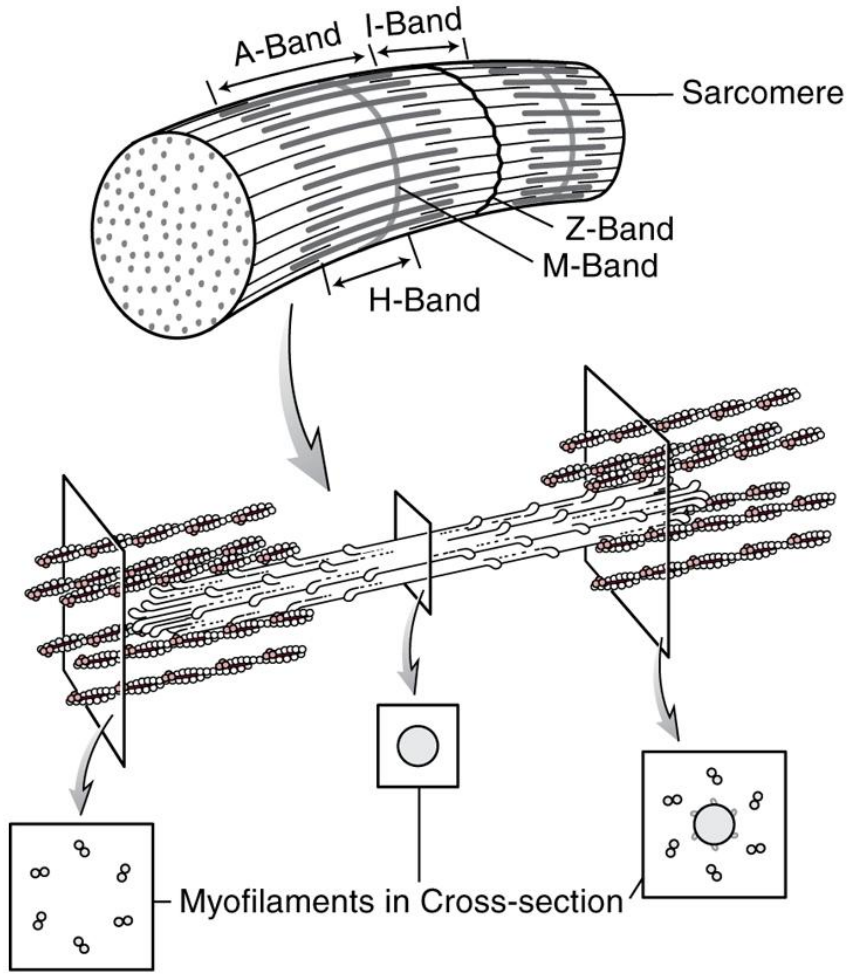
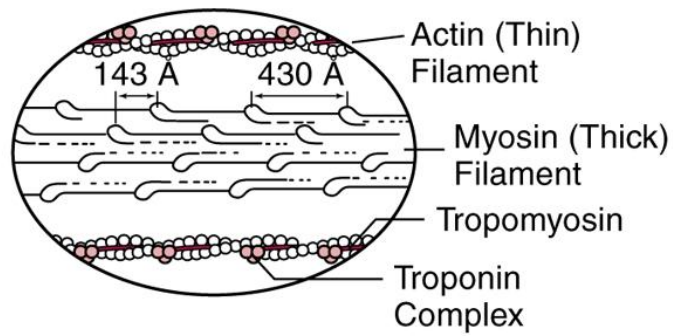
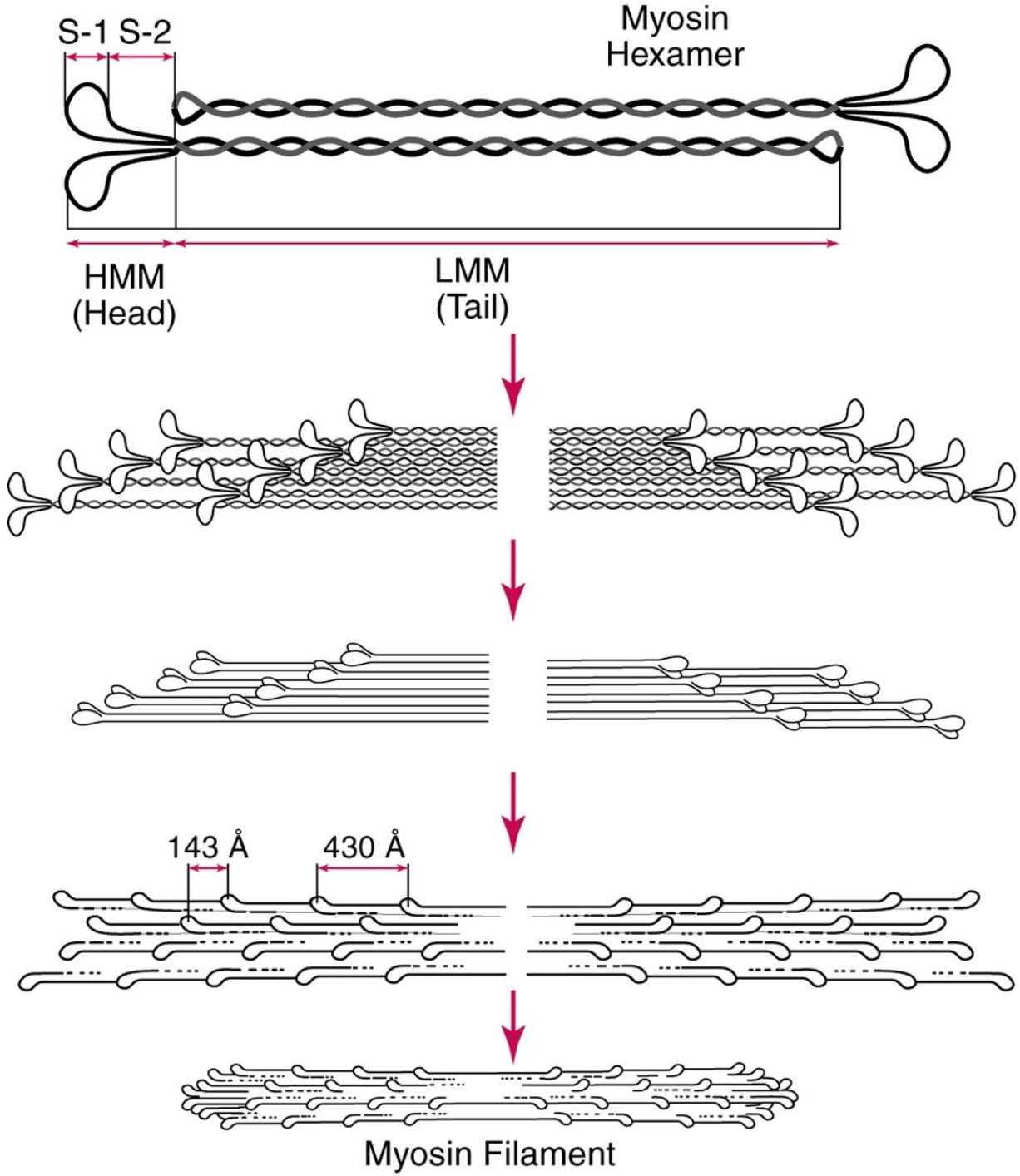
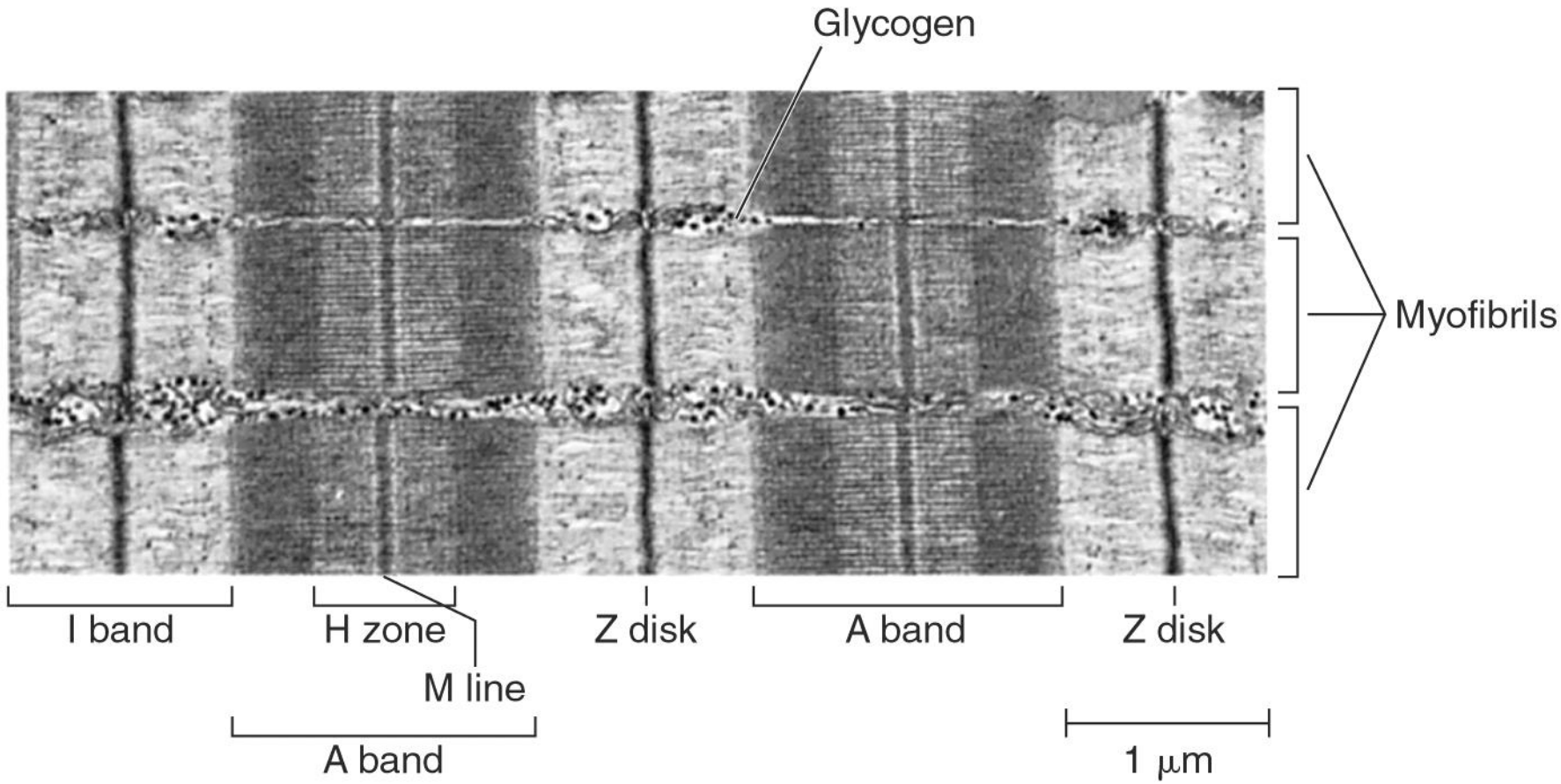
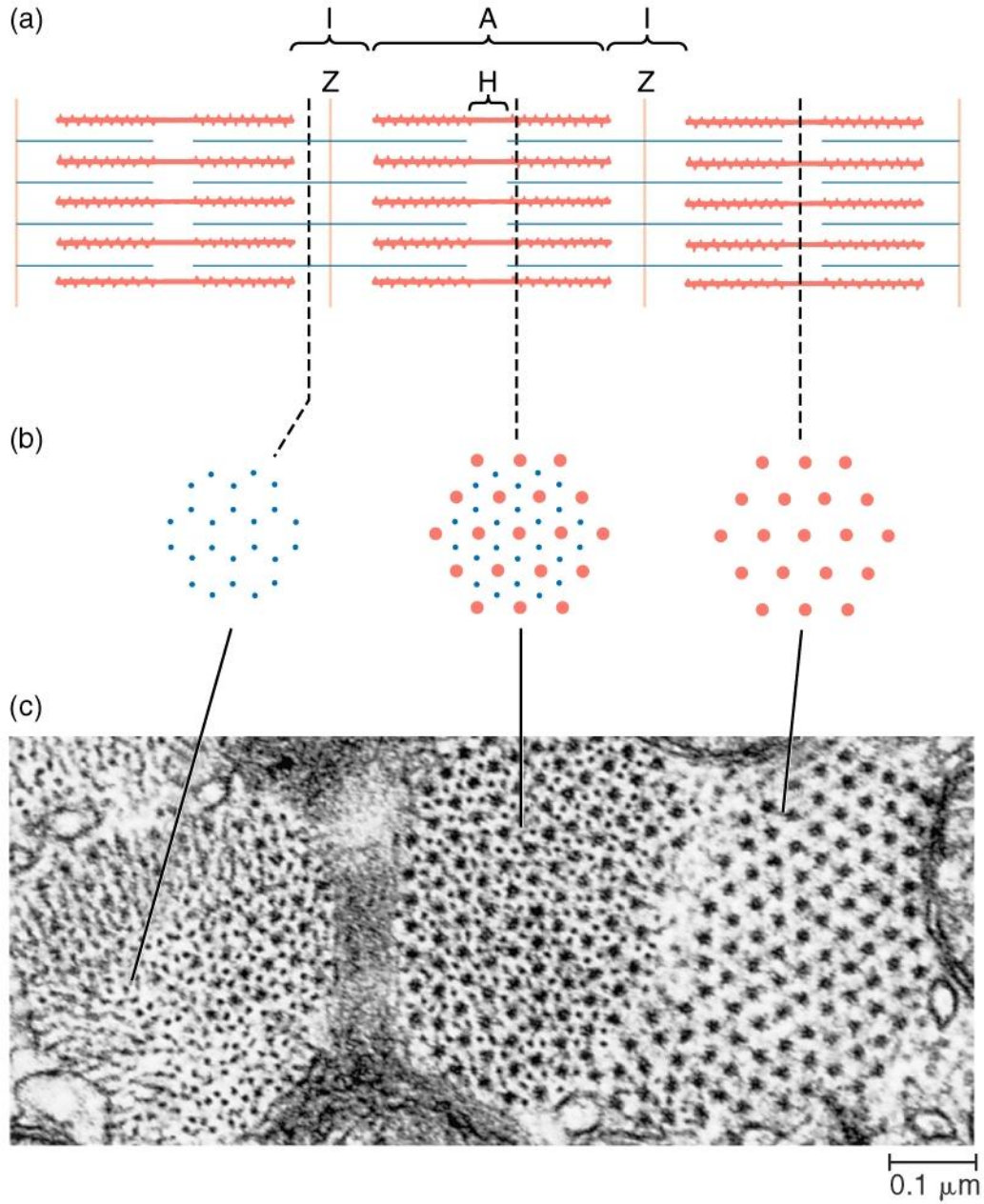
Bio 550 spring 2026

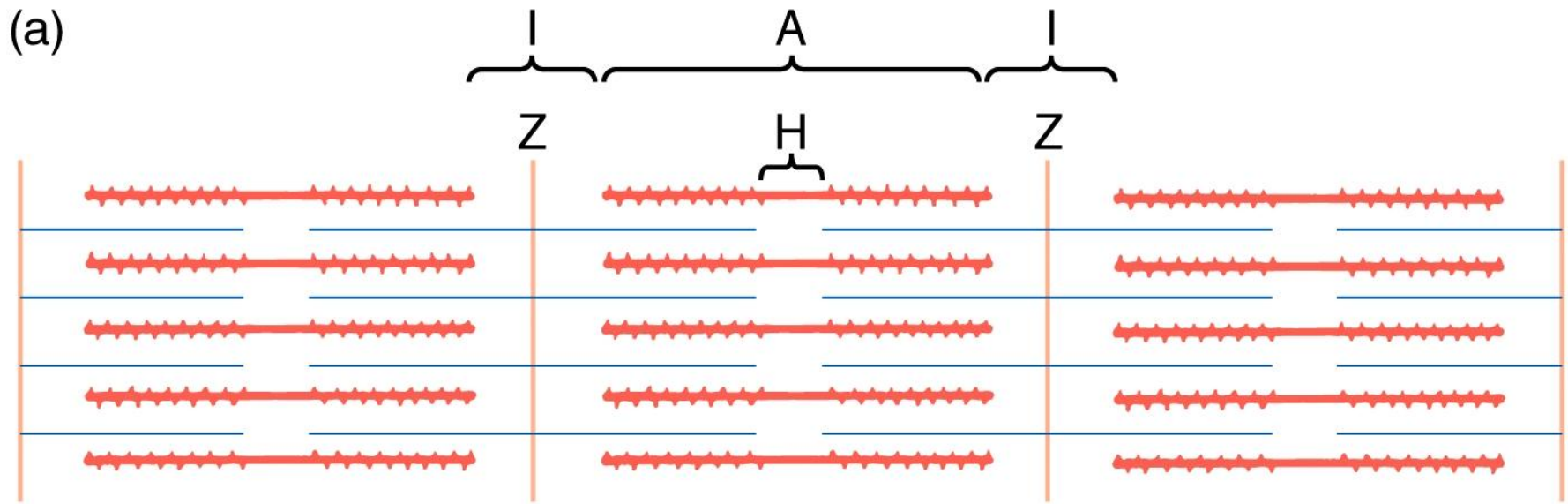




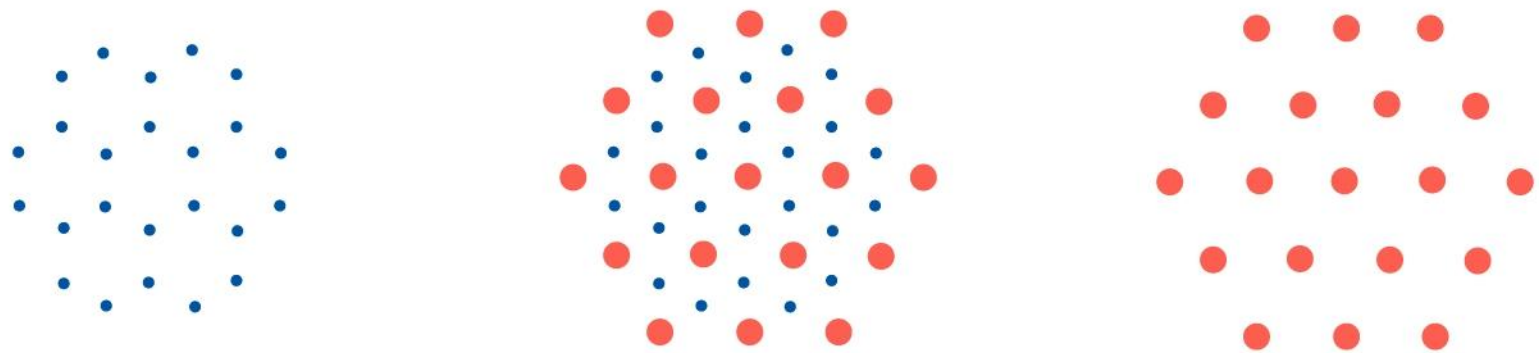


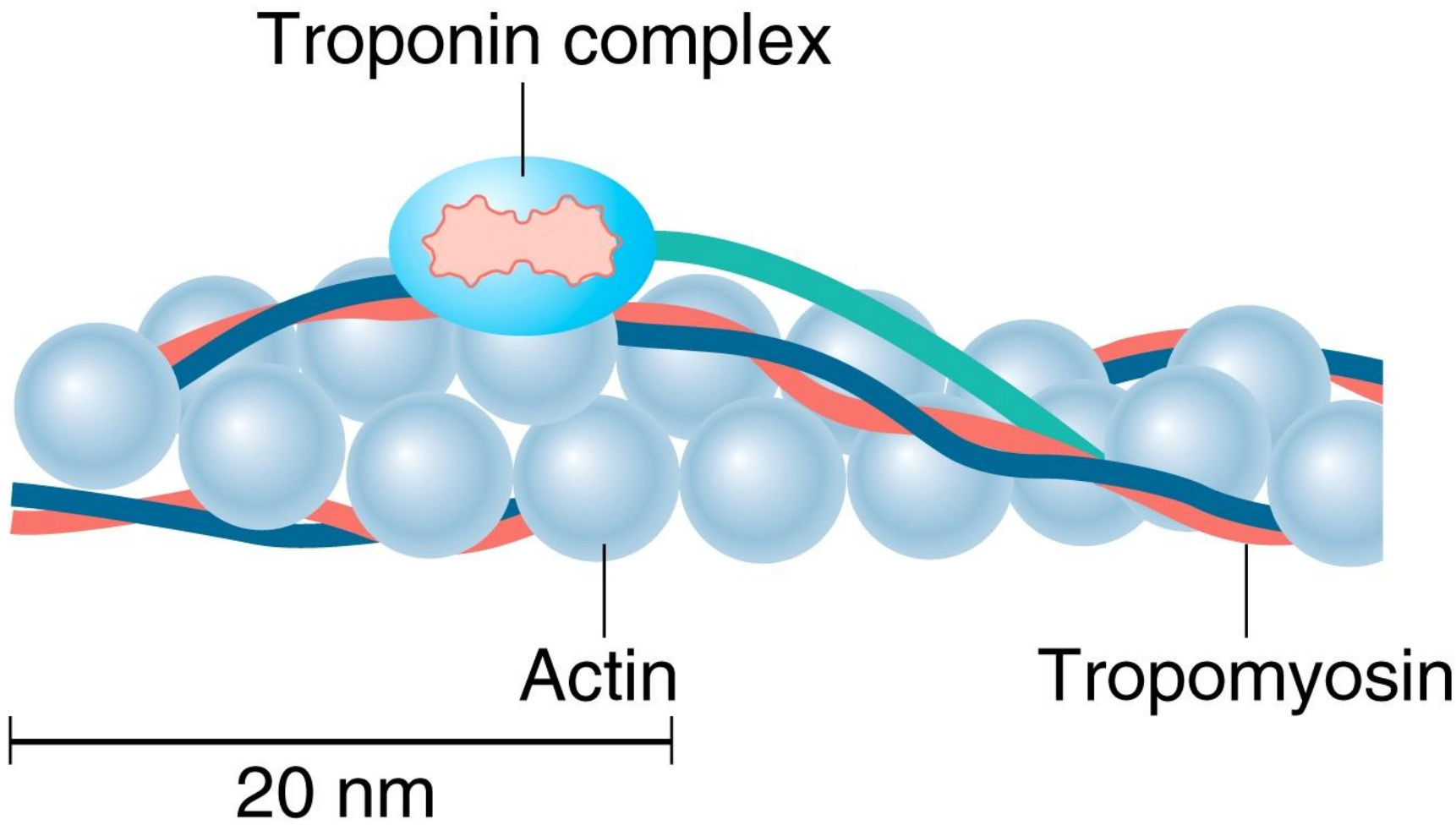

Glycogen
Myofibrils
I band
H zone
Z disk
A band
Z disk
M line
A band
1 μm

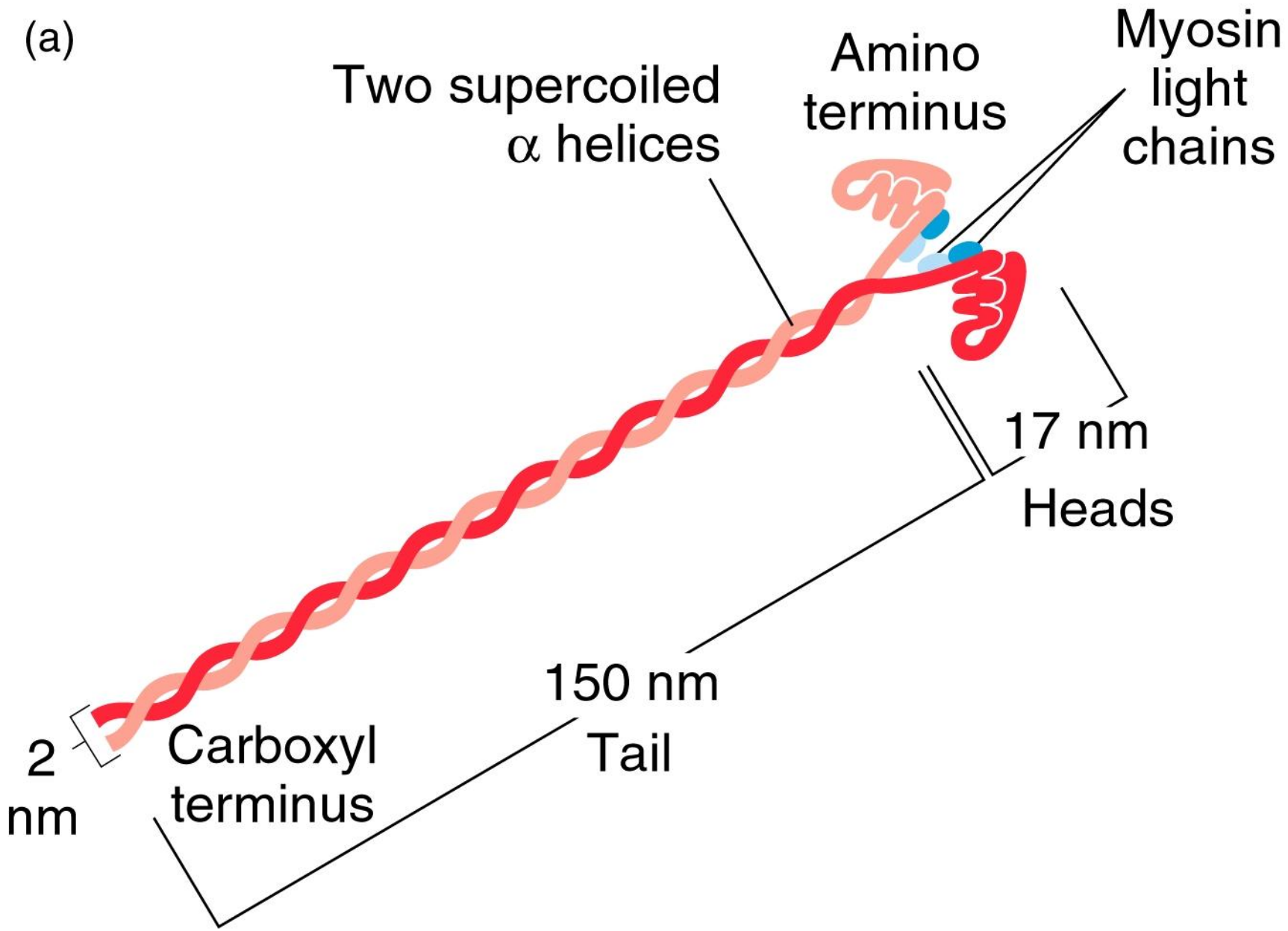

(a)
I
A
I
Z
H
Z
(b)
(c)
0.1 μm


(a)
I
A
I
Z
H
Z

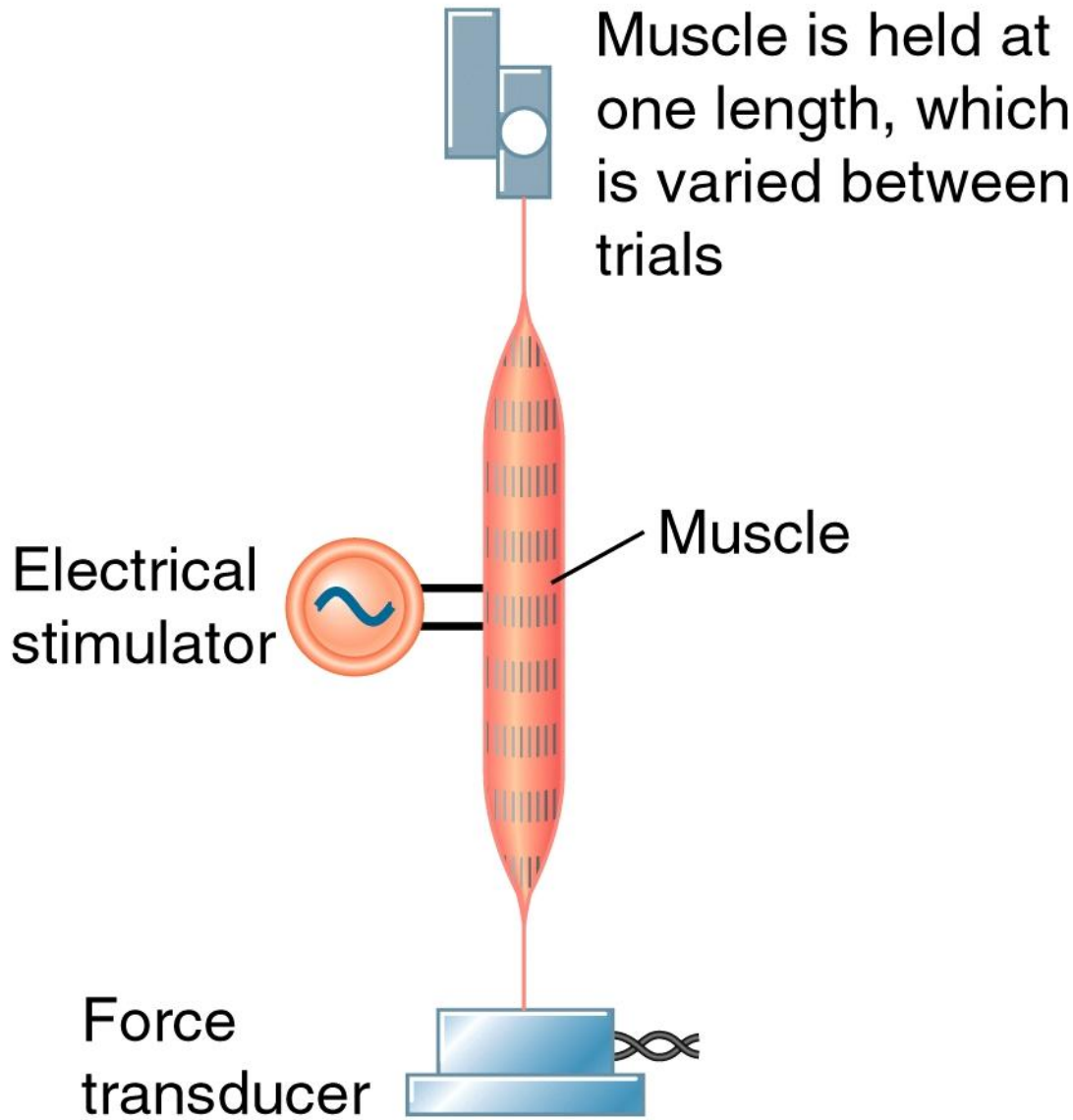
(b)

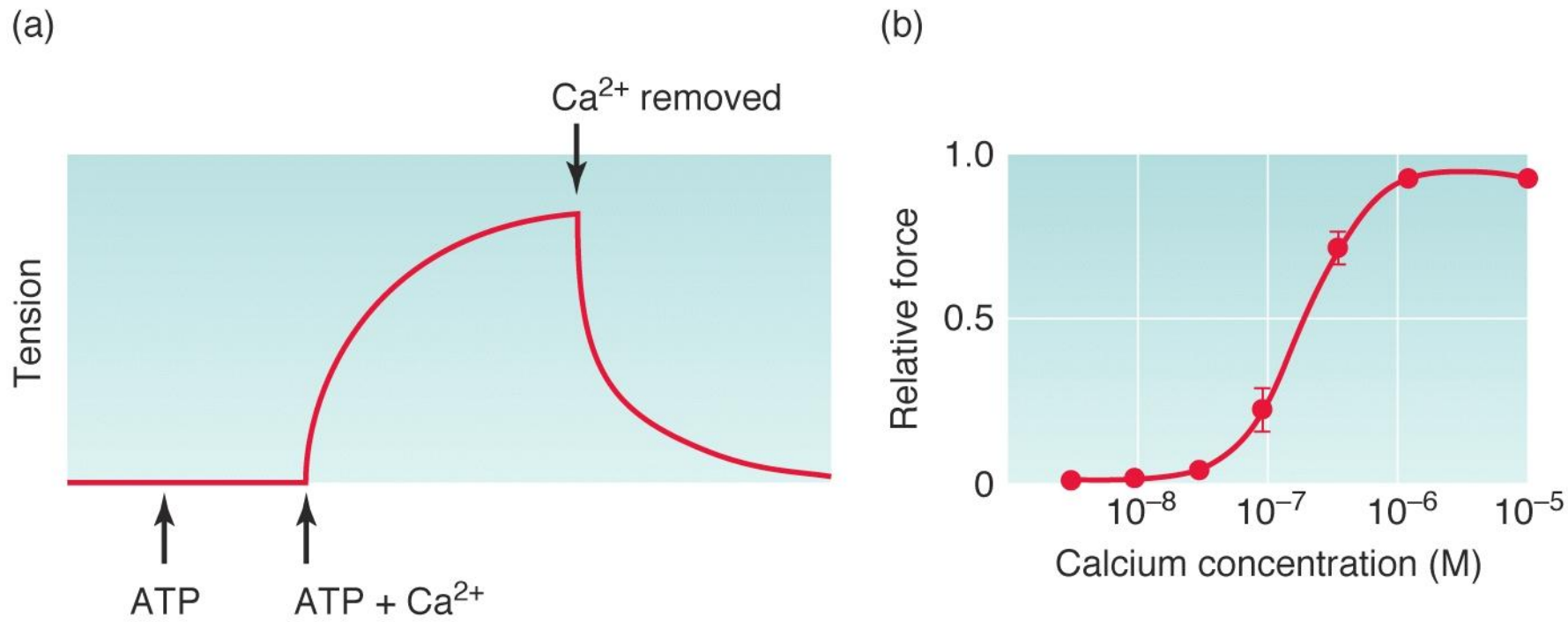


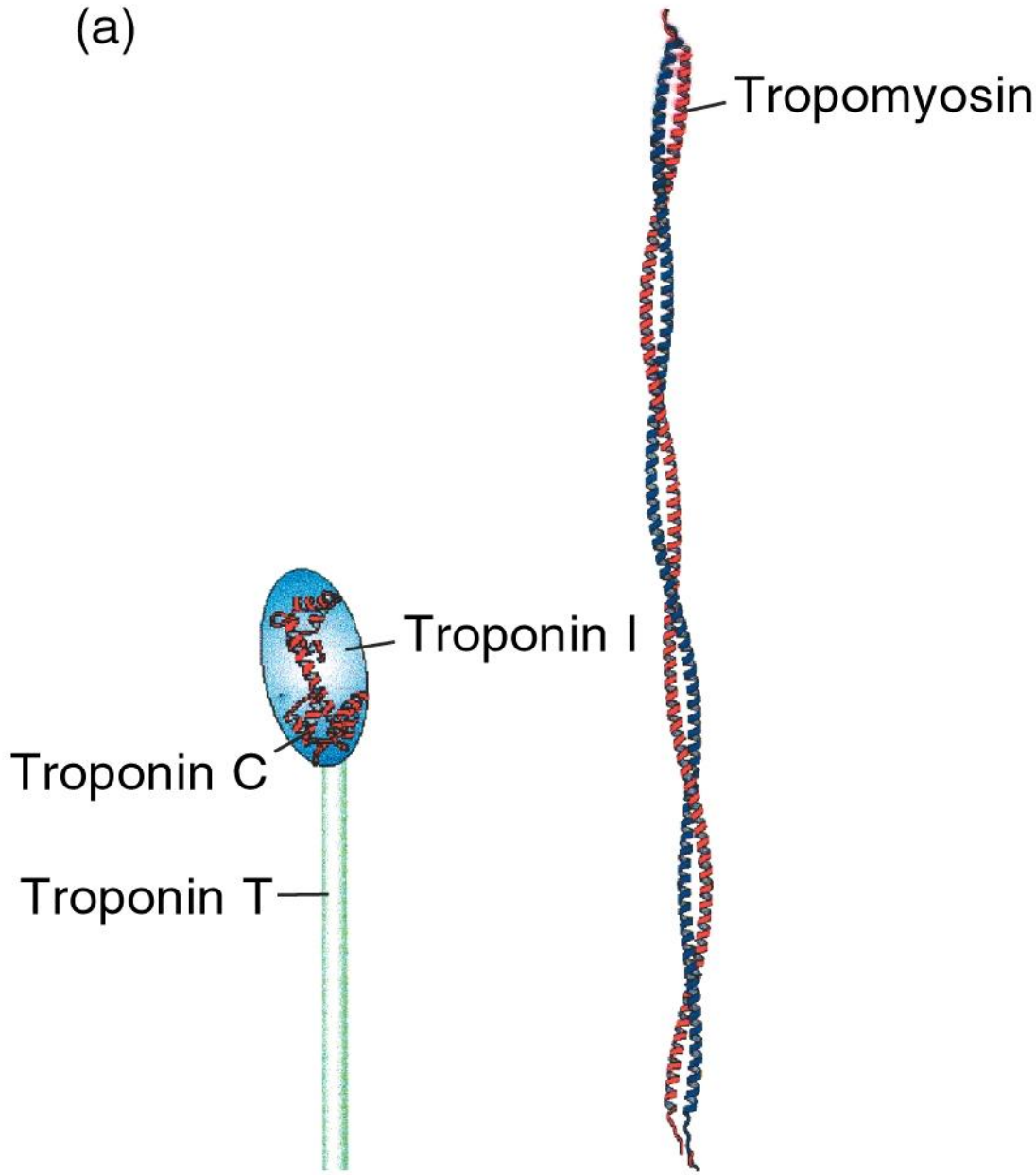

Troponin complex
Actin
Tropomyosin
20 nm

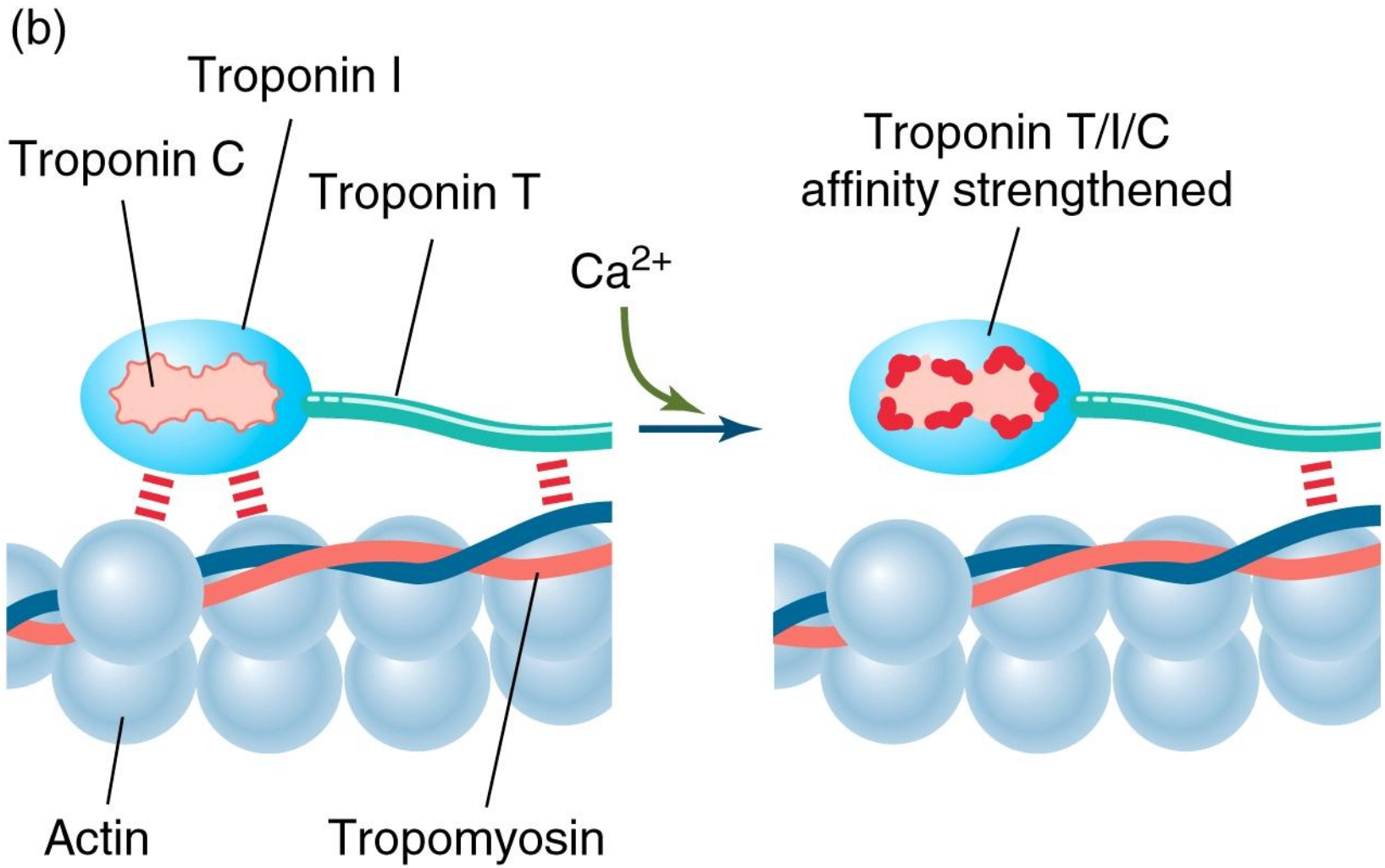

(a)
Two supercoiled α helices
Amino terminus
Myosin light chains
17 nm
Heads
150 nm
Tail
2 nm
Carboxyl terminus

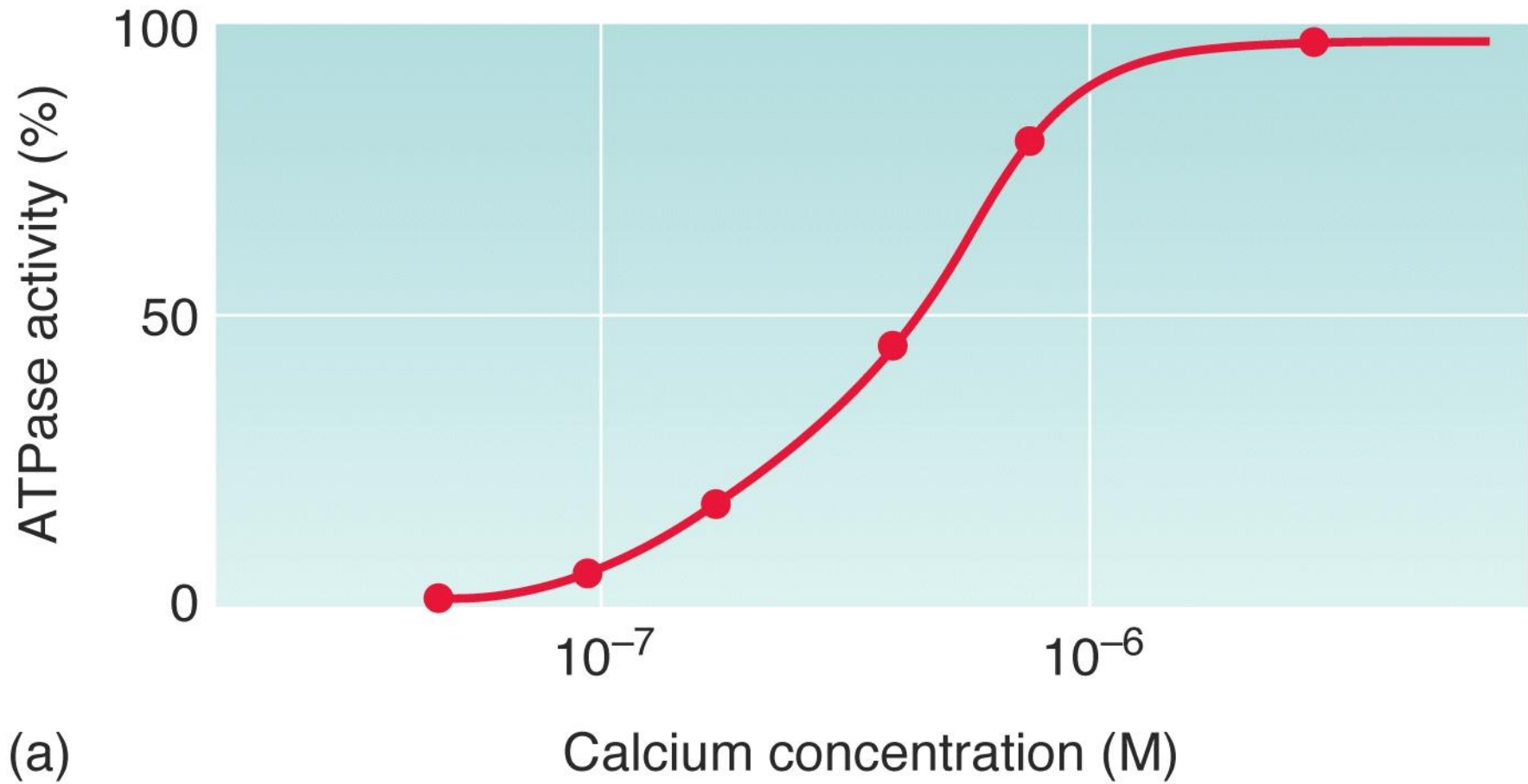
(c)


Muscle is held at one length, which is varied between trials
Muscle
Electrical stimulator
Force transducer


(a)
Ca2+ removed
Tension
ATP
ATP + Ca2+
(b)
1.0
0.5
0
Relative force
10–8
10–7
10–6
10–5
Calcium concentration (M)

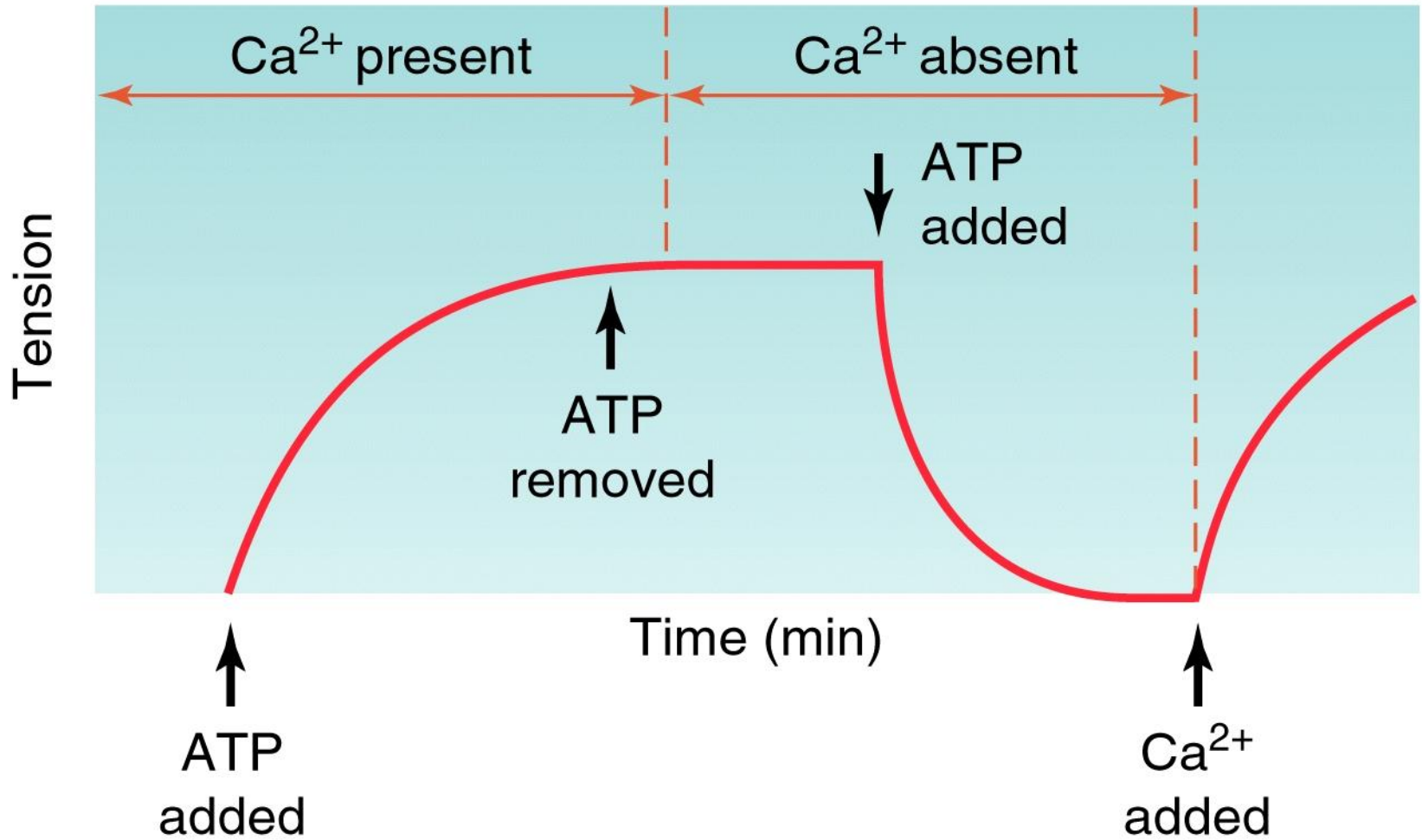

(a)
Tropomyosin
Troponin I
Troponin C
Troponin T


(b)
Troponin I
Troponin C
Troponin T
Ca^{2+}
Troponin T/I/C
affinity strengthened
Actin
Tropomyosin

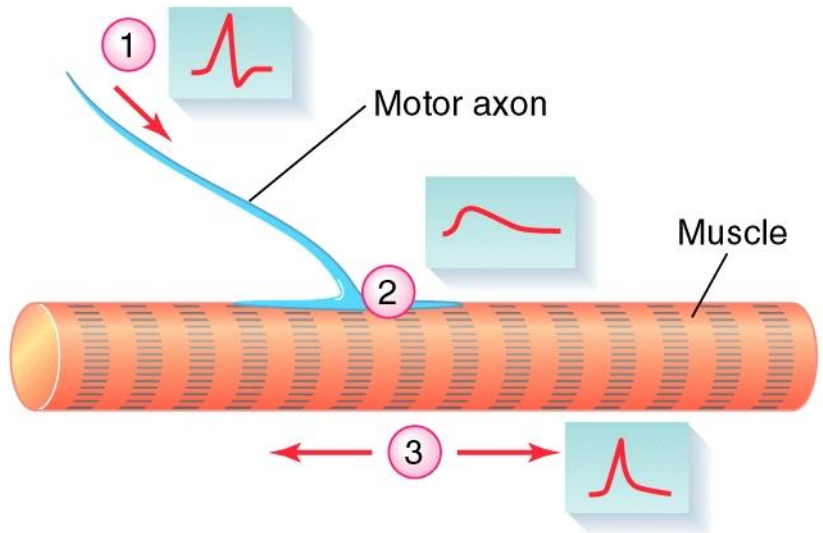


(a)

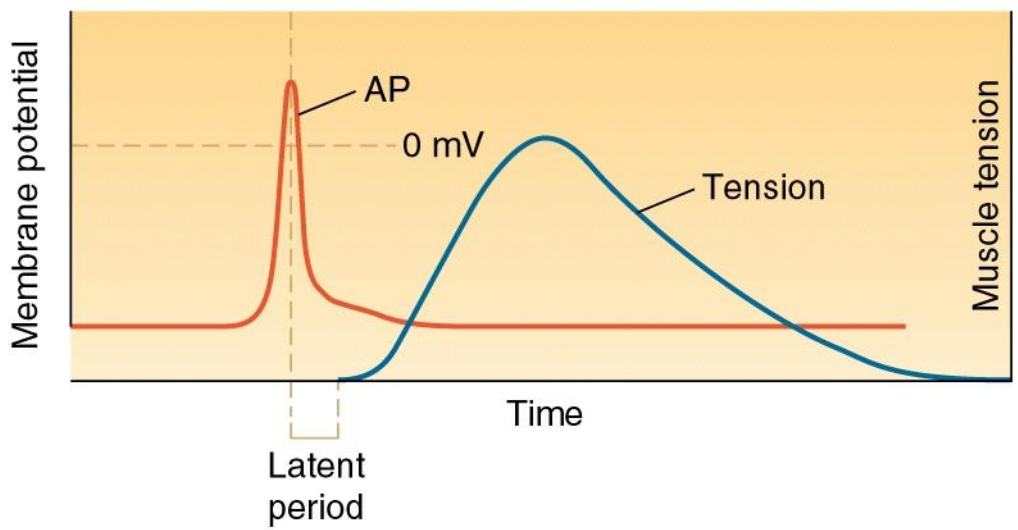
(b)


Ca2+ present
Ca2+ absent
ATP added
ATP removed
Tension
Time (min)
ATP added
Ca2+ added

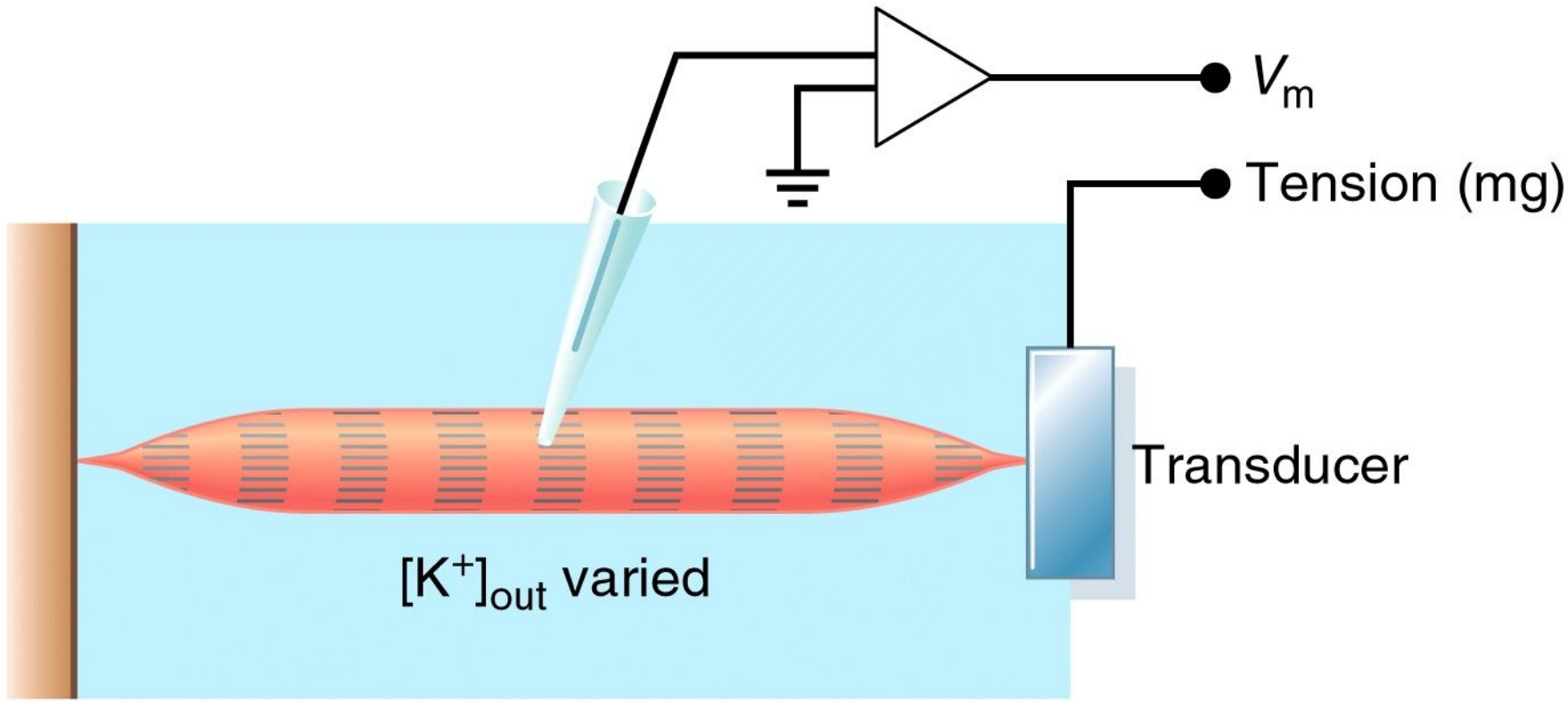
(a)

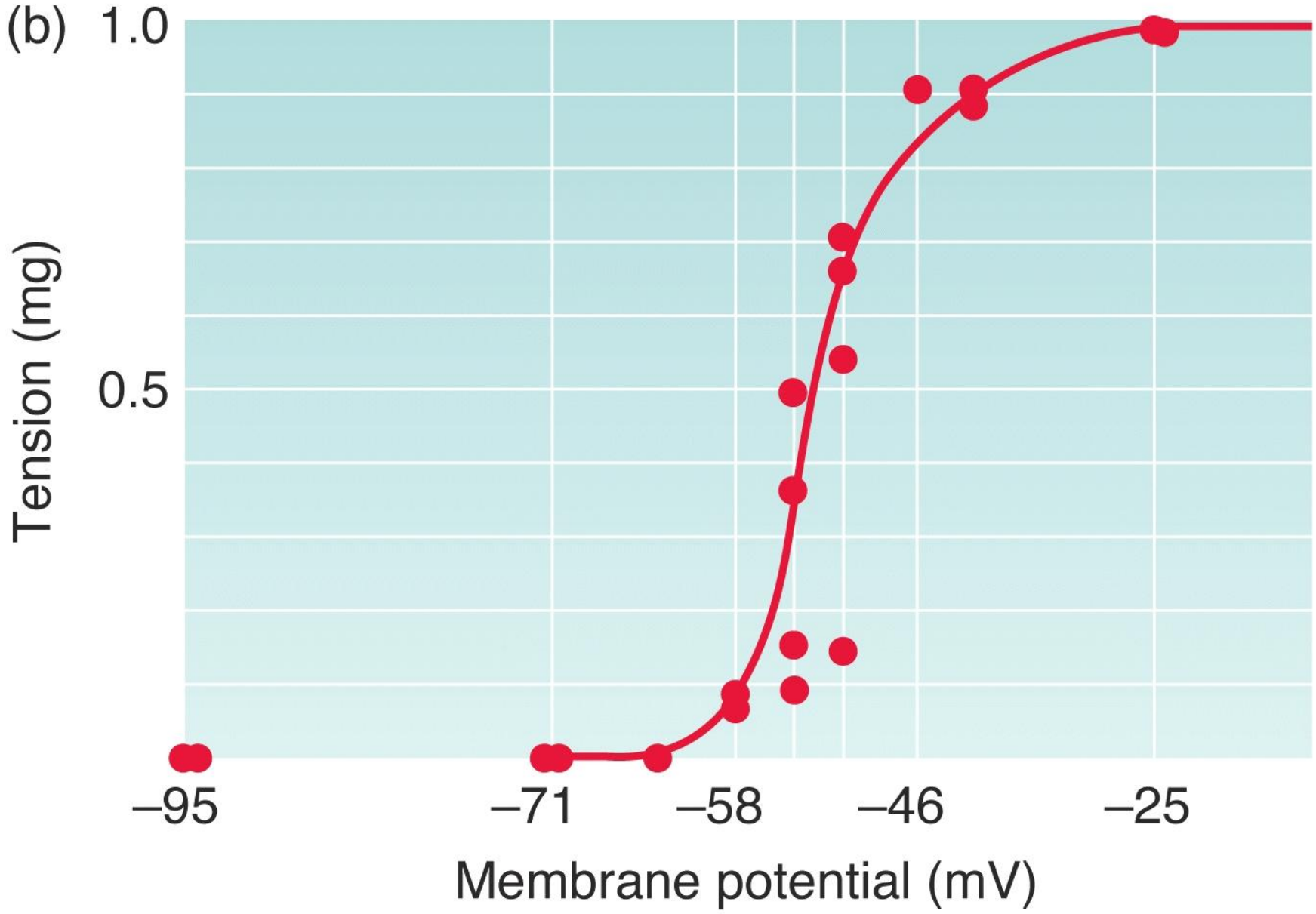

1
Motor axon
Muscle
2
3

(b)

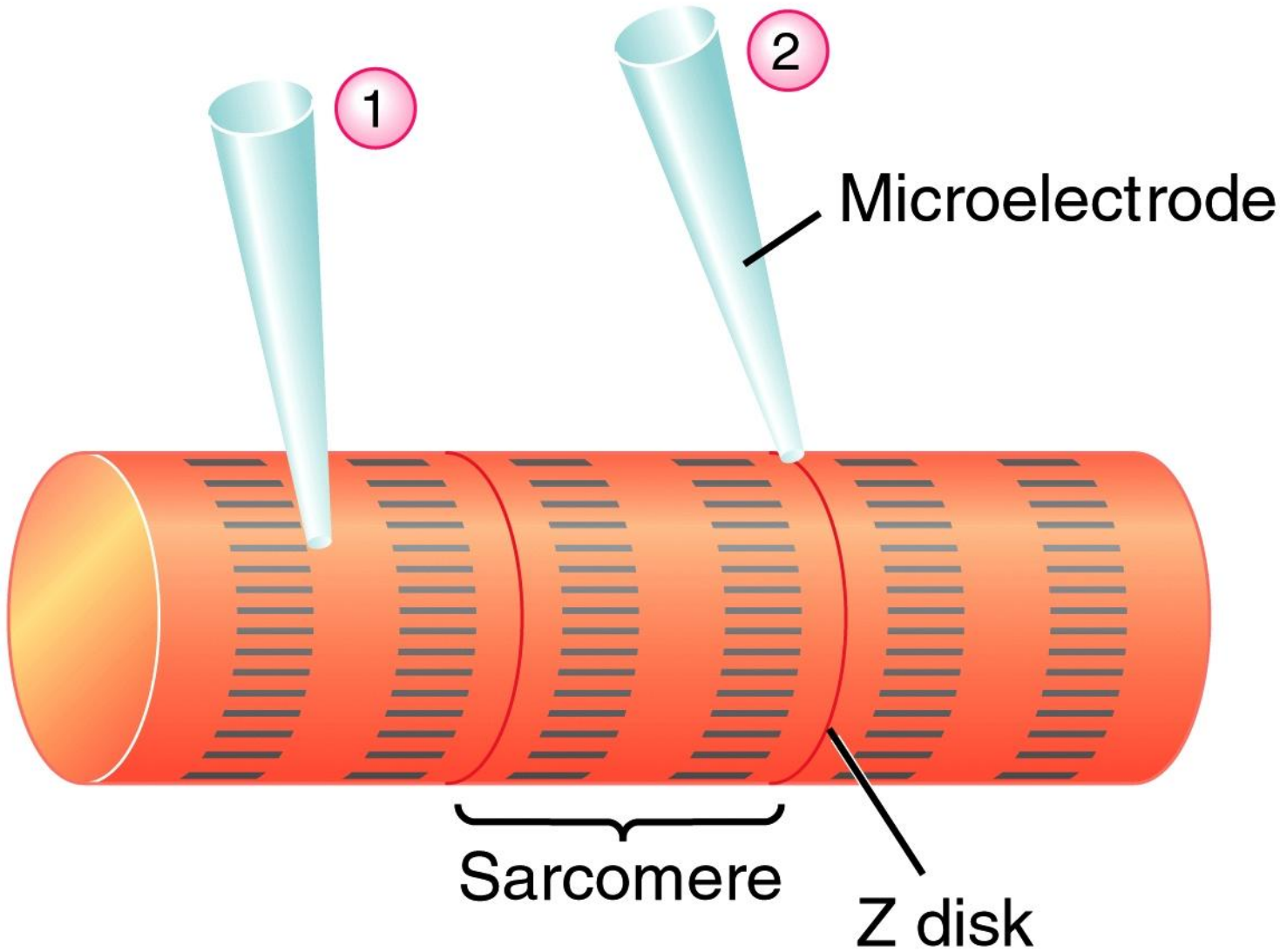

Membrane potential
AP
0 mV
Tension
Muscle tension
Time
Latent
period

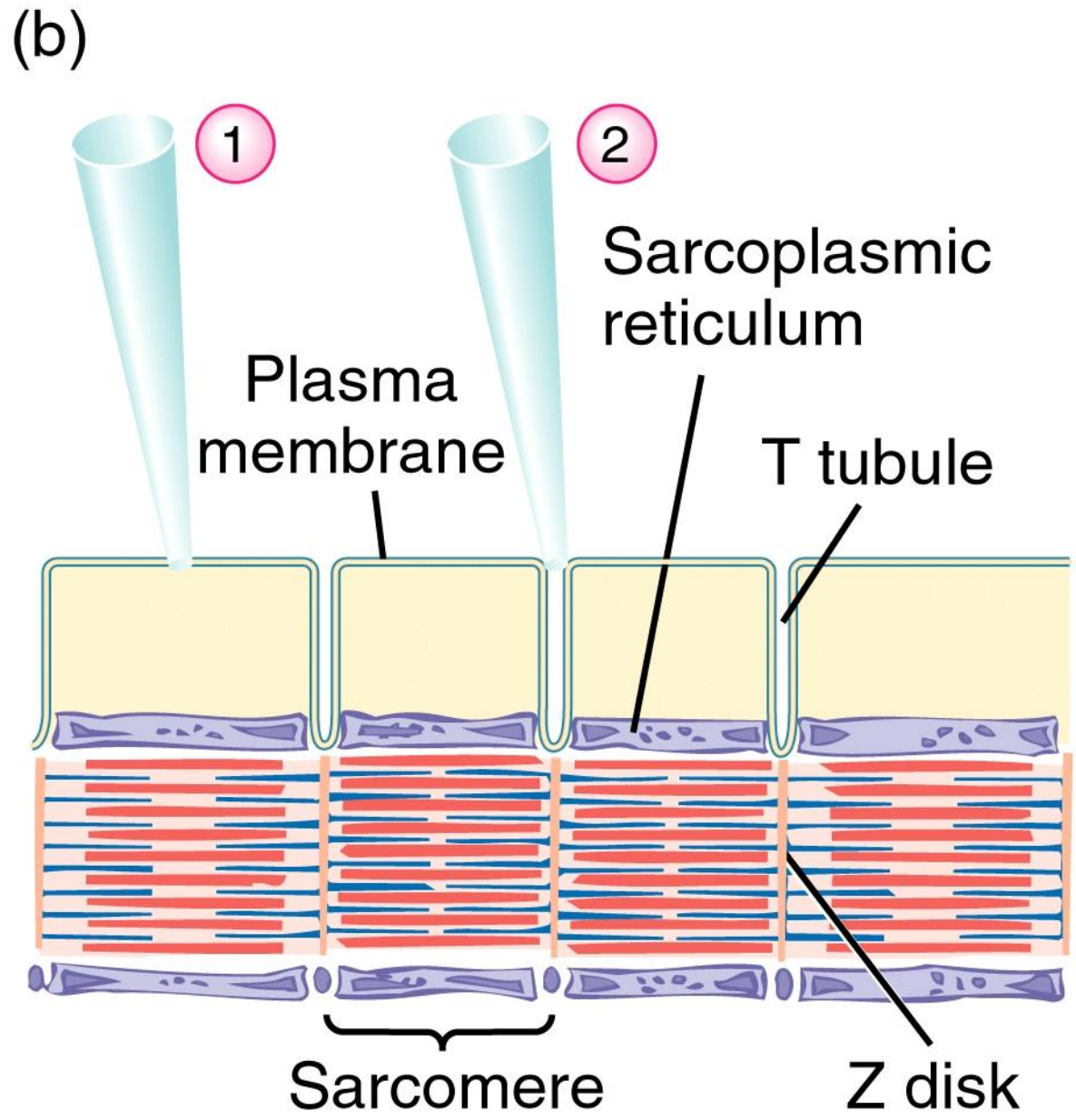
(a)

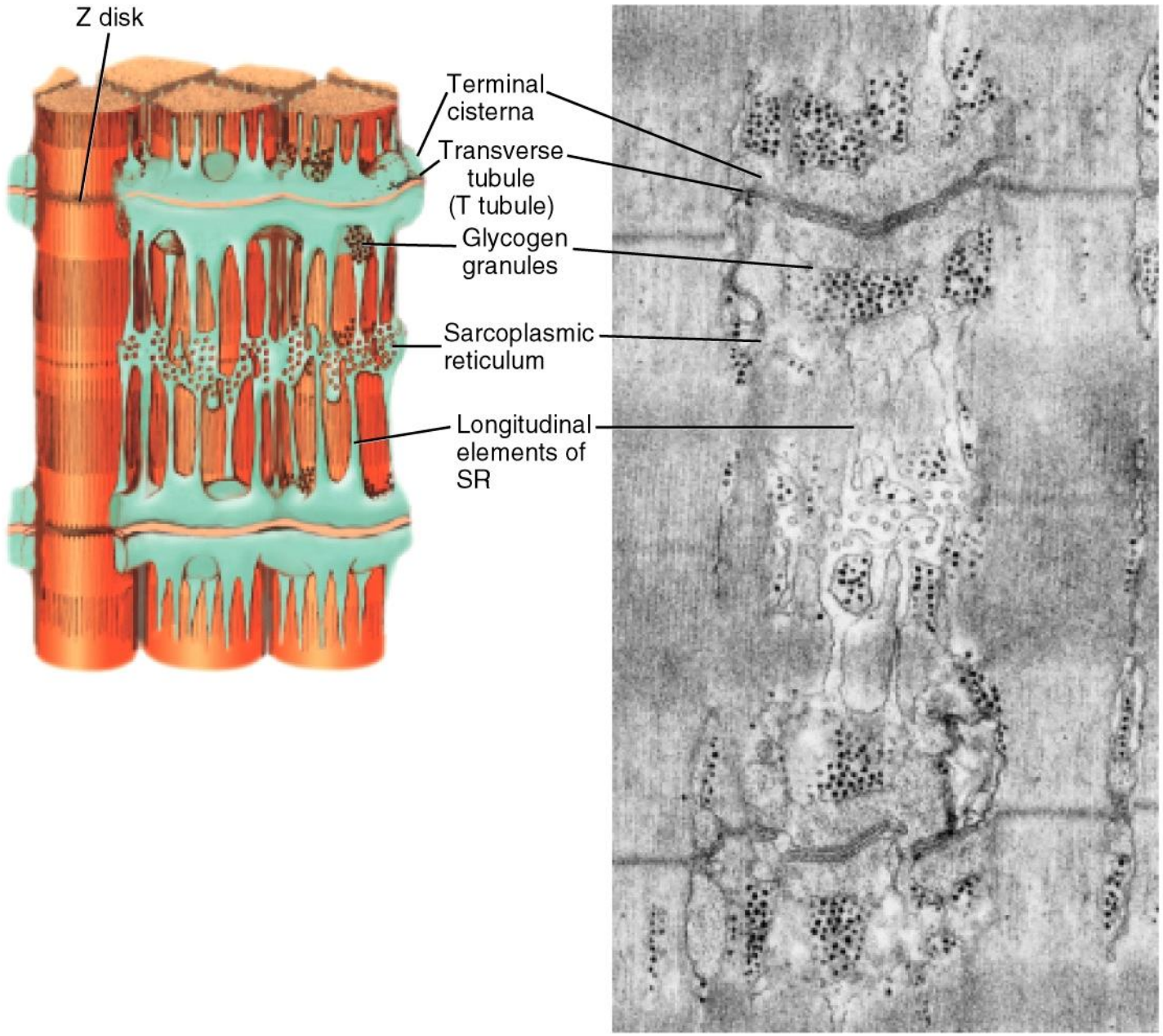


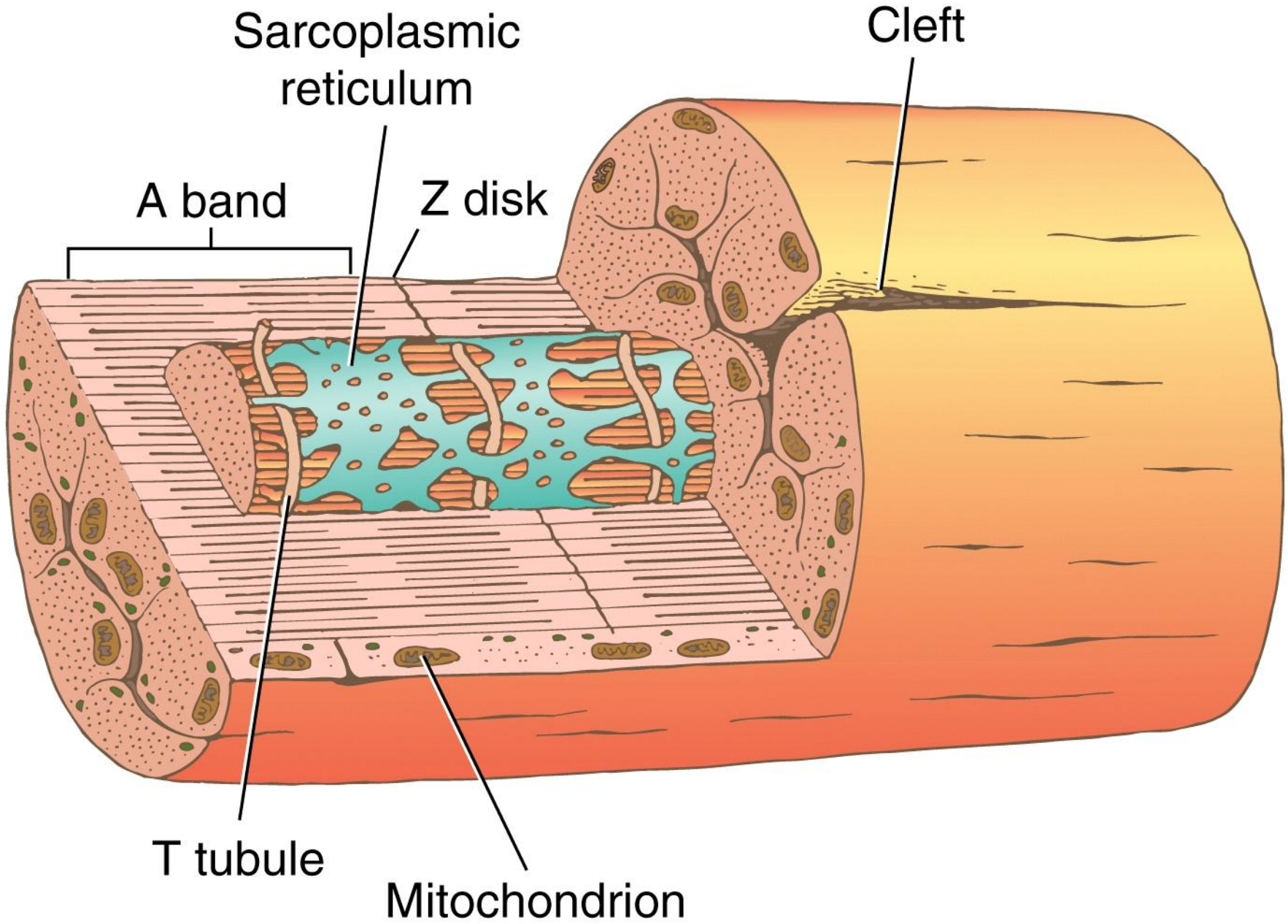

(b)
1.0
0.5
Tension (mg)
–95
–71
–58
–46
–25
Membrane potential (mV)

(a)

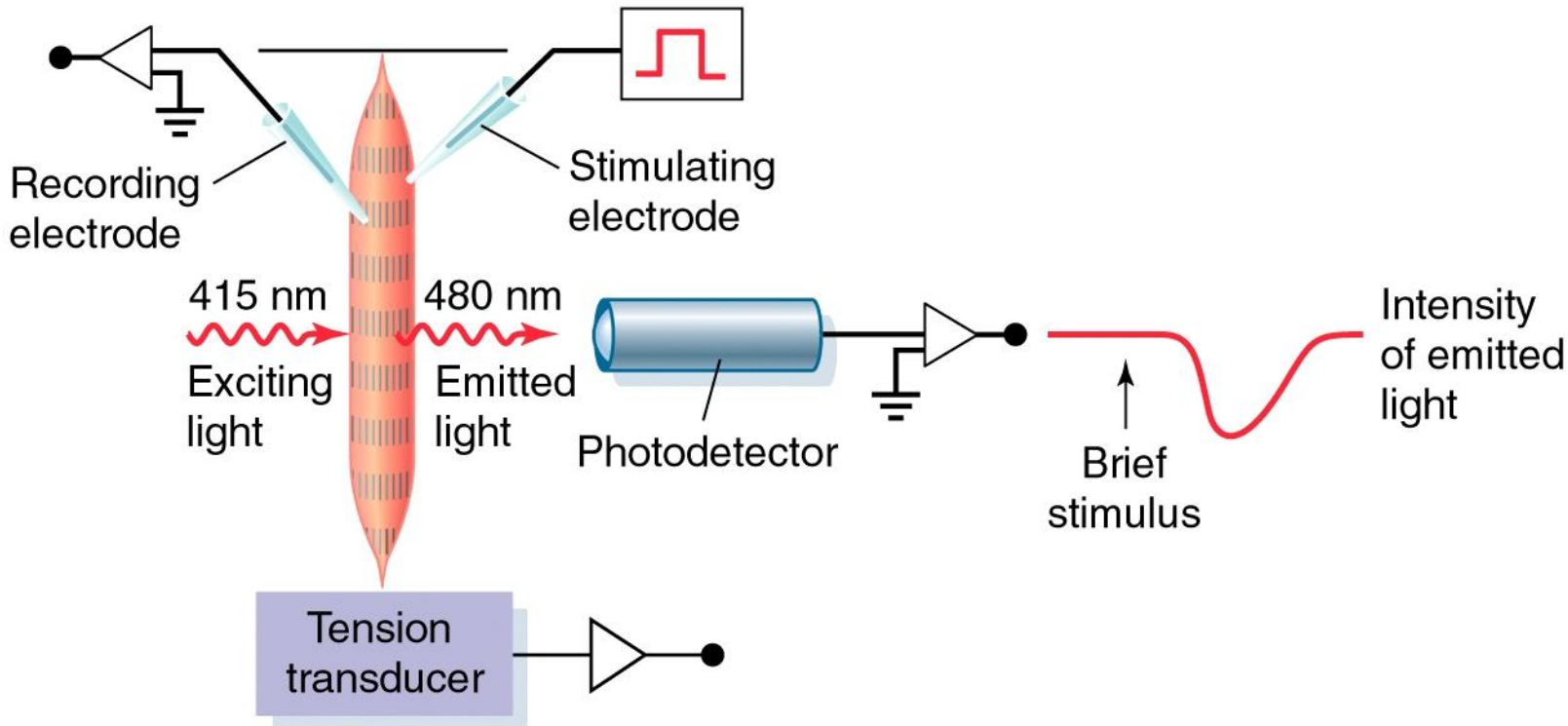


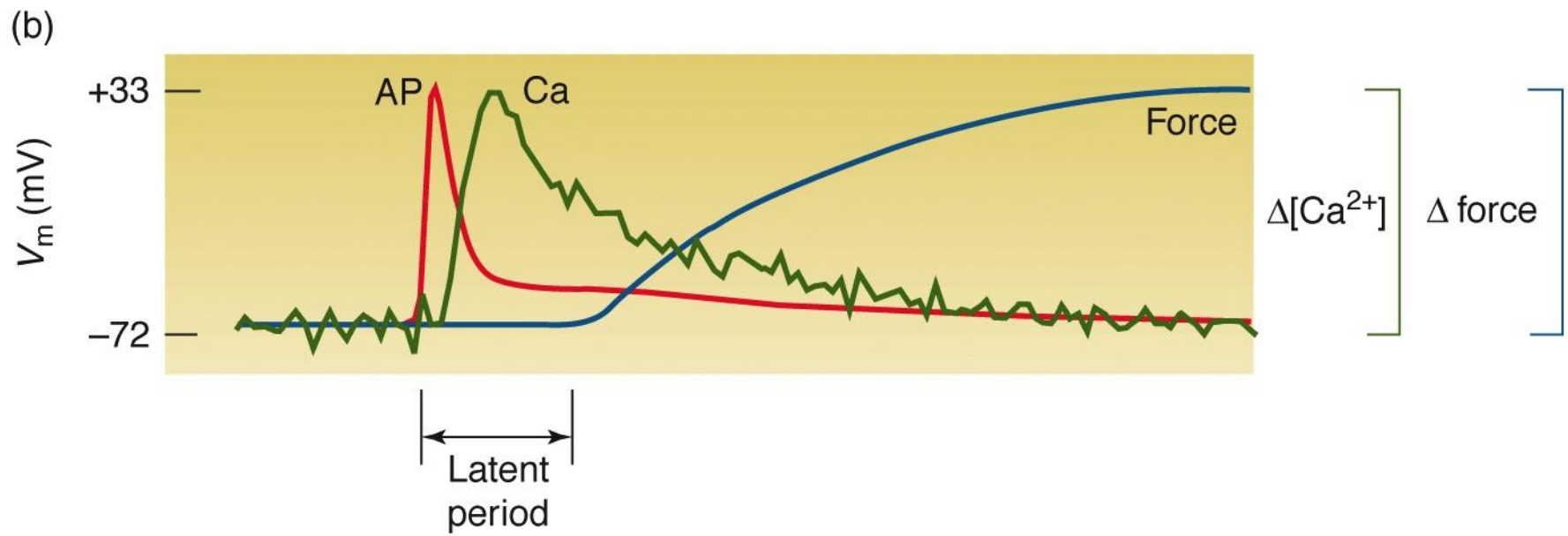

(b)
1
2
Sarcoplasmic reticulum
Plasma membrane
T tubule
Sarcomere
Z disk


Z disk
Terminal cisterna
Transverse tubule (T tubule)
Glycogen granules
Sarcoplasmic reticulum
Longitudinal elements of SR

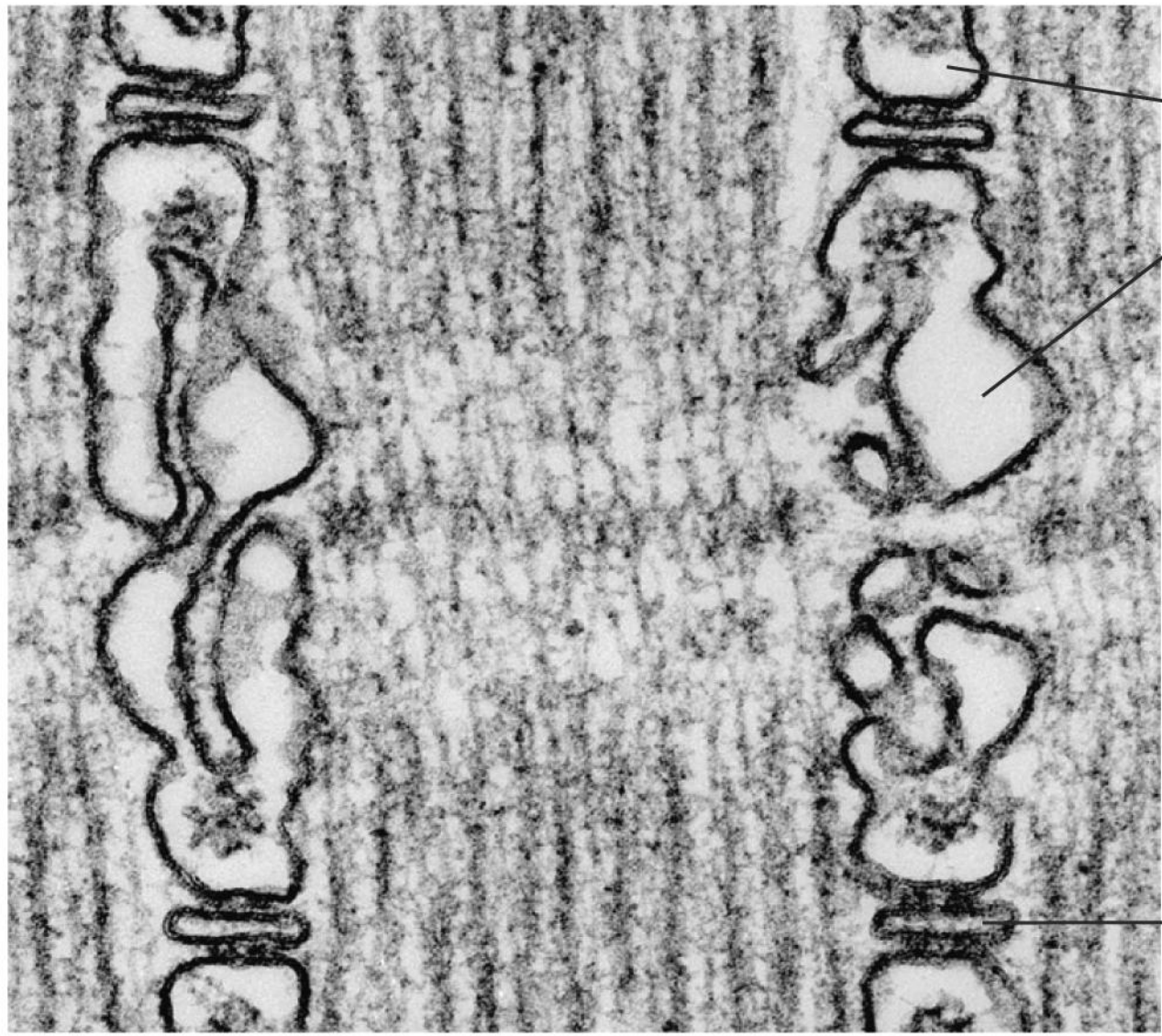

Sarcoplasmic reticulum
Cleft
A band
Z disk
T tubule
Mitochondrion

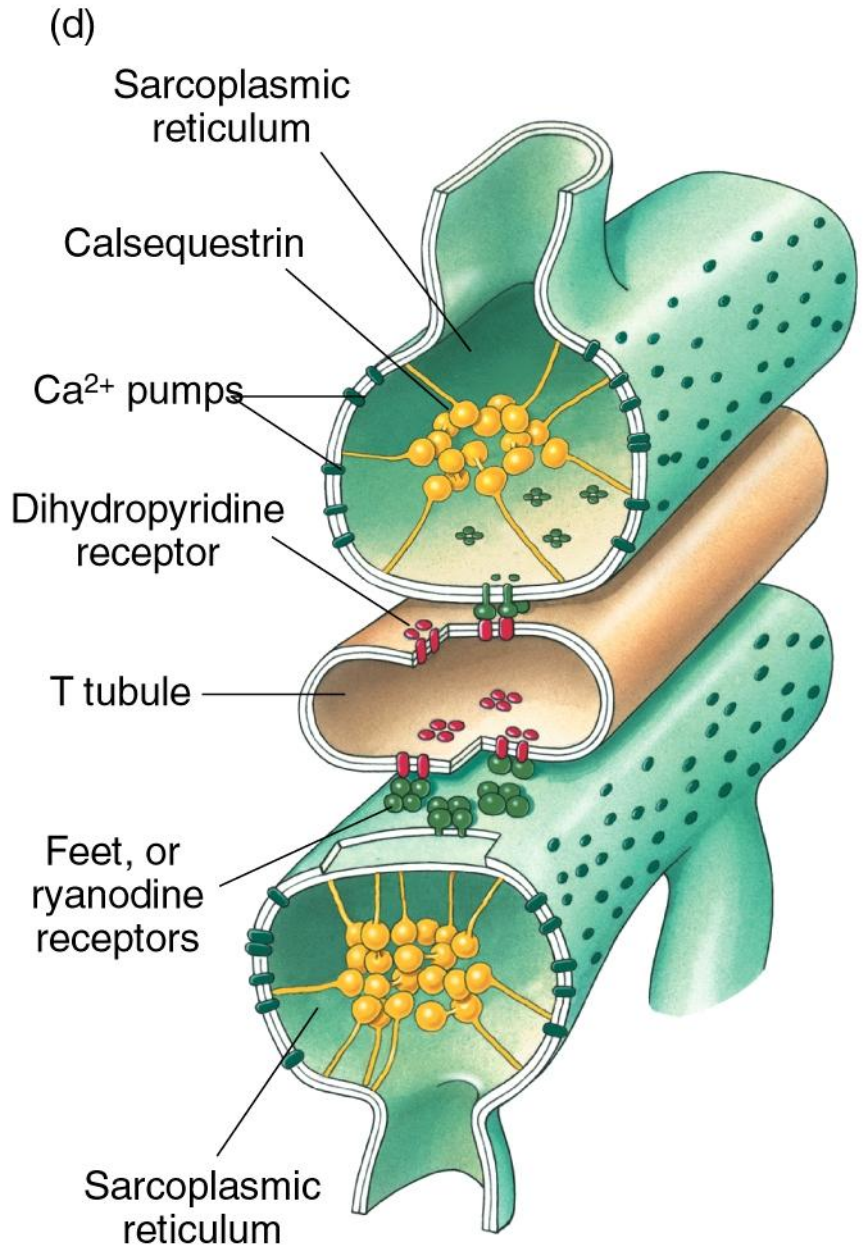
(a)

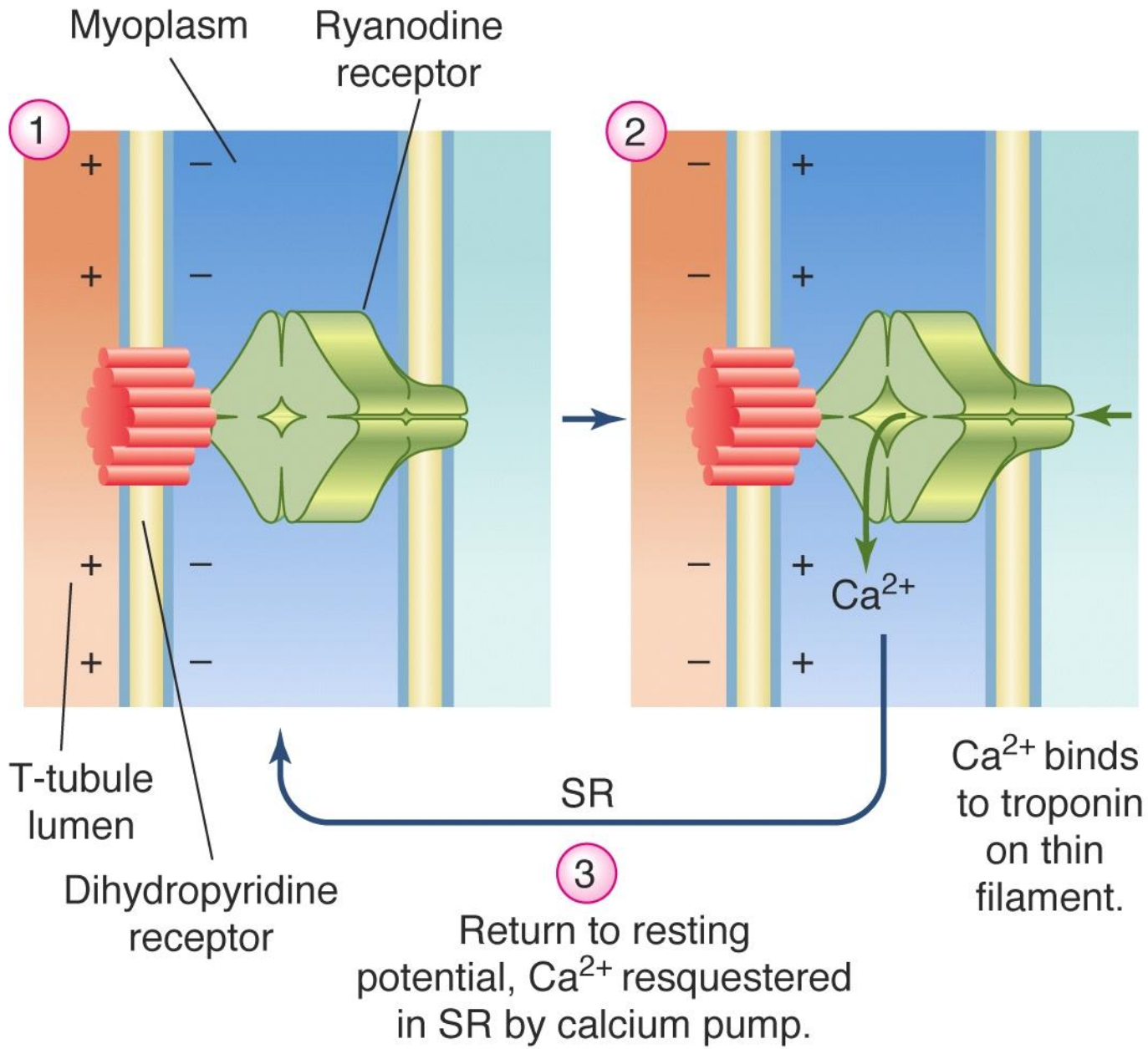

Recording electrode
Stimulating electrode
415 nm
Exciting light
480 nm
Emitted light
Photodetector
Intensity of emitted light
Brief stimulus
Tension transducer

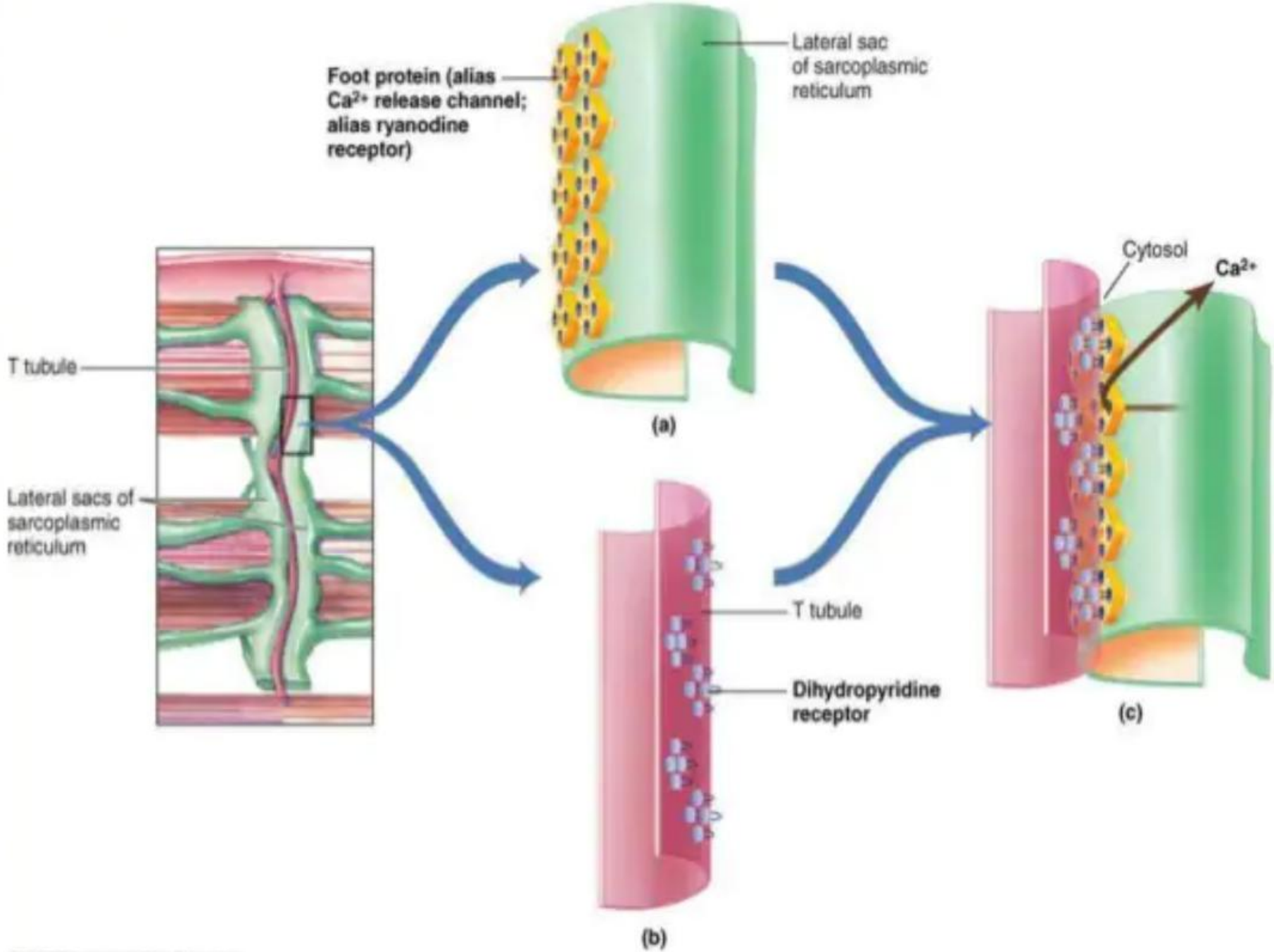

(b)
+33
–72
V_m (mV)
AP
Ca
Force
Δ[Ca2+]
Δ force
Latent
period

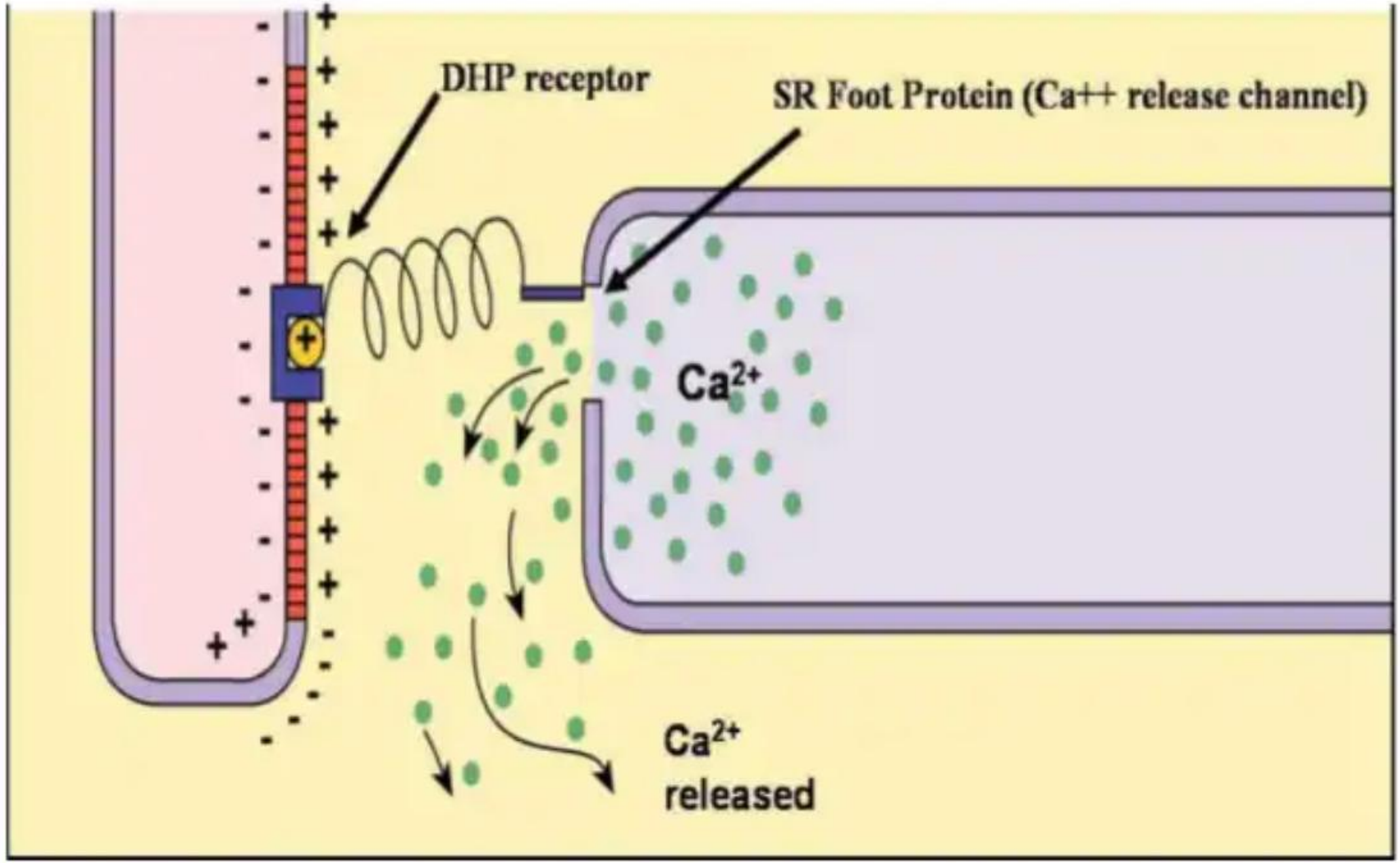
(a)




(d)
Sarcoplasmic reticulum
Calsequestrin
Ca^{2+} pumps
Dihydropyridine receptor
T tubule
Feet, or ryanodine receptors
Sarcoplasmic reticulum

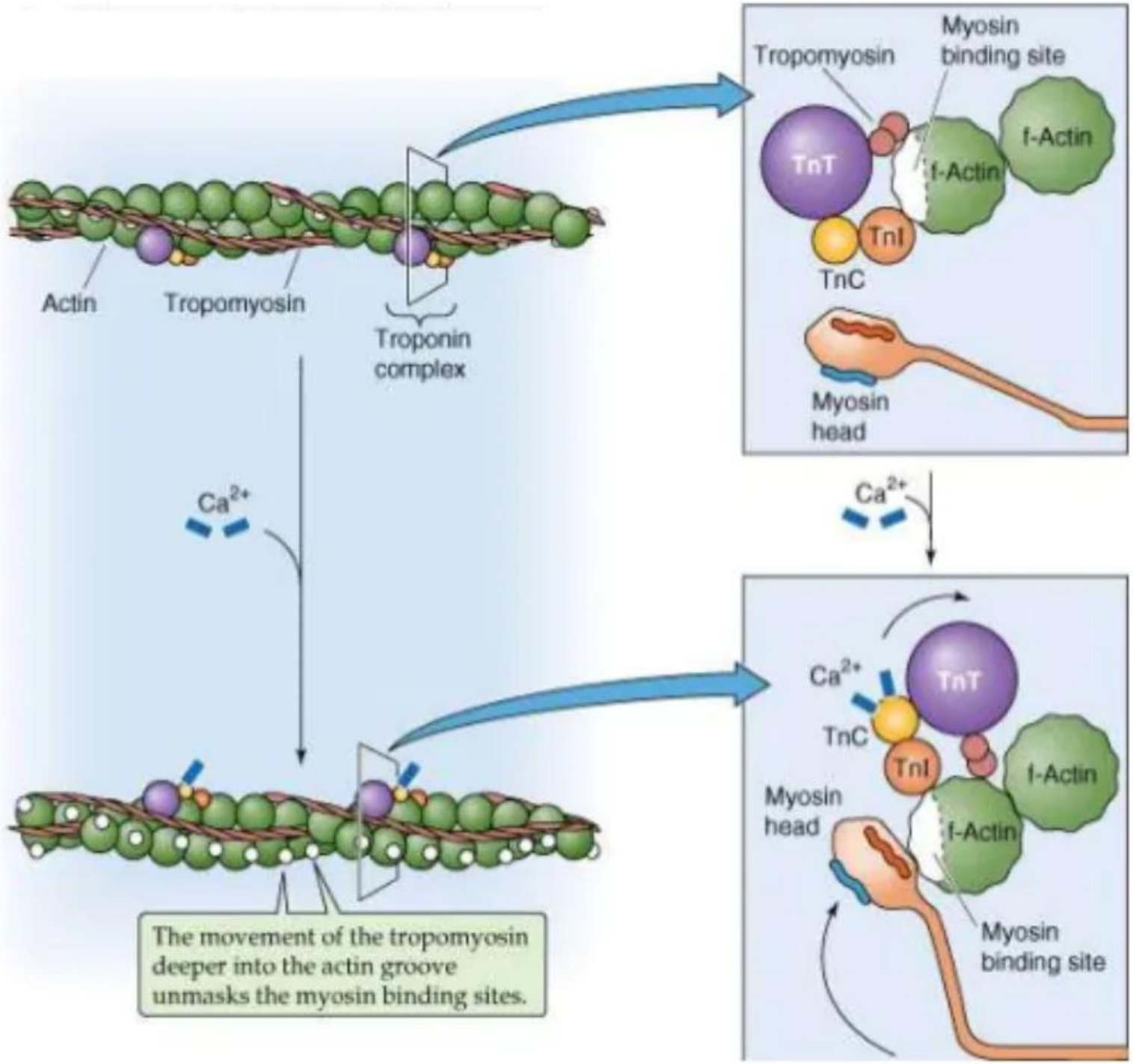

Myoplasm
Ryanodine receptor
1
2
+
−
Ca^{2+}
T-tubule lumen
Dihydropyridine receptor
SR
3
Return to resting potential, Ca^{2+} resquestered in SR by calcium pump.
Ca^{2+} binds to troponin on thin filament.




DHP receptor
SR Foot Protein (Ca++ release channel)
Ca2+
Ca2+
released

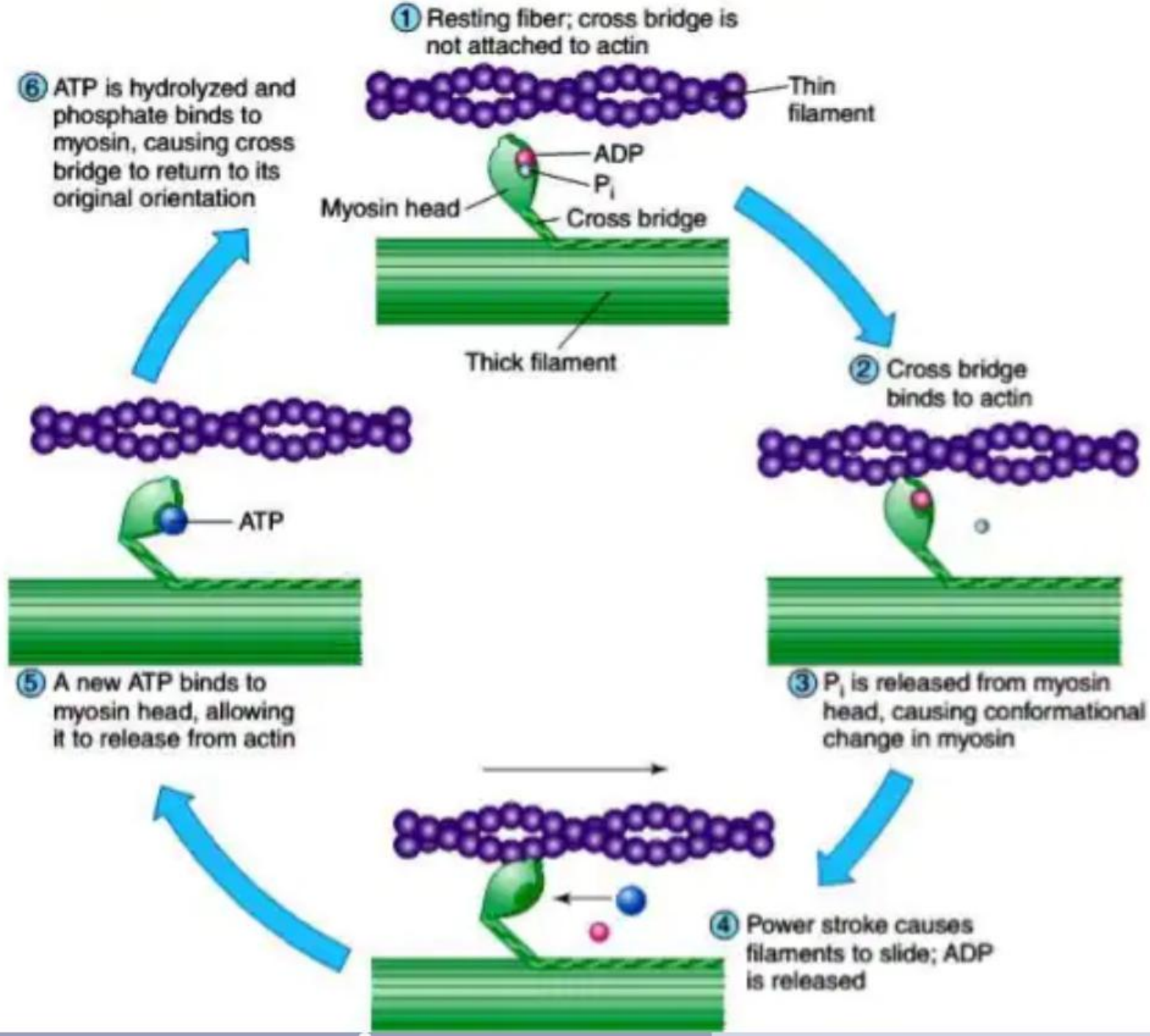
Excitation Contraction(EC) coupling

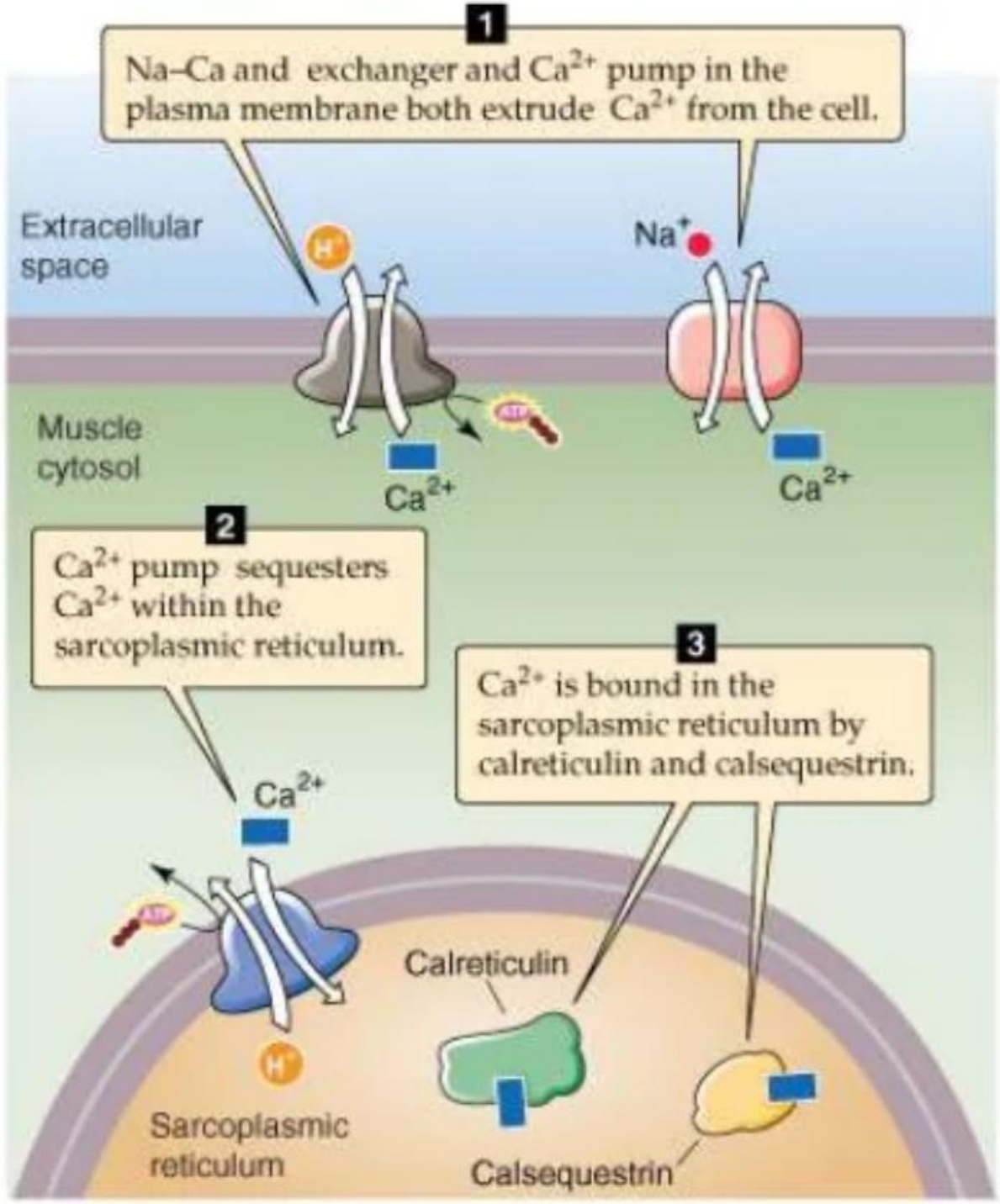
- Ca^{++} binds with Troponin C
- Troponin – Tropomyosin complex inhibits the interaction between actin and myosin
- When Ca^{++} binds to Trop C, active sites of actin are uncovered & ATP is split to ADP releasing P- energy & contraction occurs

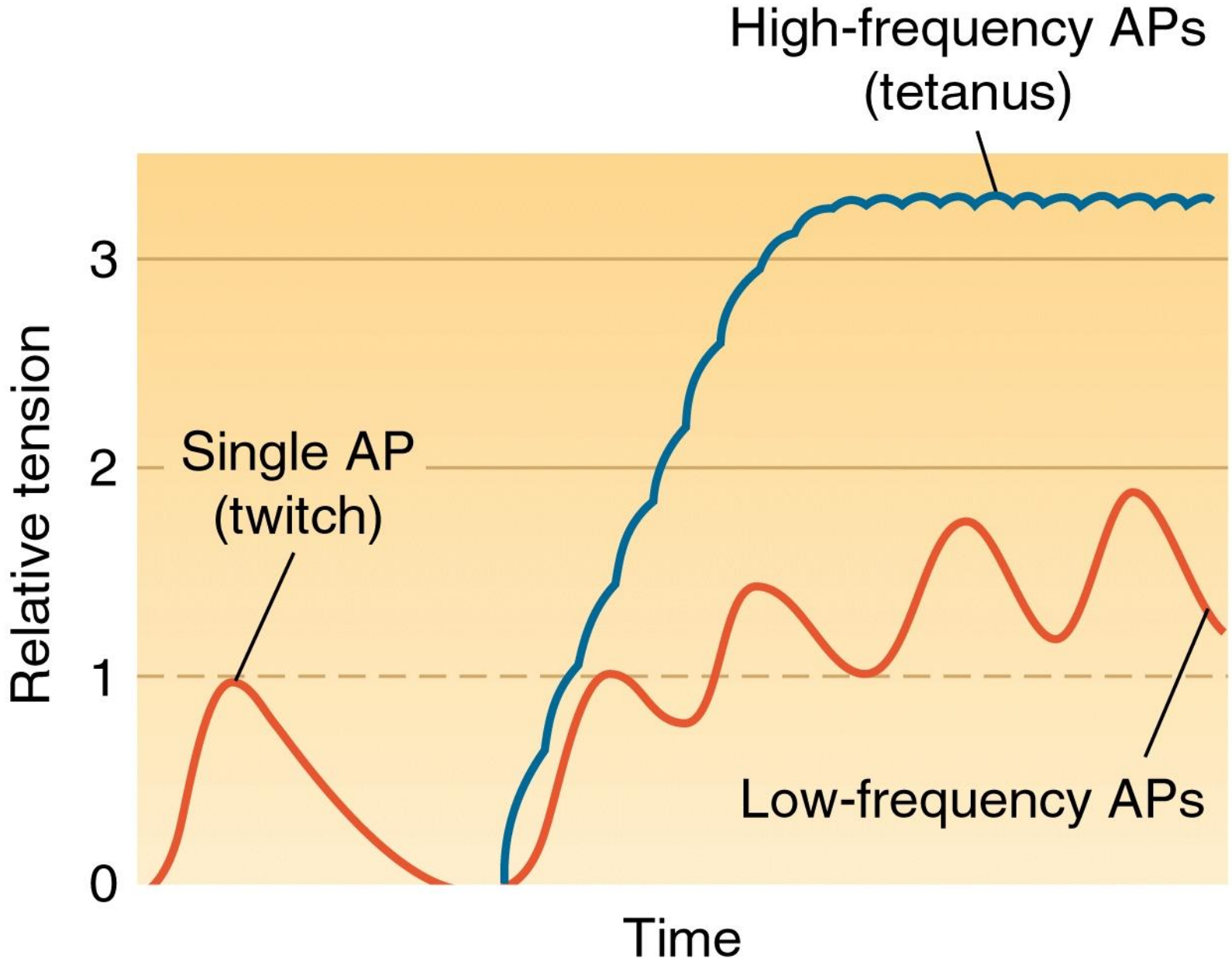

Actin
Tropomyosin
Troponin complex
Tropomyosin
Myosin binding site
TnT
f-Actin
f-Actin
TnI
TnC
Myosin head
Ca^{2+}
Ca^{2+}
Ca^{2+}
TnT
TnC
TnI
f-Actin
f-Actin
Myosin head
Myosin binding site
The movement of the tropomyosin deeper into the actin groove unmasks the myosin binding sites.

Cross Bridge Cycle

- In presence of calcium, myosin head binds to an actin filament
- Changes its orientation relative to myosin filament which causes filaments to slide relative to each other - **Power Stroke**
- During the Cross-Bridge Cycle, Contractile Proteins Convert the Energy of ATP Hydrolysis Into Mechanical Energy
- Each power stroke shortens sarcomere by **10nm**
- Cross bridge cycling is asynchronous
  - 500 myosin in one thick filament, each head cycling 5 times per second


1 Resting fiber; cross bridge is not attached to actin
Thin filament
ADP
P_i
Myosin head
Cross bridge
Thick filament
2 Cross bridge binds to actin
3 P_i is released from myosin head, causing conformational change in myosin
4 Power stroke causes filaments to slide; ADP is released
5 A new ATP binds to myosin head, allowing it to release from actin
ATP
6 ATP is hydrolyzed and phosphate binds to myosin, causing cross bridge to return to its original orientation


1
Na–Ca and exchanger and Ca^{2+} pump in the plasma membrane both extrude Ca^{2+} from the cell.
Extracellular space
H^+
Na^+
ATP
Muscle cytosol
Ca^{2+}
Ca^{2+}
2
Ca^{2+} pump sequesters Ca^{2+} within the sarcoplasmic reticulum.
3
Ca^{2+} is bound in the sarcoplasmic reticulum by calreticulin and calsequestrin.
Ca^{2+}
ATP
H^+
Calreticulin
Sarcoplasmic reticulum
Calsequestrin


High-frequency APs
(tetanus)
Relative tension
3
2
1
0
Single AP
(twitch)
Low-frequency APs
Time

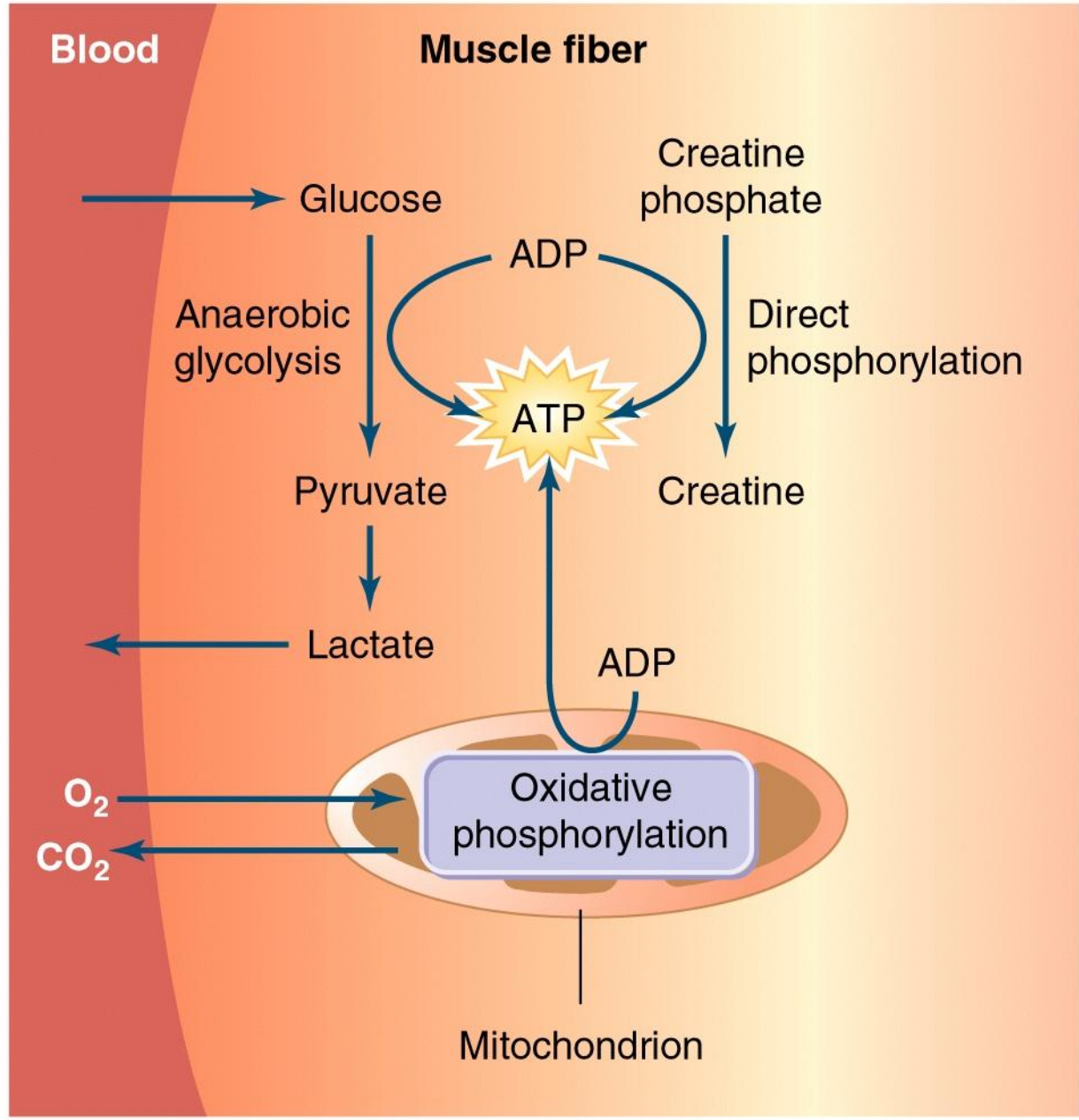
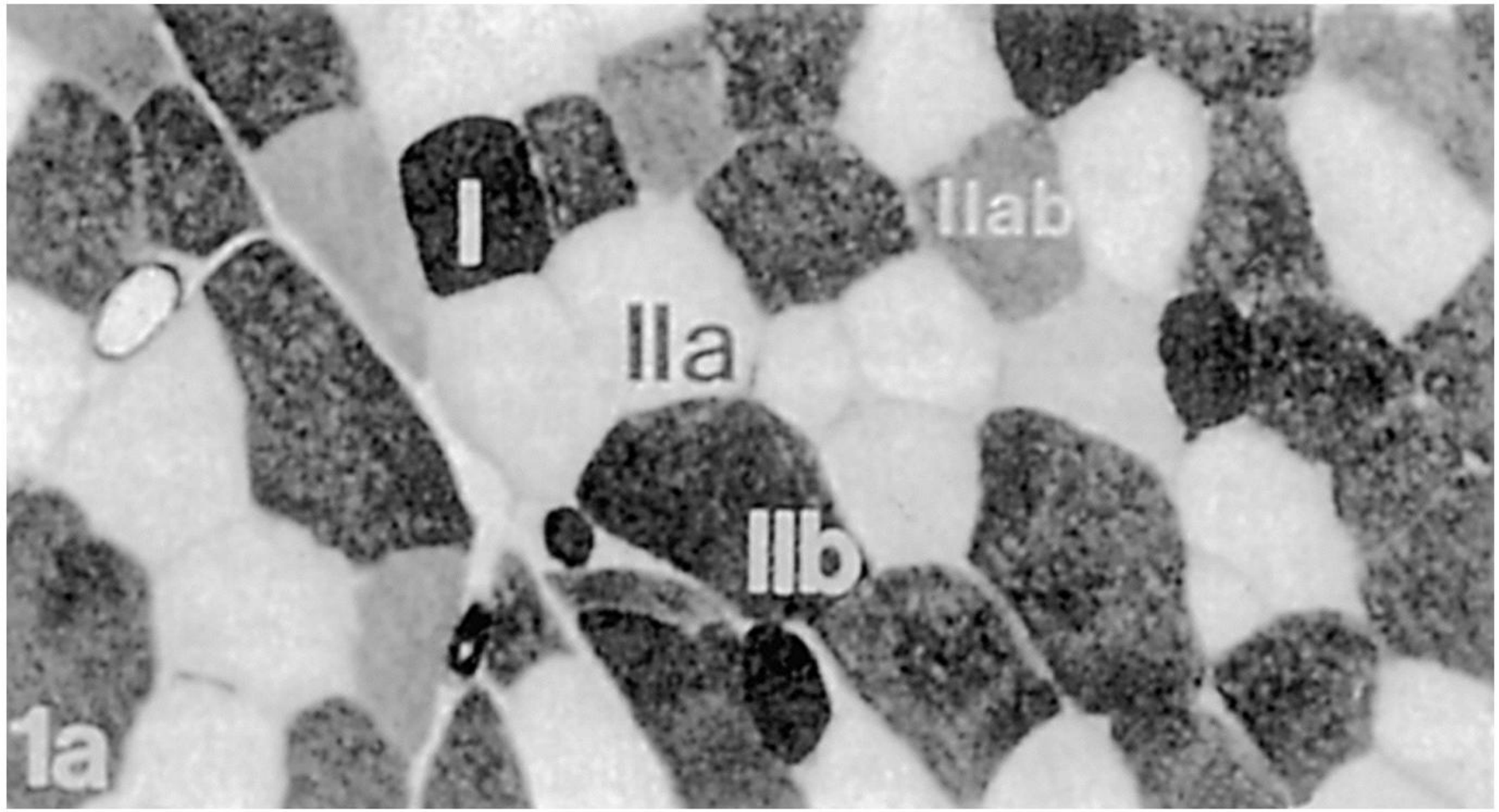
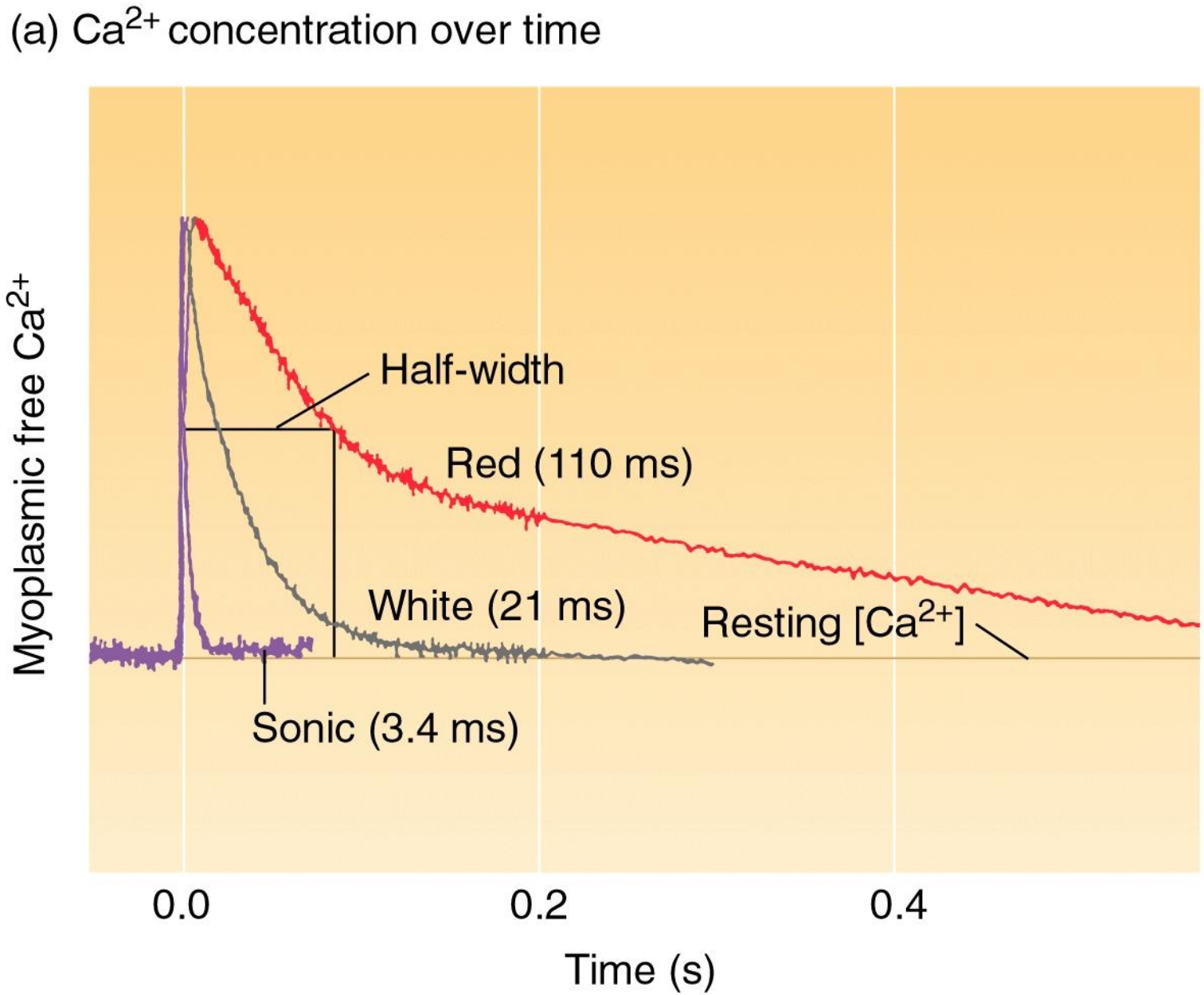

Blood
Muscle fiber
Glucose
Creatine phosphate
ADP
Anaerobic glycolysis
Direct phosphorylation
ATP
Pyruvate
Creatine
Lactate
ADP
O_2
CO_2
Oxidative phosphorylation
Mitochondrion

Table 10-1 Properties of twitch (phasic) fibers in mammalian skeletal muscles

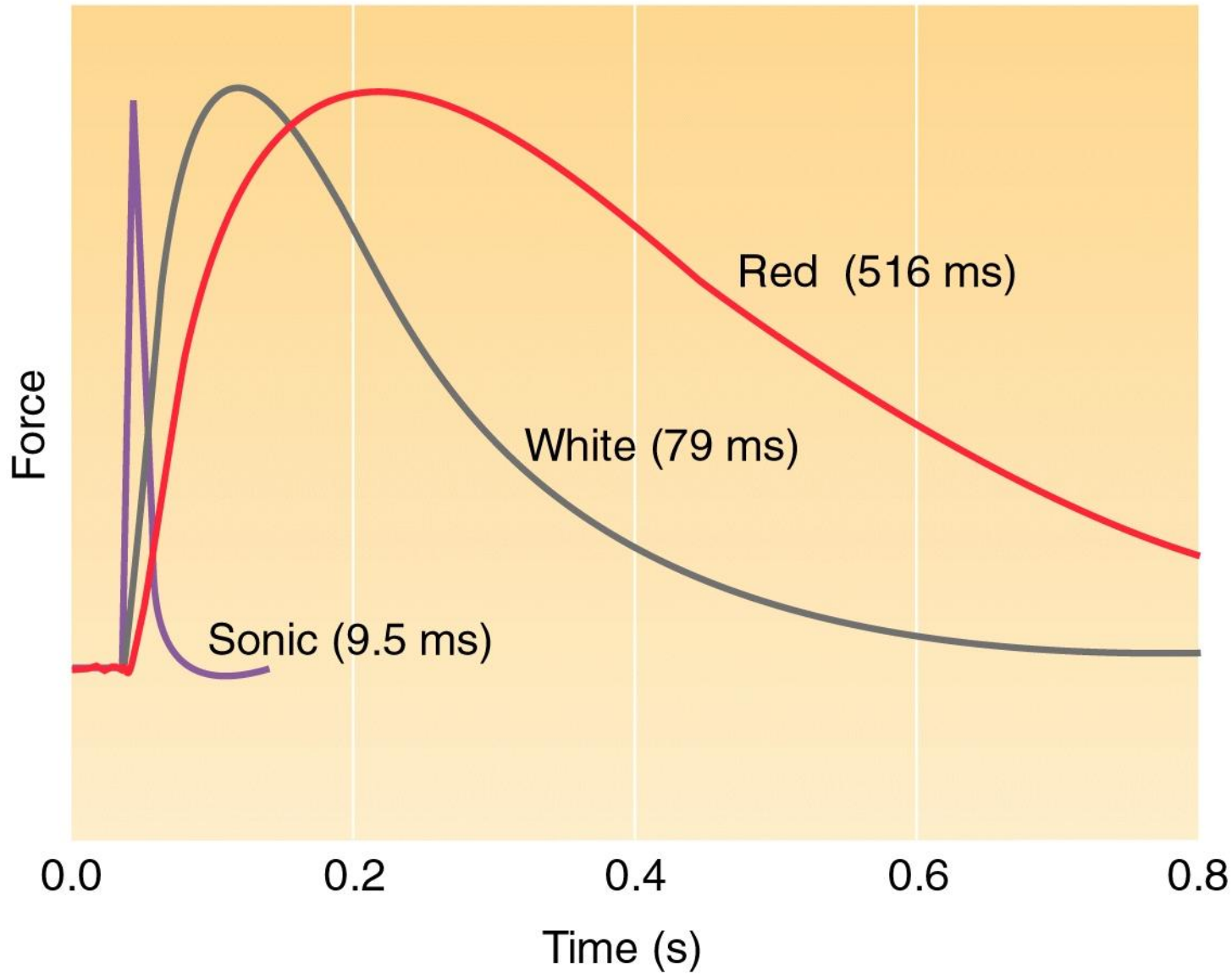
Property	Slow oxidative (type I)	Fast oxidative (type IIa)	Fast glycolytic (type IIb)
Fiber diameter	↓	↔	↑
Force per cross-sectional area	↓	↔	↑
Rate of contraction (V_{max})	↓	↑	↑
Myosin ATPase activity	↓	↑	↑
Resistance to fatigue	↑	↔	↓
Number of mitochondria	↑	↑	↓
Capacity for oxidative phosphorylation	↑	↑	↓
Enzymes for anaerobic glycolysis	↓	↔	↑

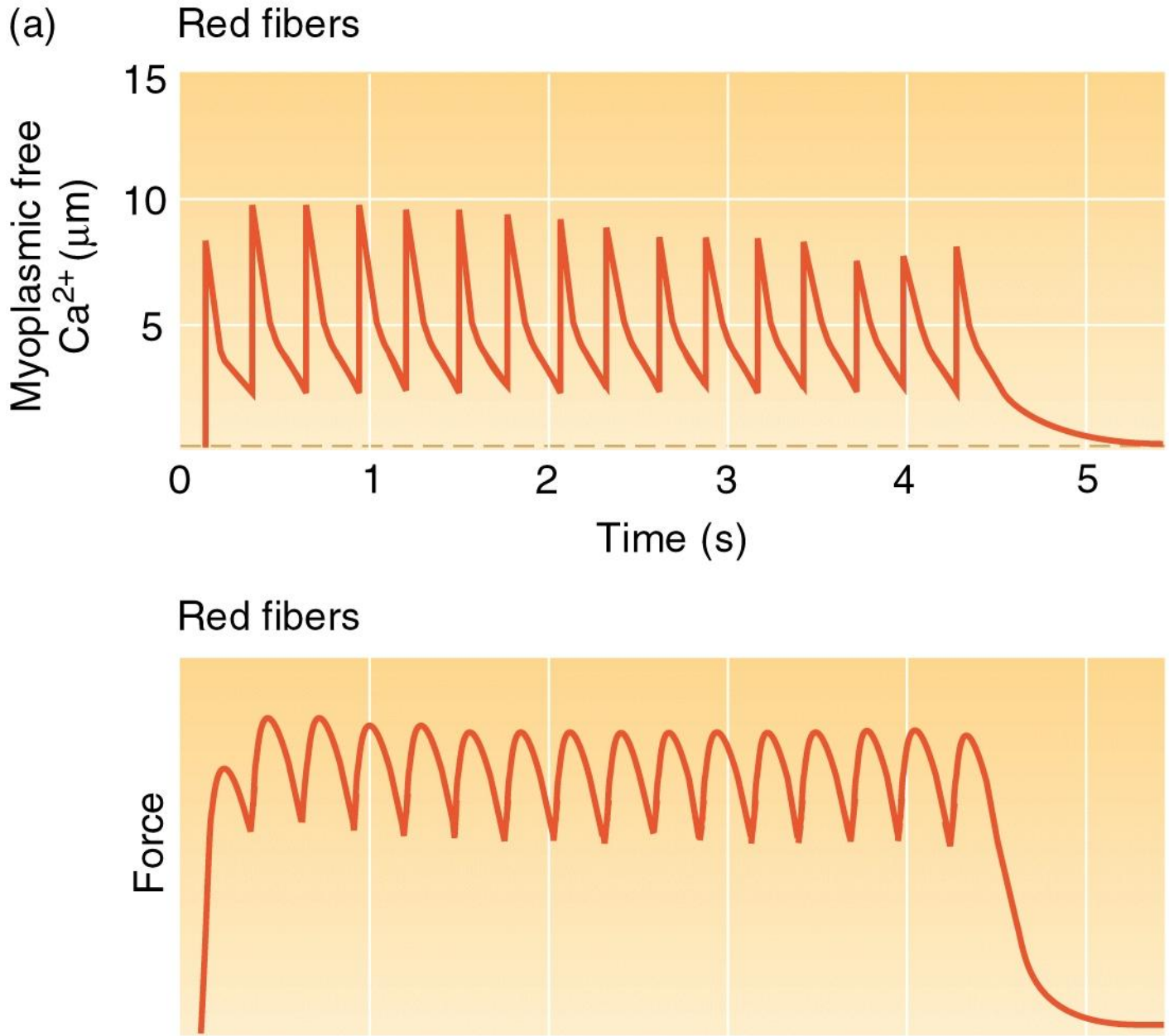
Source: Adapted from Sherwood, 2001. Key = ↓ Low ↔ Intermediate ↑ High

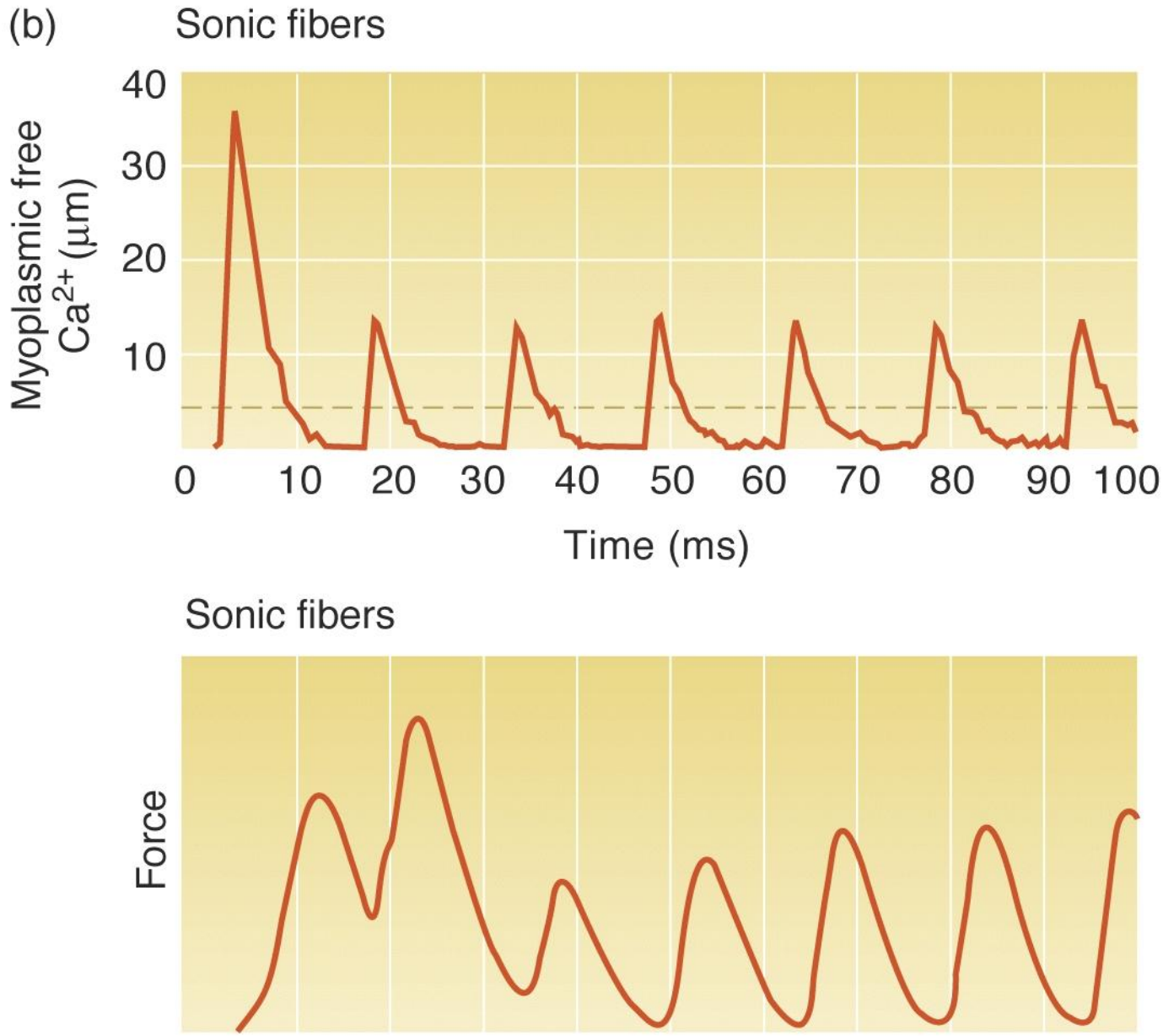

I
IIab
IIa
IIb
1a

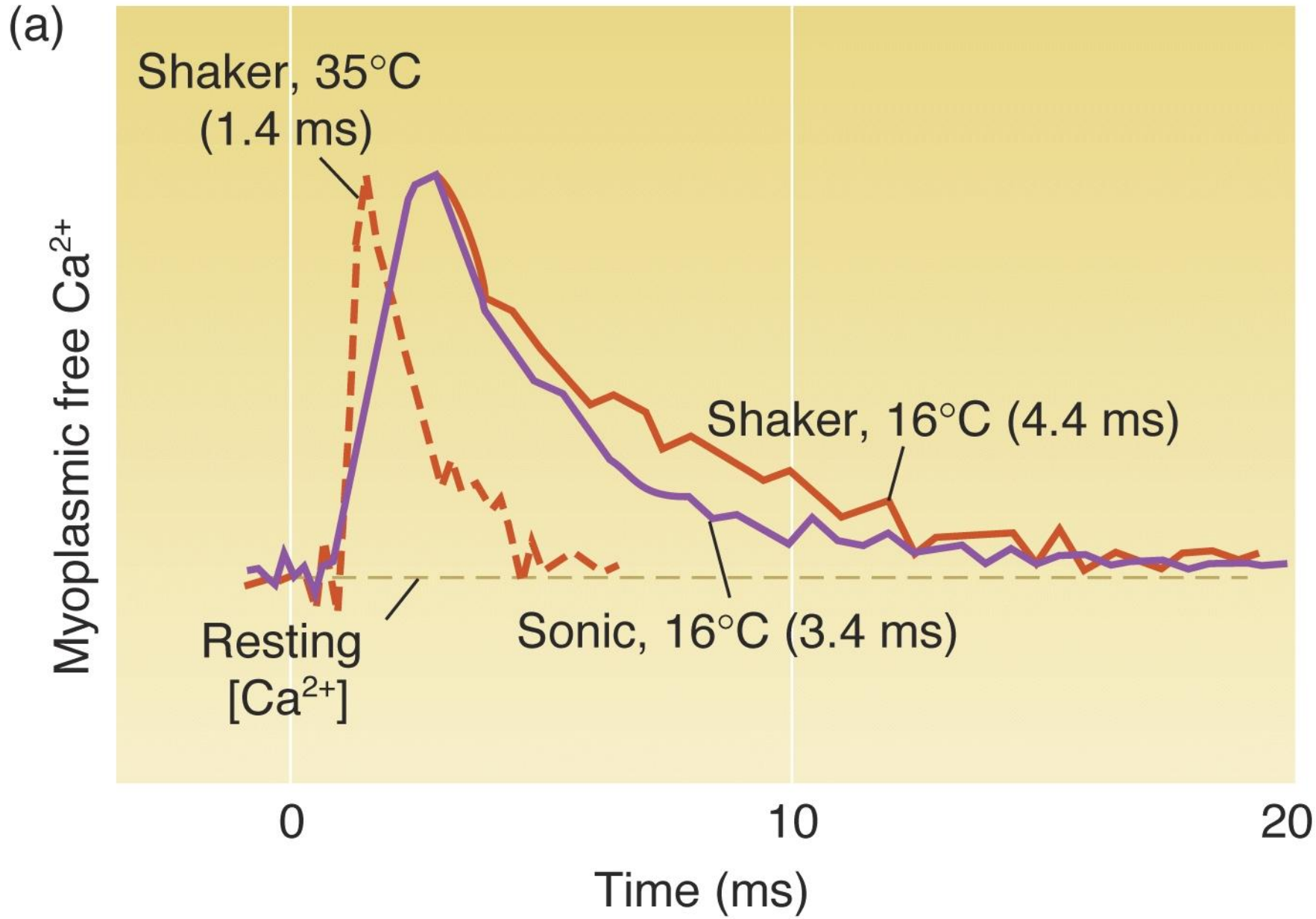

(a) Ca^{2+} concentration over time
Myoplasmic free Ca^{2+}
Half-width
Red (110 ms)
White (21 ms)
Resting $[Ca^{2+}]$
Sonic (3.4 ms)
0.0
0.2
0.4
Time (s)

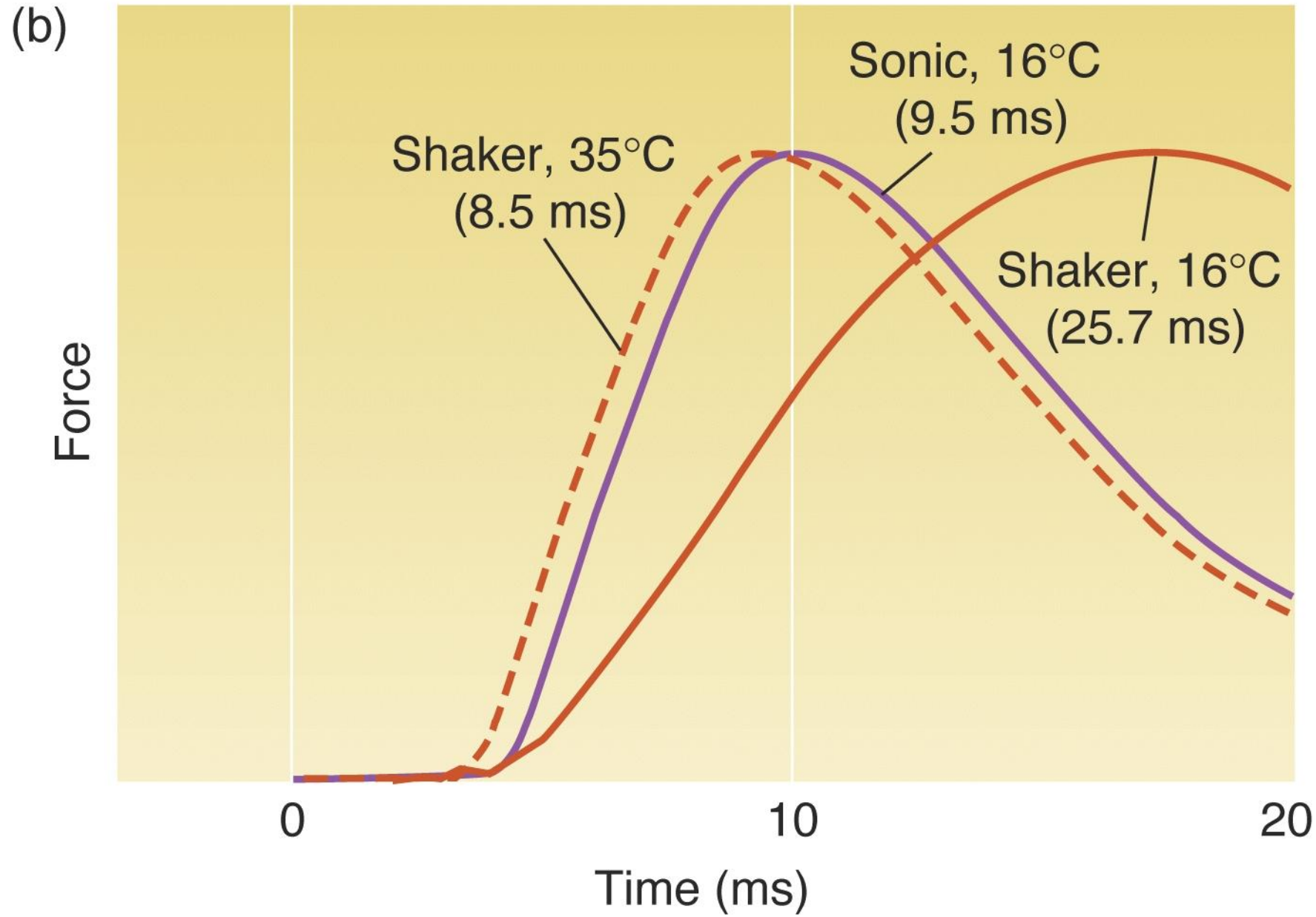
(b) Twitch tension over time




(a)
Red fibers
Myoplasmic free Ca^{2+} (μm)
15
10
5
0
1
2
3
4
5
Time (s)
Red fibers
Force


(b)
Sonic fibers
Myoplasmic free Ca^{2+} (μm)
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
Time (ms)
Sonic fibers
Force


(a)
Shaker, 35°C
(1.4 ms)
Shaker, 16°C (4.4 ms)
Sonic, 16°C (3.4 ms)
Resting
[Ca2+]
Myoplasmic free Ca2+
0
10
20
Time (ms)


(b)
Sonic, 16°C
(9.5 ms)
Shaker, 35°C
(8.5 ms)
Shaker, 16°C
(25.7 ms)
Force
0
10
20
Time (ms)

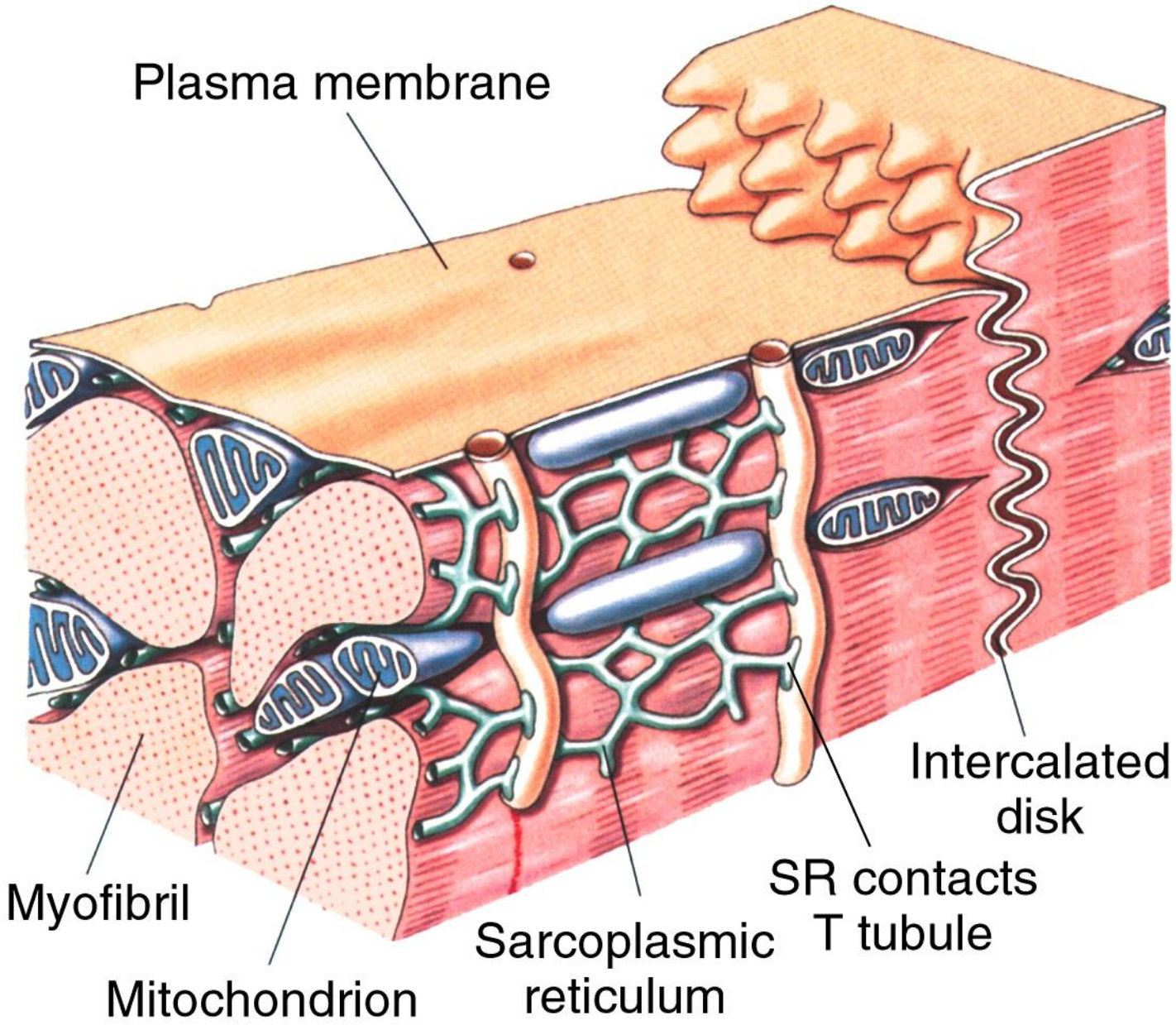
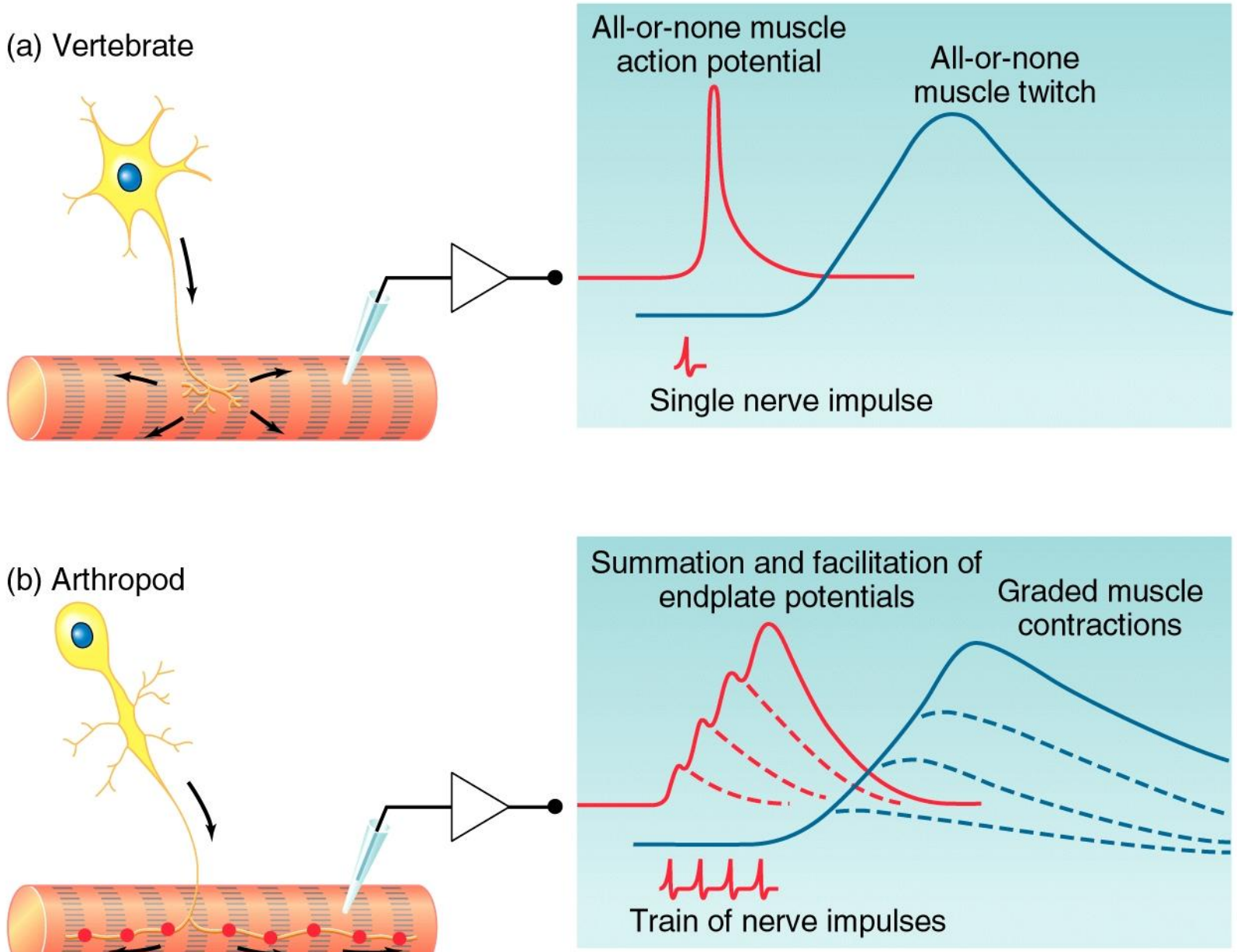

Plasma membrane
Intercalated disk
SR contacts
T tubule
Sarcoplasmic reticulum
Mitochondrion
Myofibril

Table 10-2 Characteristics of the major types of muscle fibers in vertebrates

Property/component	Striated muscle	
	Skeletal	Cardiac
Visible banding pattern	Yes	Yes
Myosin thick filaments and actin thin filaments	Yes	Yes
Tropomyosin and troponin	Yes	Yes
Transverse tubules	Yes	Yes
Sarcoplasmic reticulum	Well developed	Well developed
Mechanism of contraction	Sliding of thick and thin filaments past each other	Sliding of thick and thin filaments past each other
Innervation	Somatic nerves	Autonomic nerves
Initiation of contraction*	Neurogenic	Myogenic
Source of Ca^{2+} for activation†	SR	ECF and SR
Gap junctions between fibers?	No	Yes
Speed of contraction	Fast or slow depending on fiber type	Slow
Clear-cut relationship between length and tension	Yes	Yes

*Neurogenic muscles contract only when stimulated by synaptic input from a neuron. Myogenic muscles endogenously produce depolarizing membrane potentials, allowing them to contract independently of any neuronal input.
†SR, sarcoplasmic reticulum; ECF, extracellular fluid.
Source: Adapted from Sherwood, 2001.


(a) Vertebrate
All-or-none muscle action potential
All-or-none muscle twitch
Single nerve impulse
(b) Arthropod
Summation and facilitation of endplate potentials
Graded muscle contractions
Train of nerve impulses