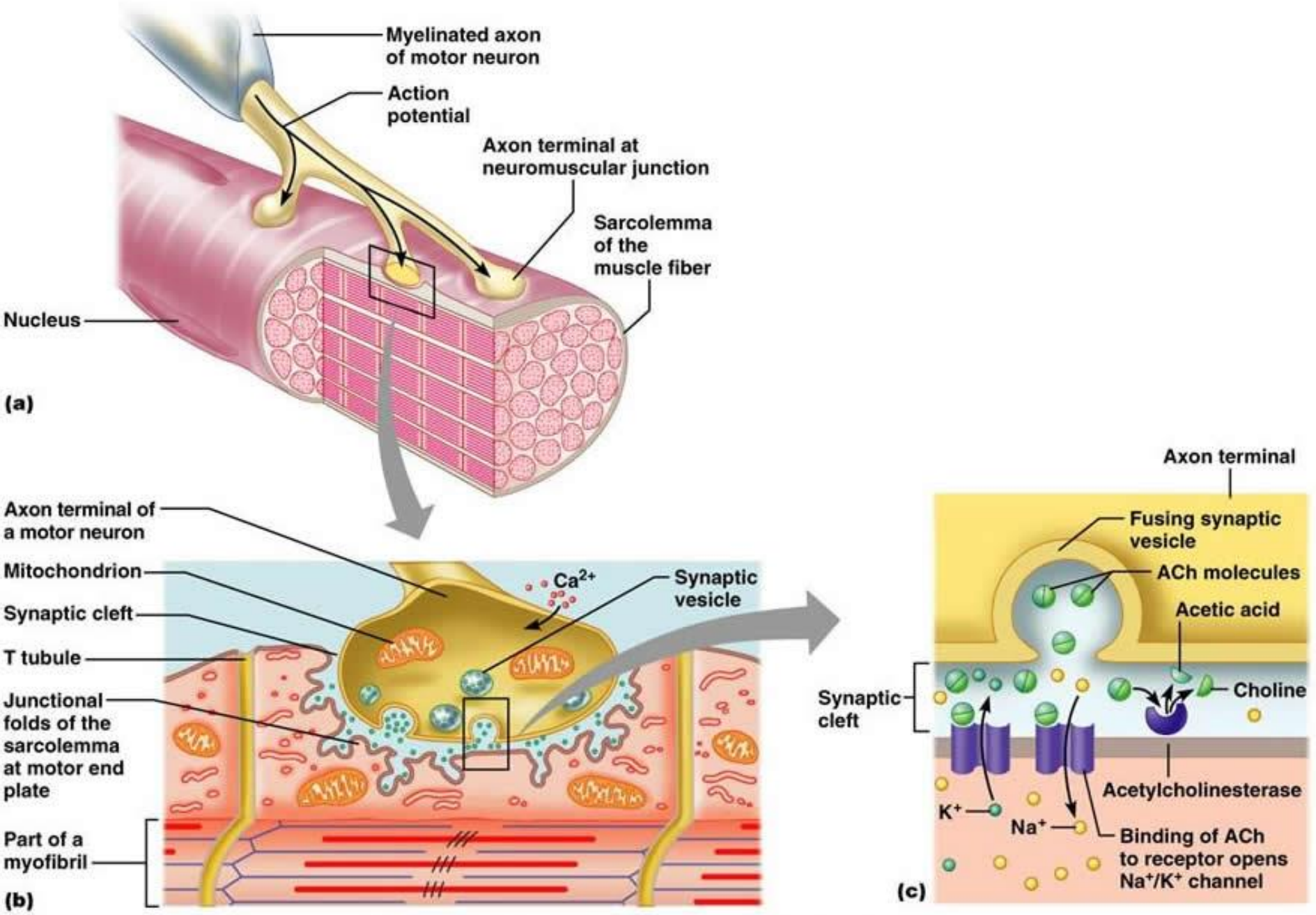
Taken from Sherwook, 2004

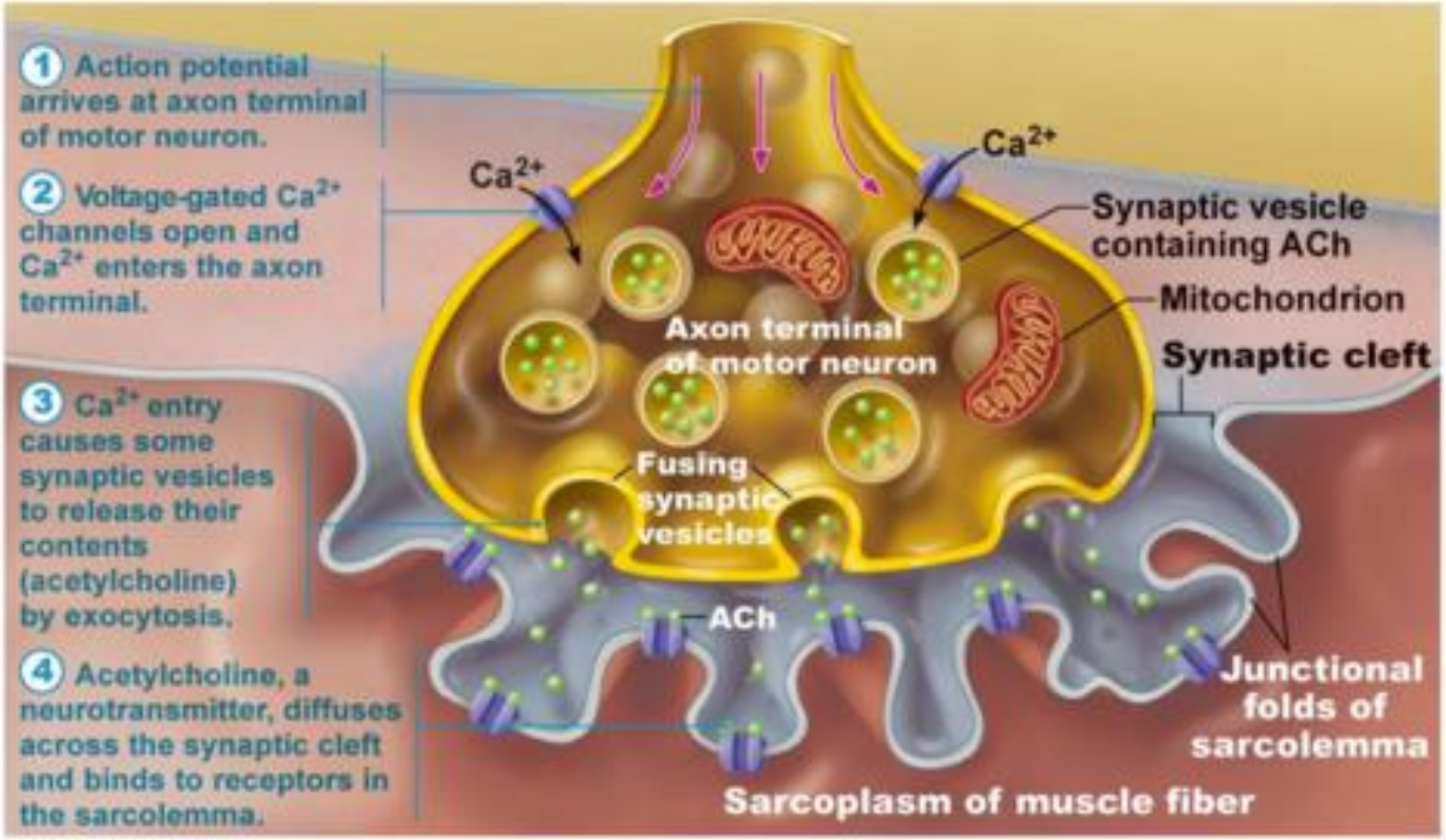
Excitation – Contraction Coupling

- https://www.youtube.com/watch?v=LlgaziPCFU0

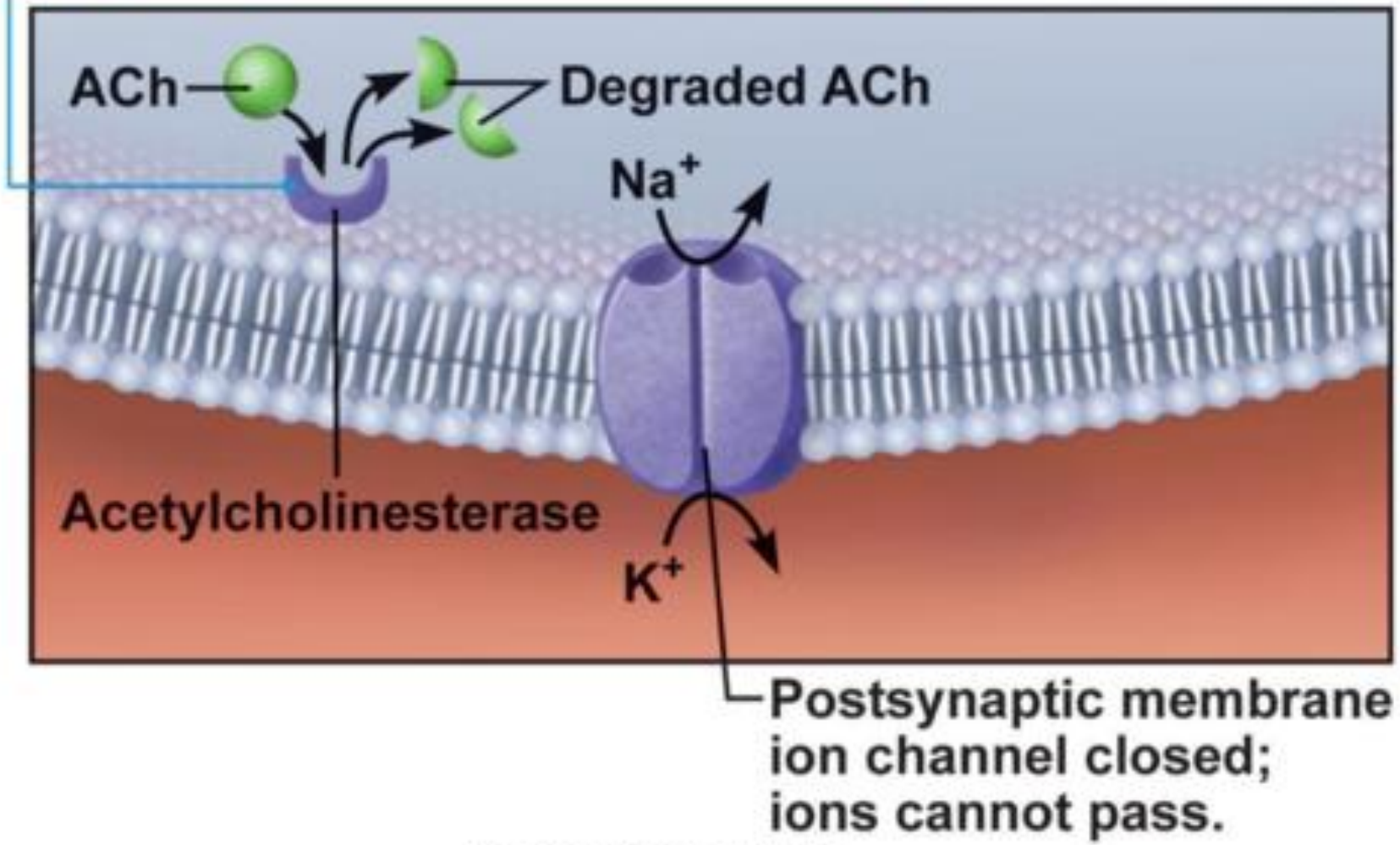


Acetate 58 (Figure 7-4)

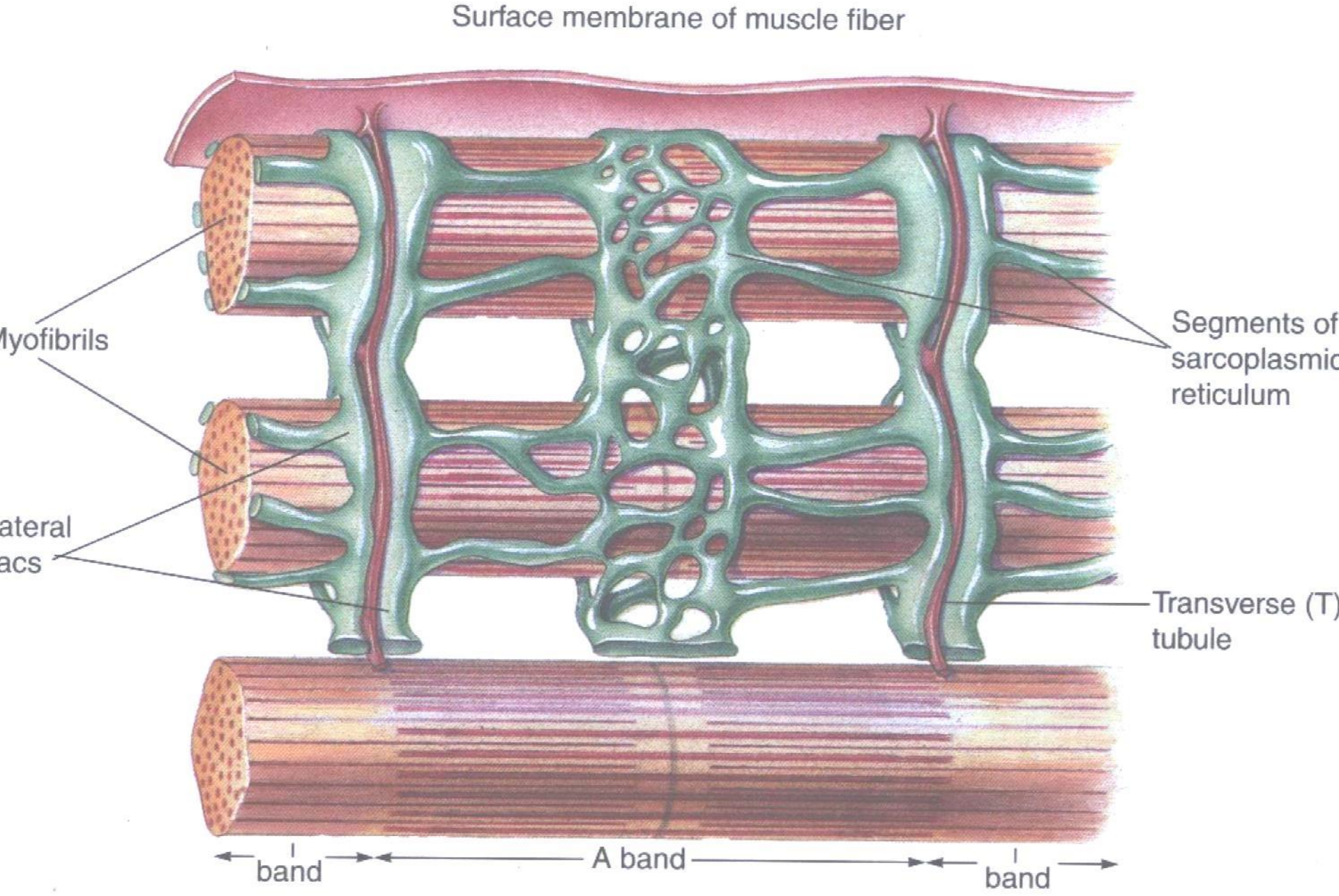

Myelinated axon of motor neuron
Action potential
Axon terminal at neuromuscular junction
Sarcolemma of the muscle fiber
Nucleus
(a)
Axon terminal of a motor neuron
Mitochondrion
Synaptic cleft
T tubule
Junctional folds of the sarcolemma at motor end plate
Part of a myofibril
(b)
Ca2+
Synaptic vesicle
Axon terminal
Fusing synaptic vesicle
ACh molecules
Acetic acid
Synaptic cleft
Choline
Acetylcholinesterase
K+
Na+
Binding of ACh to receptor opens Na+/K+ channel
(c)



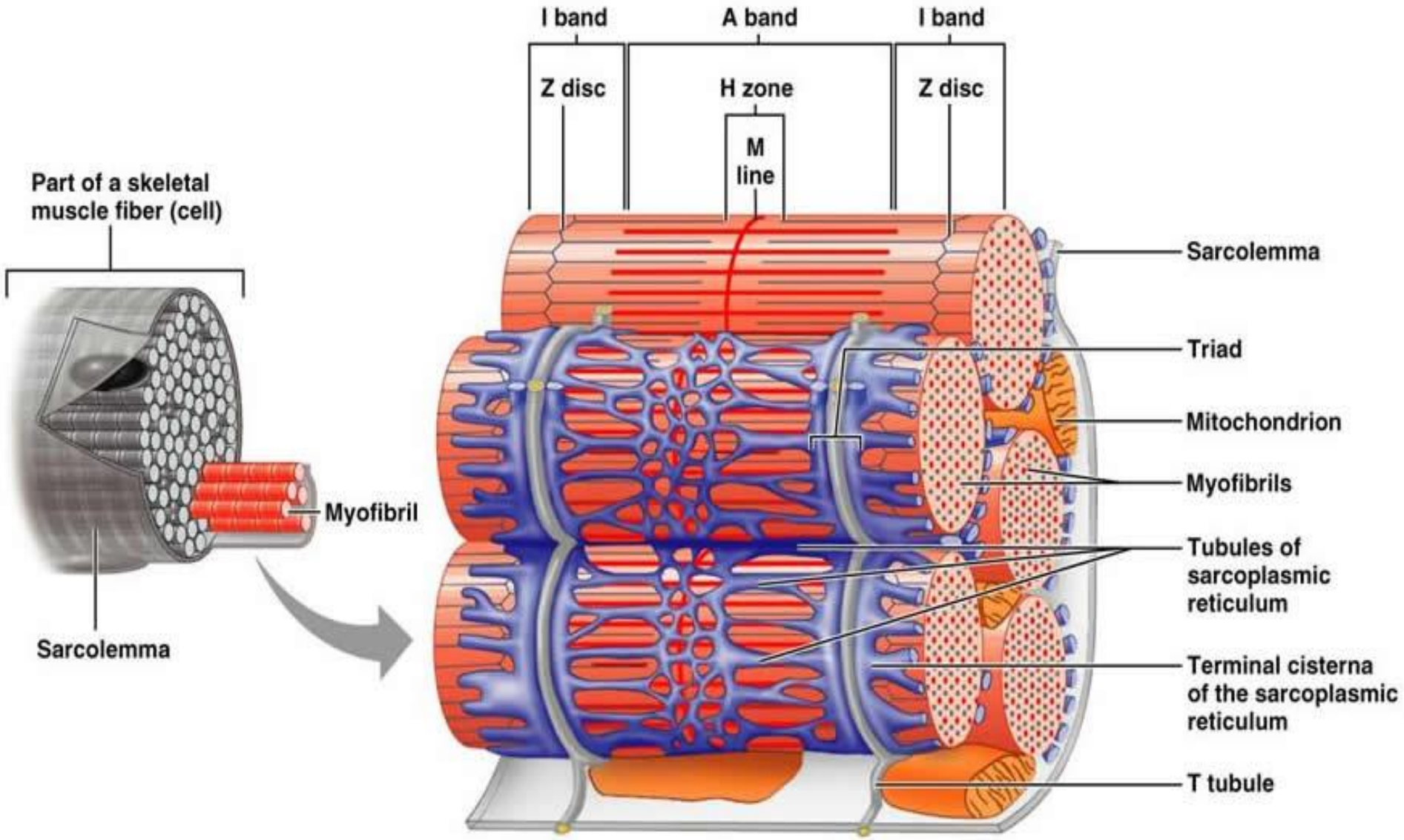
⑥ ACh effects are terminated by its enzymatic breakdown in the synaptic cleft by acetylcholinesterase.

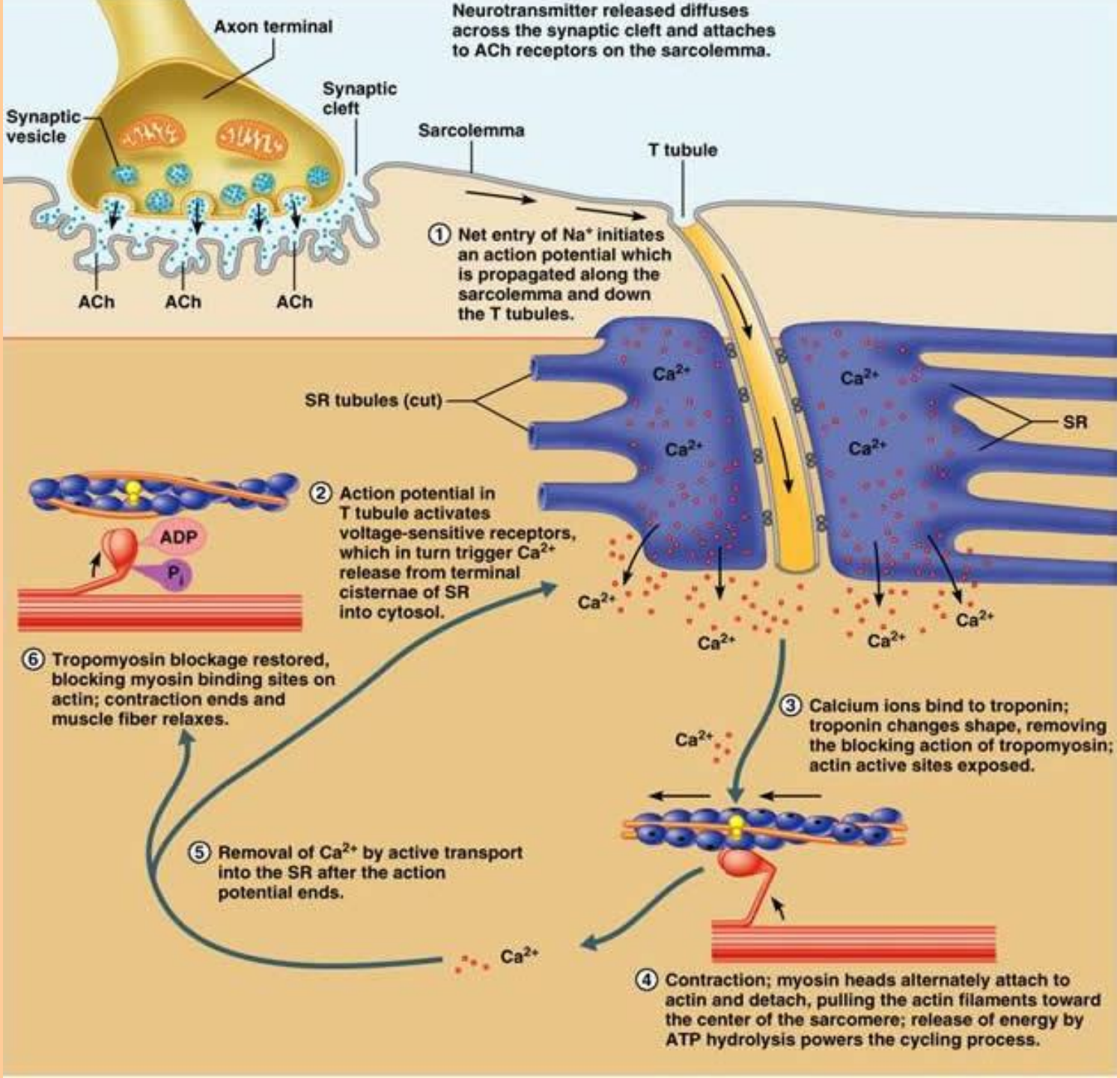


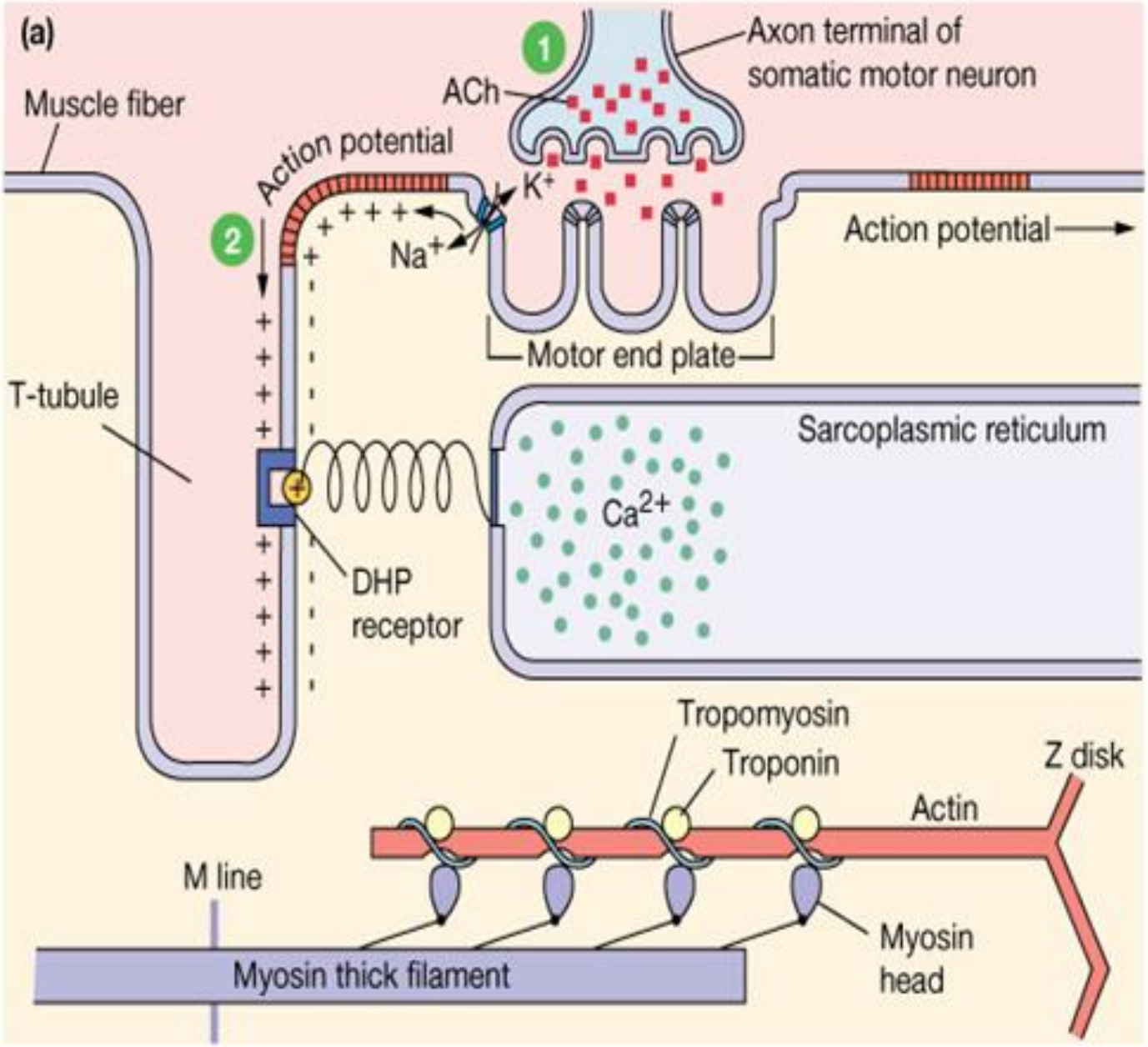
T Tubules and Sarcoplasmic Reticulum in Relationship to Myofibrils



te 65 (Figure 8-10)


I band
A band
I band
Z disc
H zone
Z disc
M line
Part of a skeletal muscle fiber (cell)
Sarcolemma
Triad
Mitochondrion
Myofibrils
Myofibril
Tubules of sarcoplasmic reticulum
Terminal cisterna of the sarcoplasmic reticulum
Sarcolemma
T tubule


Axon terminal
Neurotransmitter released diffuses across the synaptic cleft and attaches to ACh receptors on the sarcolemma.
Synaptic vesicle
Synaptic cleft
Sarcolemma
T tubule
ACh
ACh
ACh
1 Net entry of Na+ initiates an action potential which is propagated along the sarcolemma and down the T tubules.
SR tubules (cut)
SR
Ca2+
2 Action potential in T tubule activates voltage-sensitive receptors, which in turn trigger Ca2+ release from terminal cisternae of SR into cytosol.
ADP
Pi
3 Calcium ions bind to troponin; troponin changes shape, removing the blocking action of tropomyosin; actin active sites exposed.
4 Contraction; myosin heads alternately attach to actin and detach, pulling the actin filaments toward the center of the sarcomere; release of energy by ATP hydrolysis powers the cycling process.
5 Removal of Ca2+ by active transport into the SR after the action potential ends.
6 Tropomyosin blockage restored, blocking myosin binding sites on actin; contraction ends and muscle fiber relaxes.



1 Somatic motor neuron releases ACh at neuromuscular junction.

2 Net entry of Na^+ through ACh receptor-channel initiates a muscle action potential.

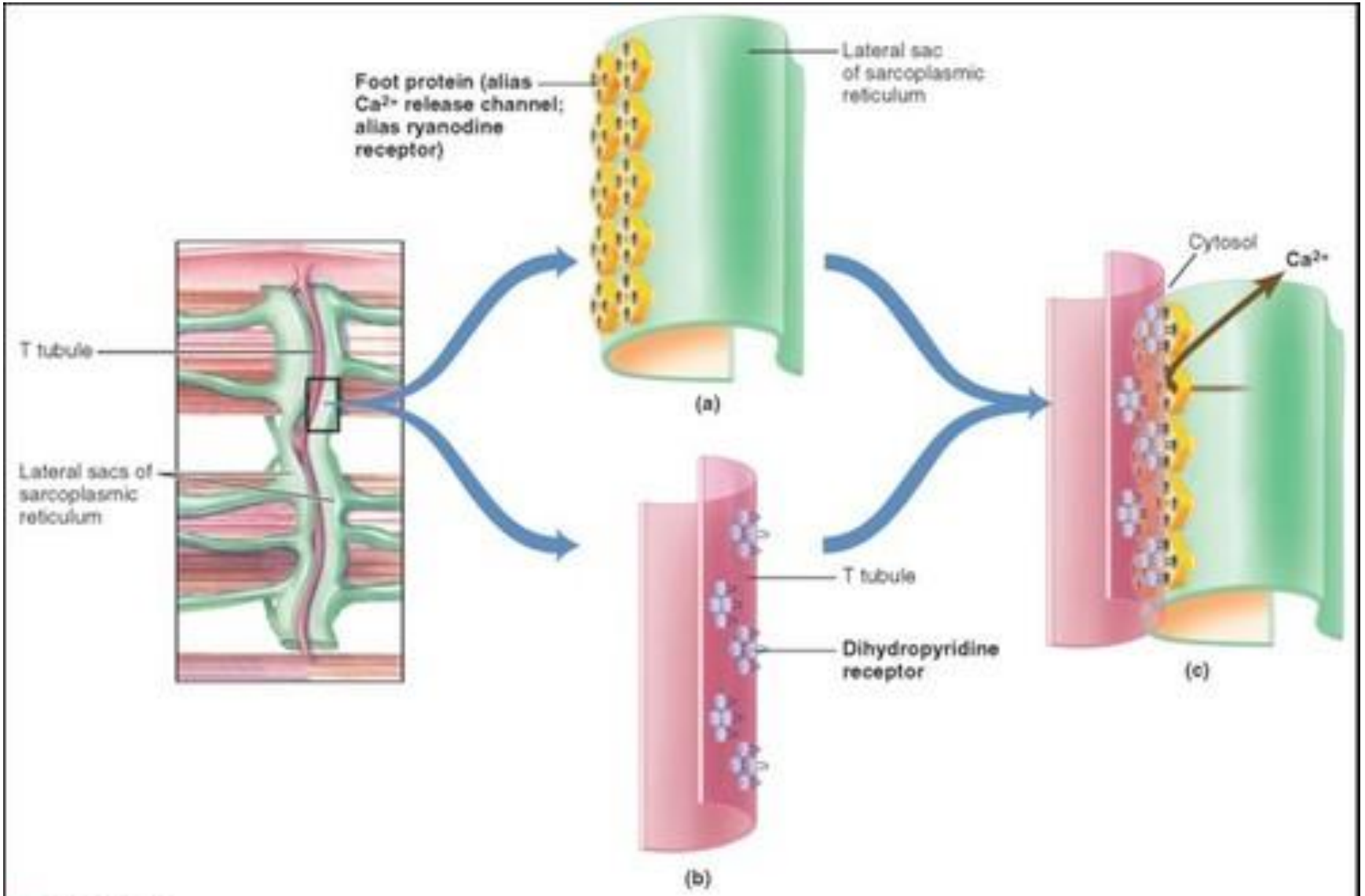
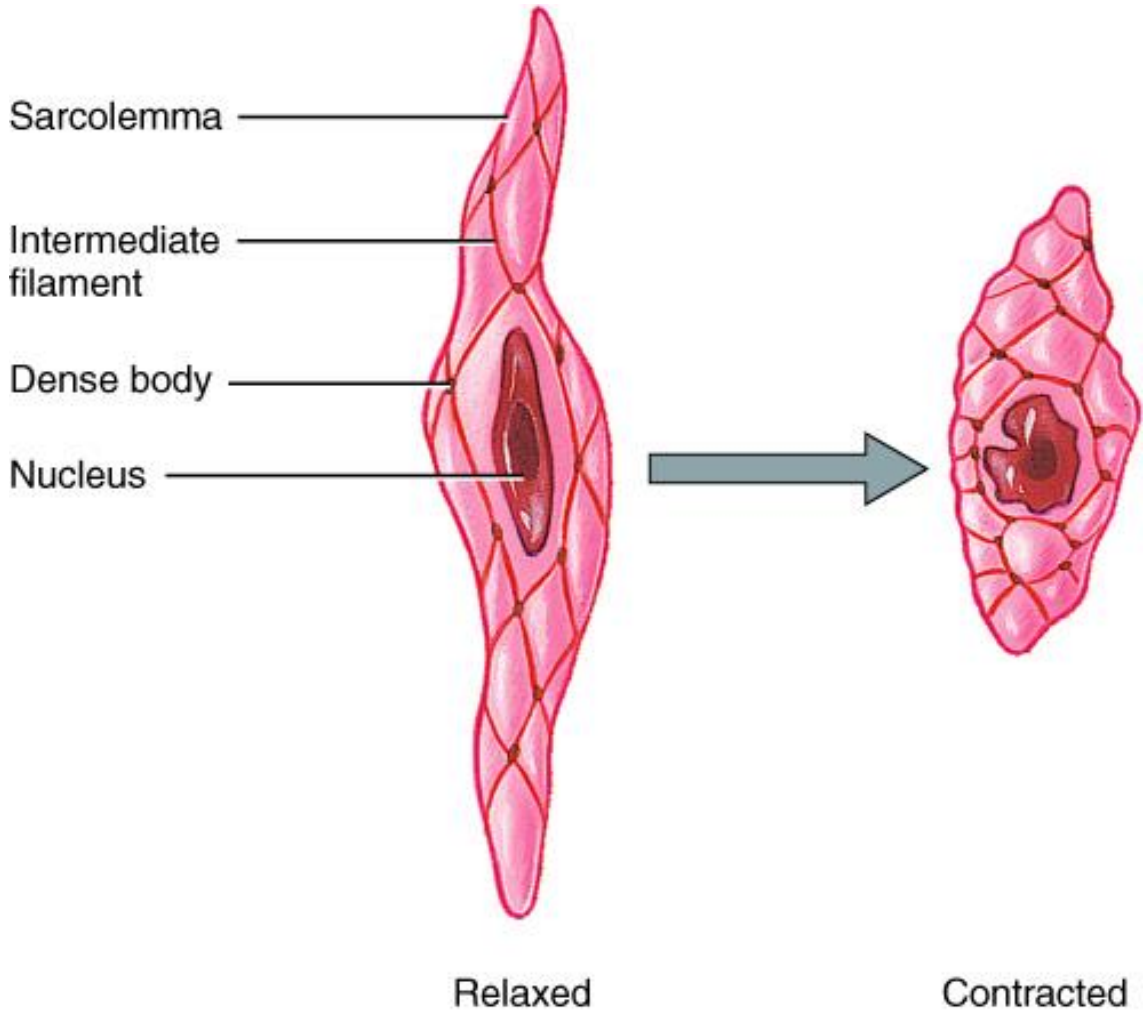


FIGURE 8-11

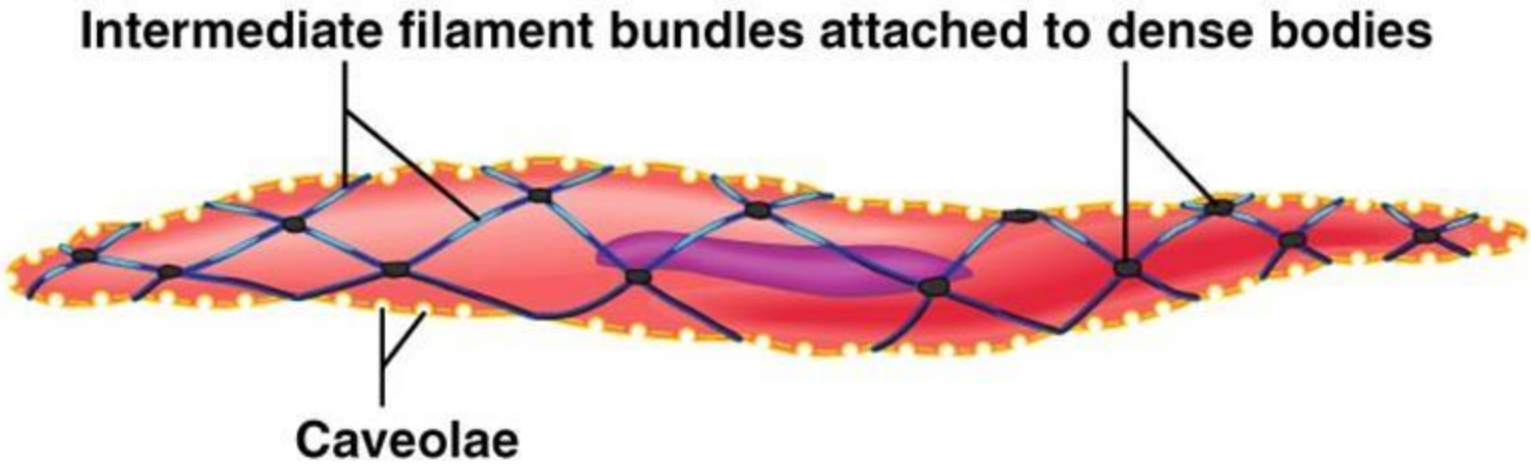
Relationship between a T tubule and the adjacent lateral sacs of the sarcoplasmic reticulum

SMOOTH MUSCLE CELLS

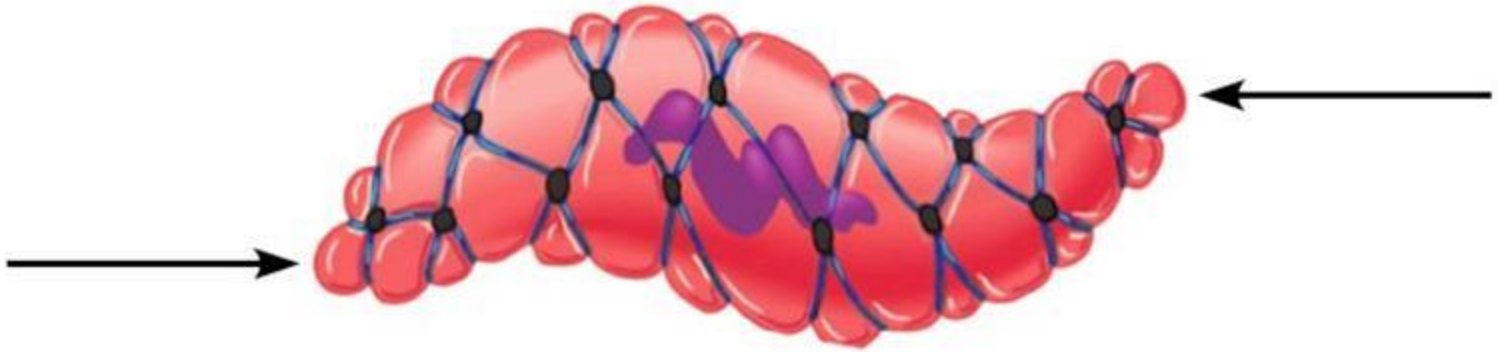
Fig. 10.19



10.19

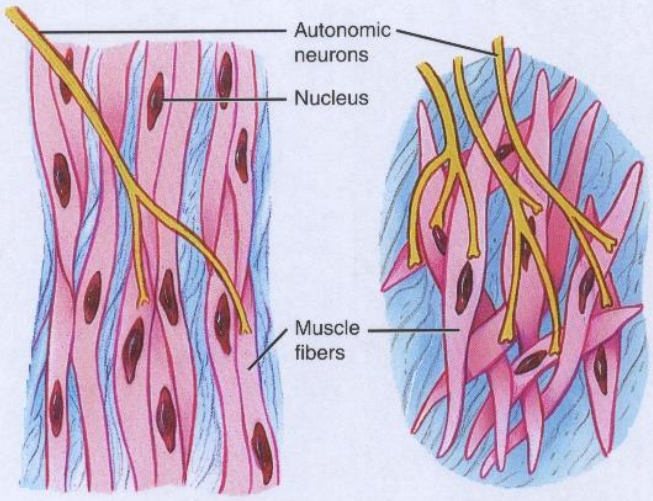


(a) Relaxed smooth muscle cell



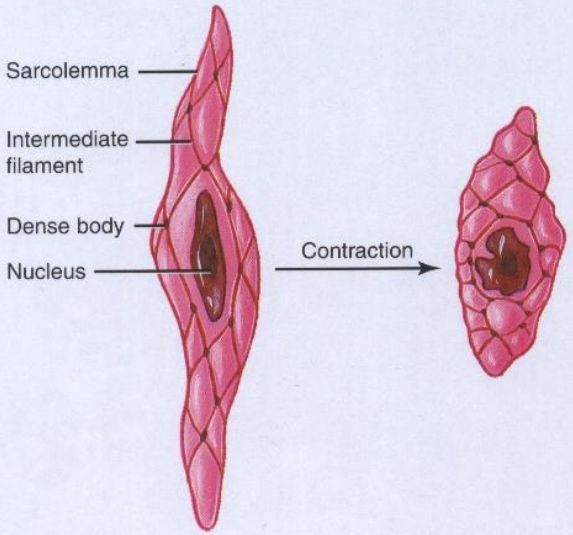
(b) Contracted smooth muscle cell

Figure 9.26



(a) Visceral (single-unit) smooth muscle tissue

(b) Multiunit smooth muscle tissue



(c) Details of a smooth muscle fiber

Histology of Smooth Muscle Tissue, Fig# 10.18a-c

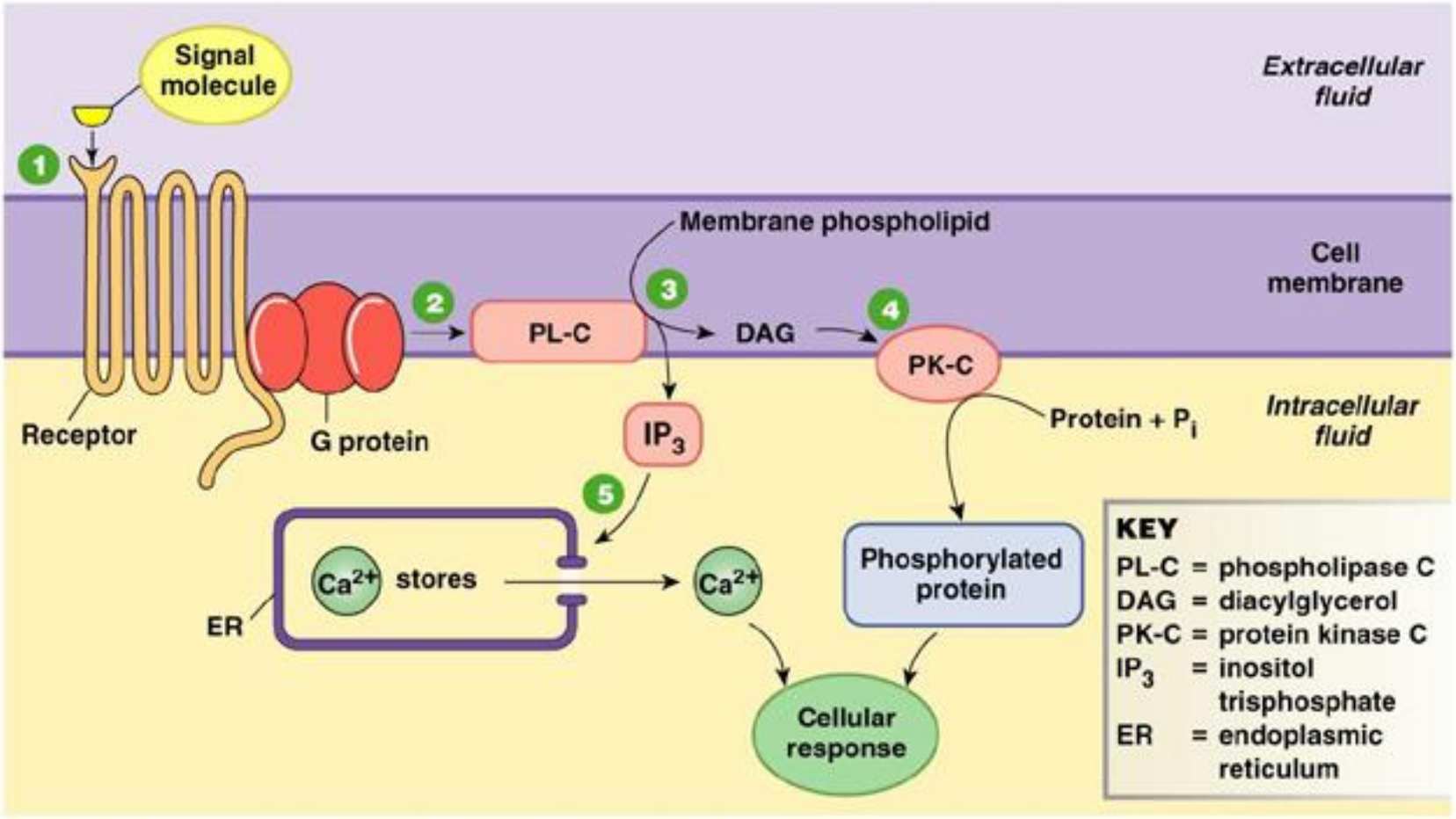


Fig. 6-12

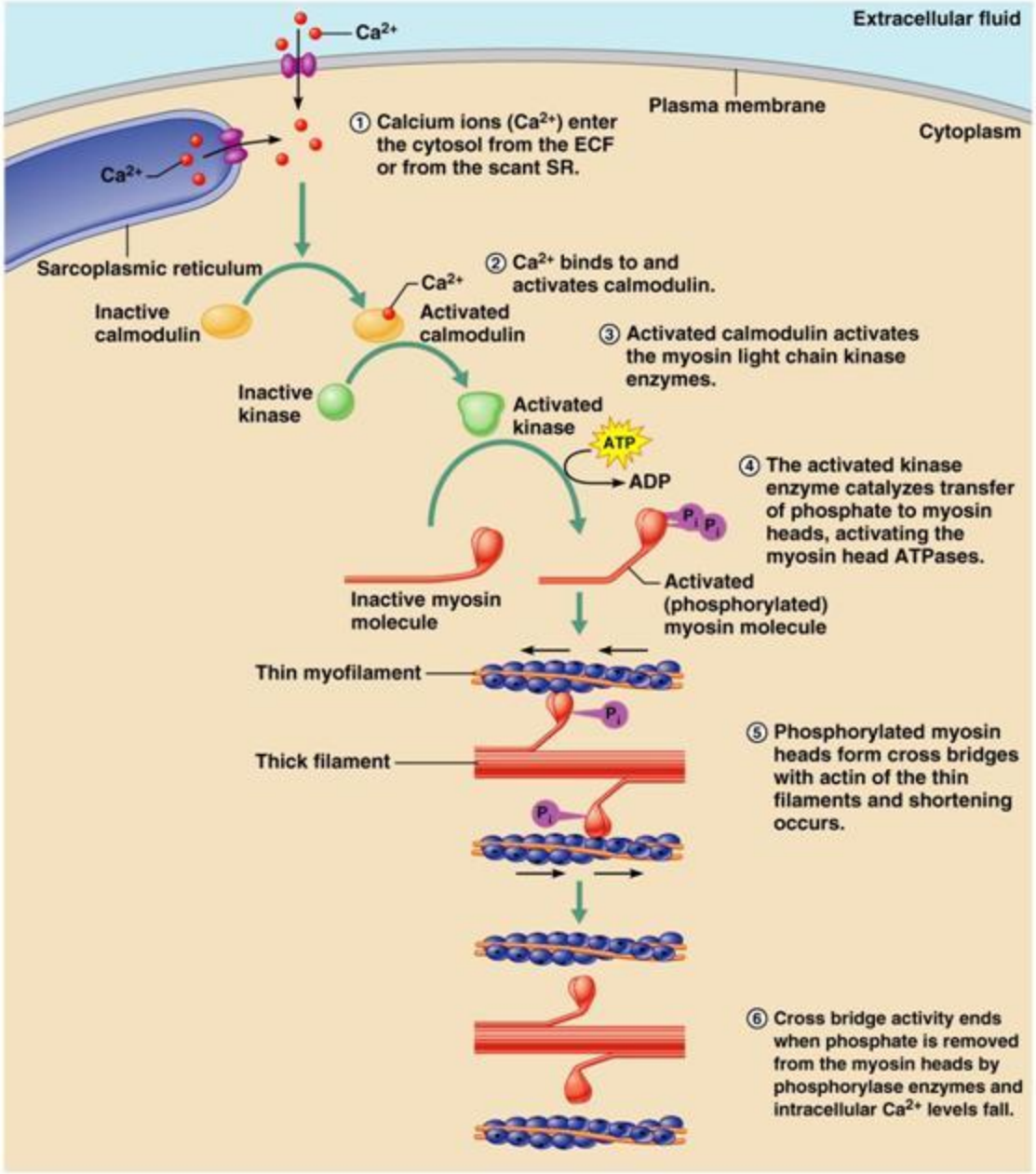
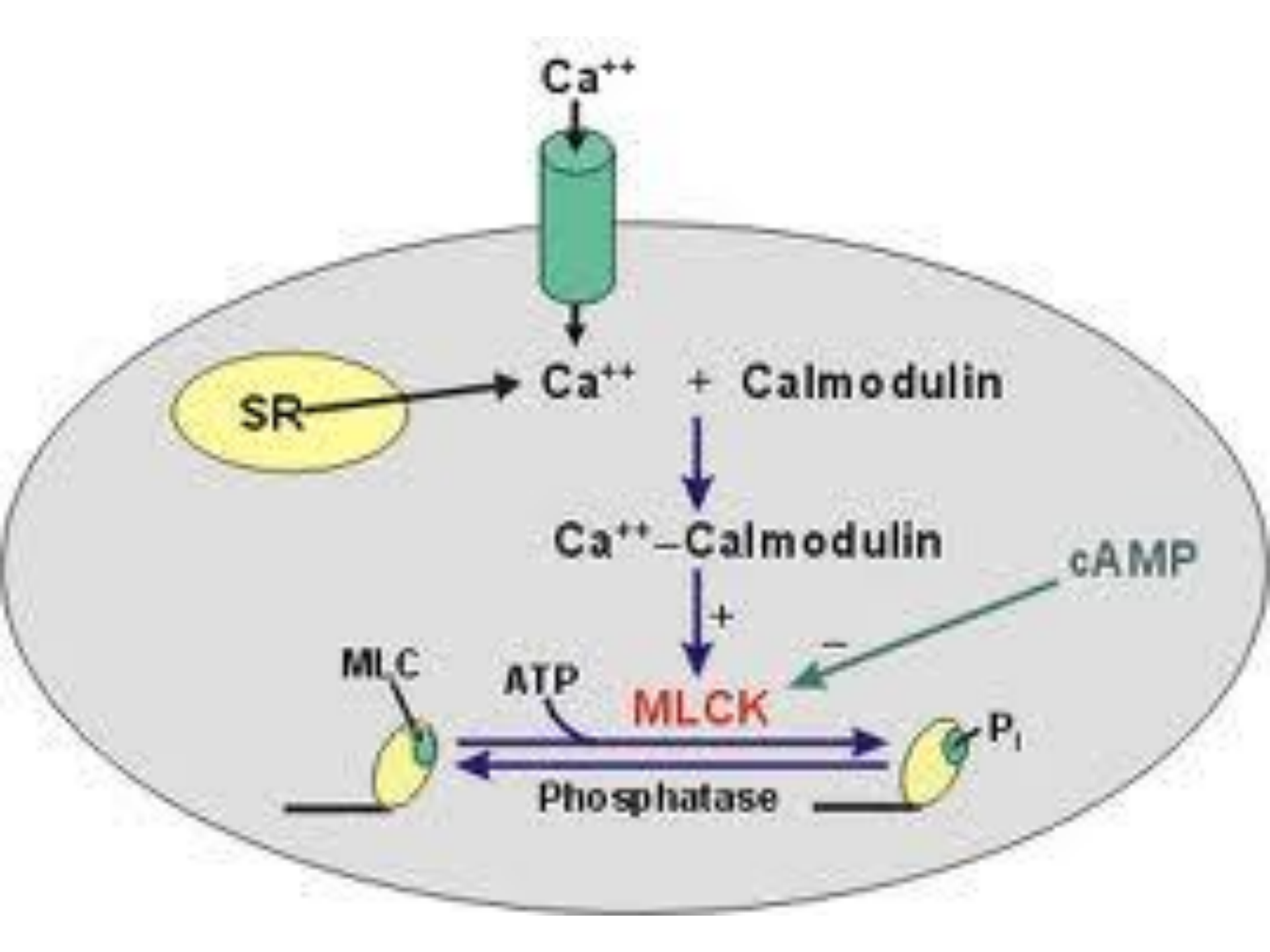


Figure 9.27


Ca++
SR
Ca++ + Calmodulin
Ca++–Calmodulin
cAMP
+
–
MLC
ATP
MLCK
Pi
Phosphatase

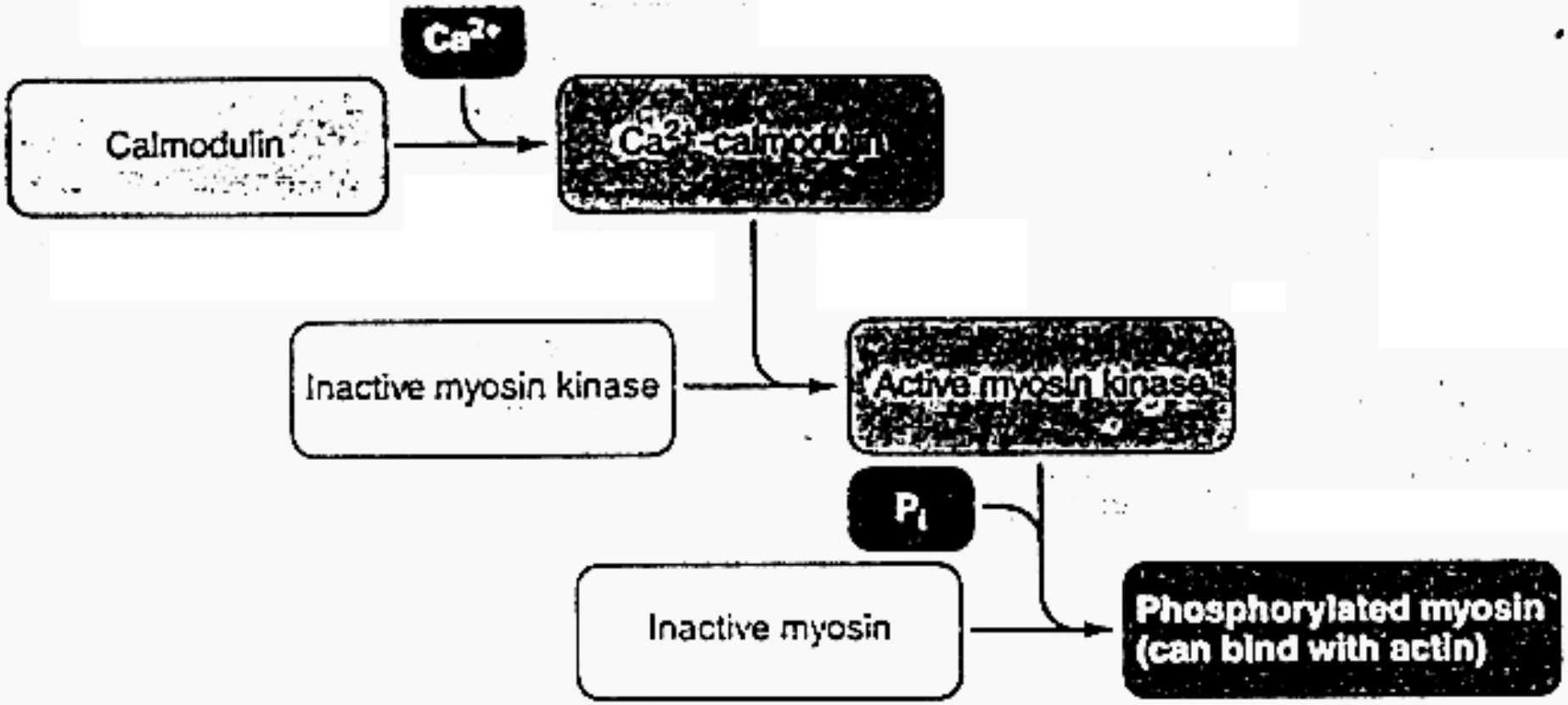

Ca^{2+}
Calmodulin
Ca^{2+}-calmodulin
Inactive myosin kinase
Active myosin kinase
P_i
Inactive myosin
Phosphorylated myosin (can bind with actin)

Table 12.8 | Comparison of Skeletal, Cardiac, and Smooth Muscle

Skeletal Muscle	Cardiac Muscle	Smooth Muscle
Striated; actin and myosin arranged in sarcomeres	Striated; actin and myosin arranged in sarcomeres	Not striated; more actin than myosin; actin inserts into dense bodies and cell membrane
Well-developed sarcoplasmic reticulum and transverse tubules	Moderately developed sarcoplasmic reticulum and transverse tubules	Poorly developed sarcoplasmic reticulum; no transverse tubules
Contains troponin in the thin filaments	Contains troponin in the thin filaments	Contains calmodulin, a protein that, when bound to Ca^{2+}, activates the enzyme myosin light-chain kinase
Ca^{2+} released into cytoplasm from sarcoplasmic reticulum	Ca^{2+} enters cytoplasm from sarcoplasmic reticulum and extracellular fluid	Ca^{2+} enters cytoplasm from extracellular fluid, sarcoplasmic reticulum, and perhaps mitochondria
Cannot contract without nerve stimulation; denervation results in muscle atrophy	Can contract without nerve stimulation; action potentials originate in pacemaker cells of heart	Maintains tone in absence of nerve stimulation; visceral smooth muscle produces pacemaker potentials; denervation results in hypersensitivity to stimulation
Muscle fibers stimulated independently; no gap junctions	Gap junctions present as intercalated discs	Gap junctions generally present