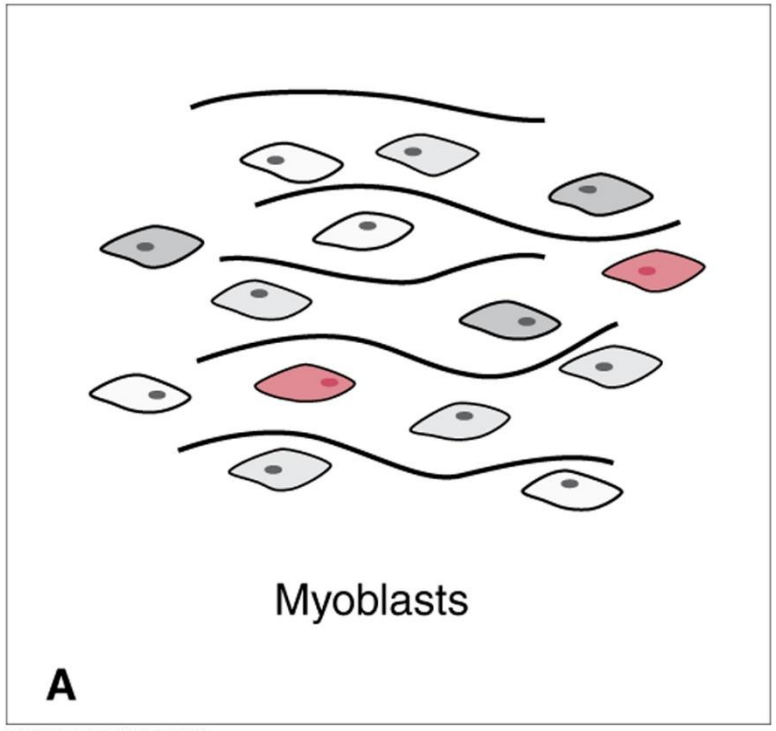
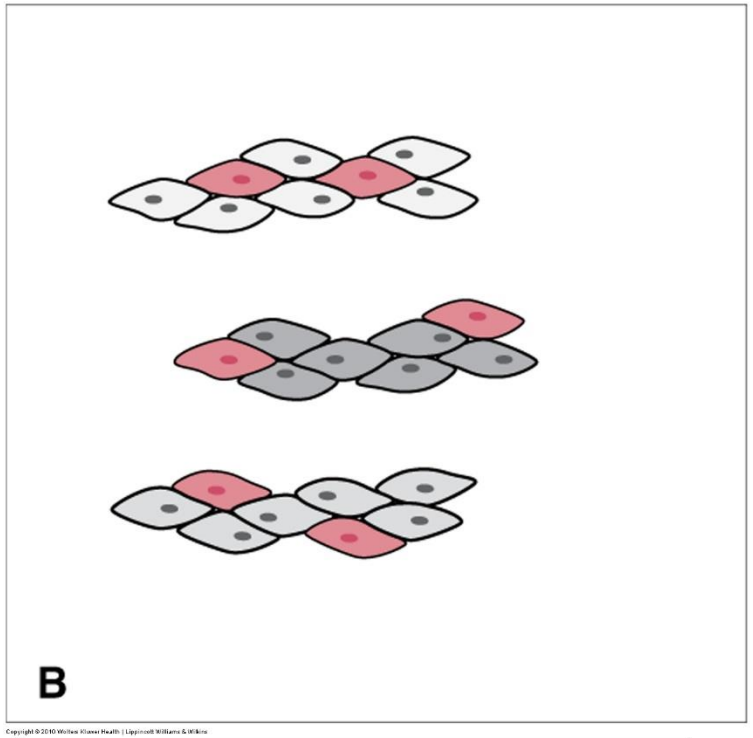
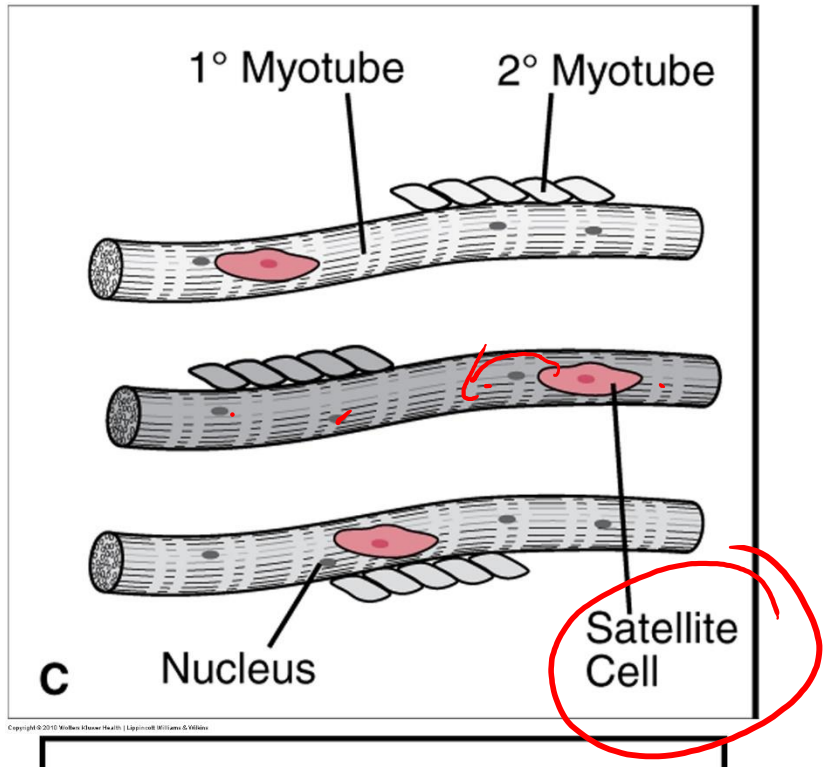
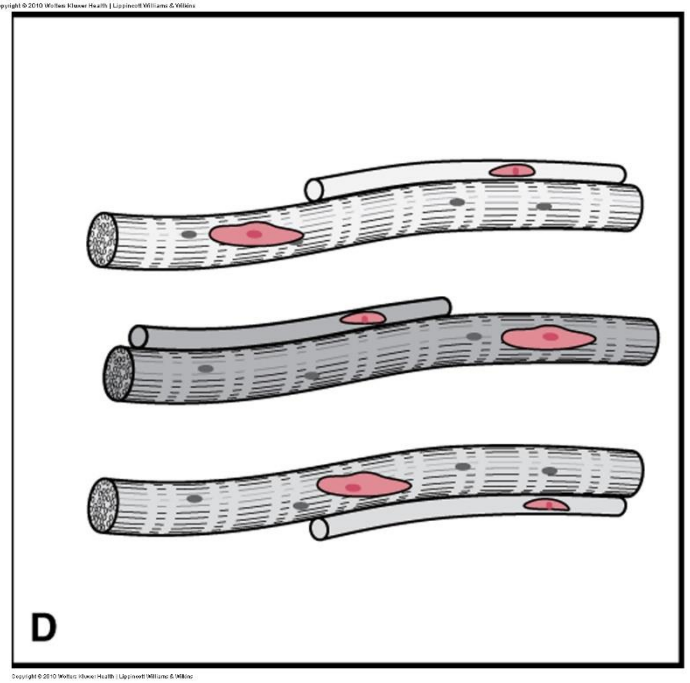
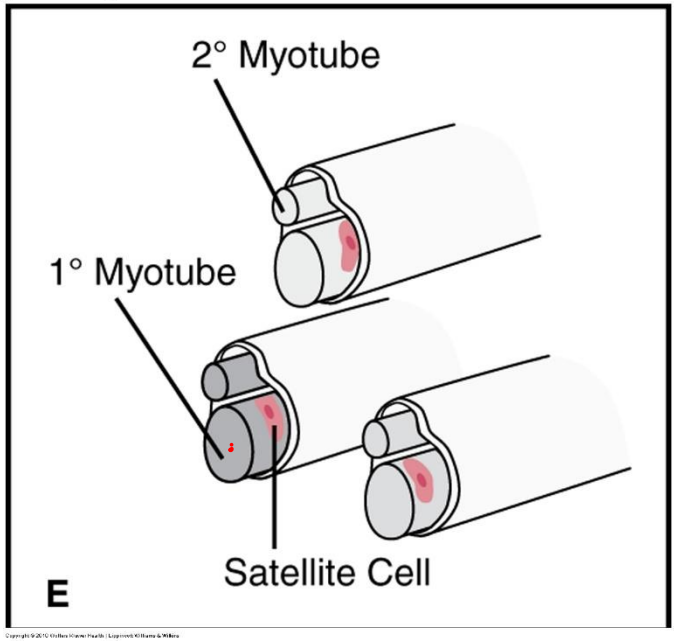
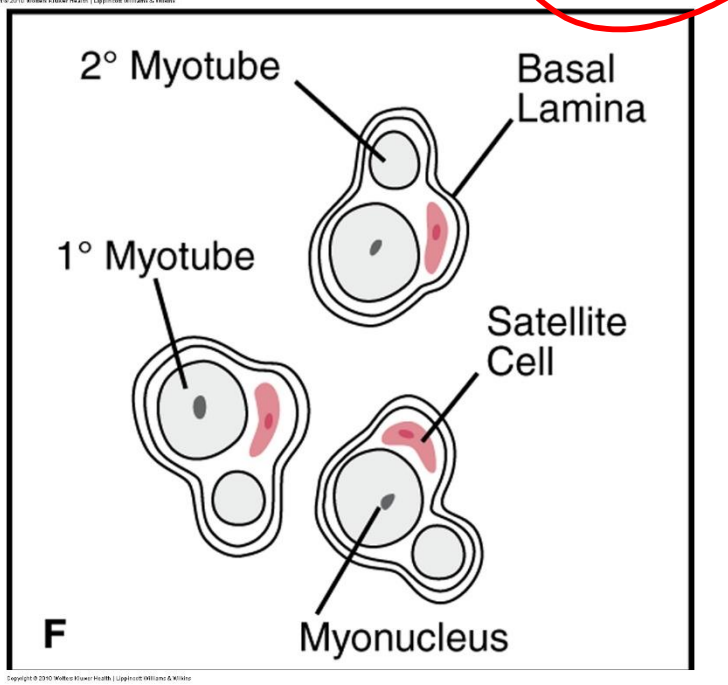

Myoblasts
A

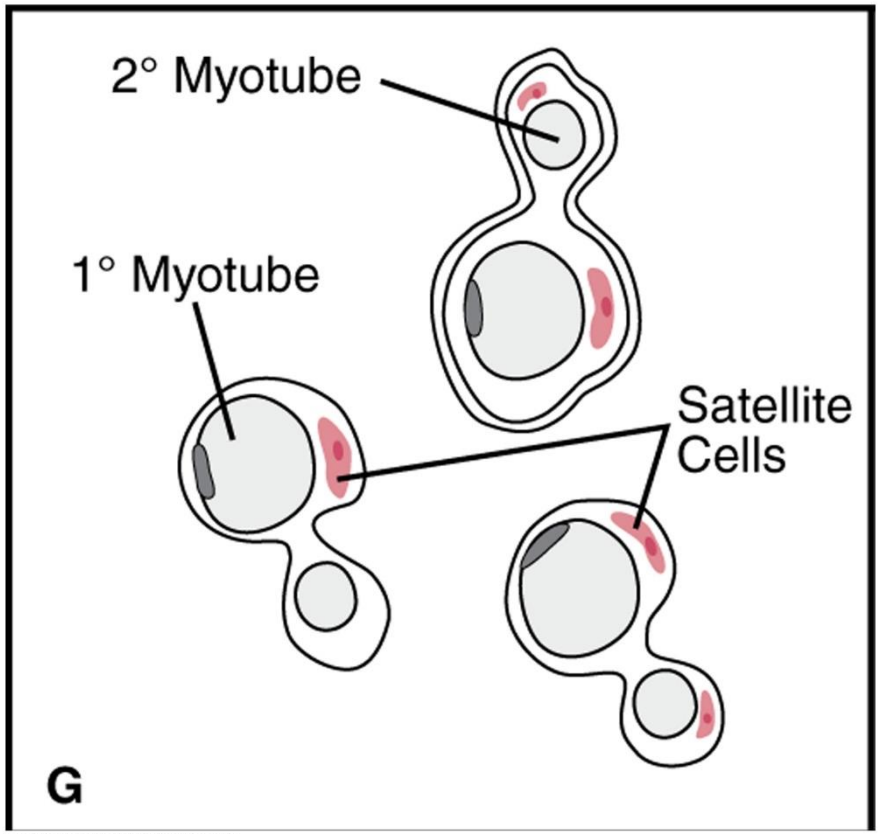

B

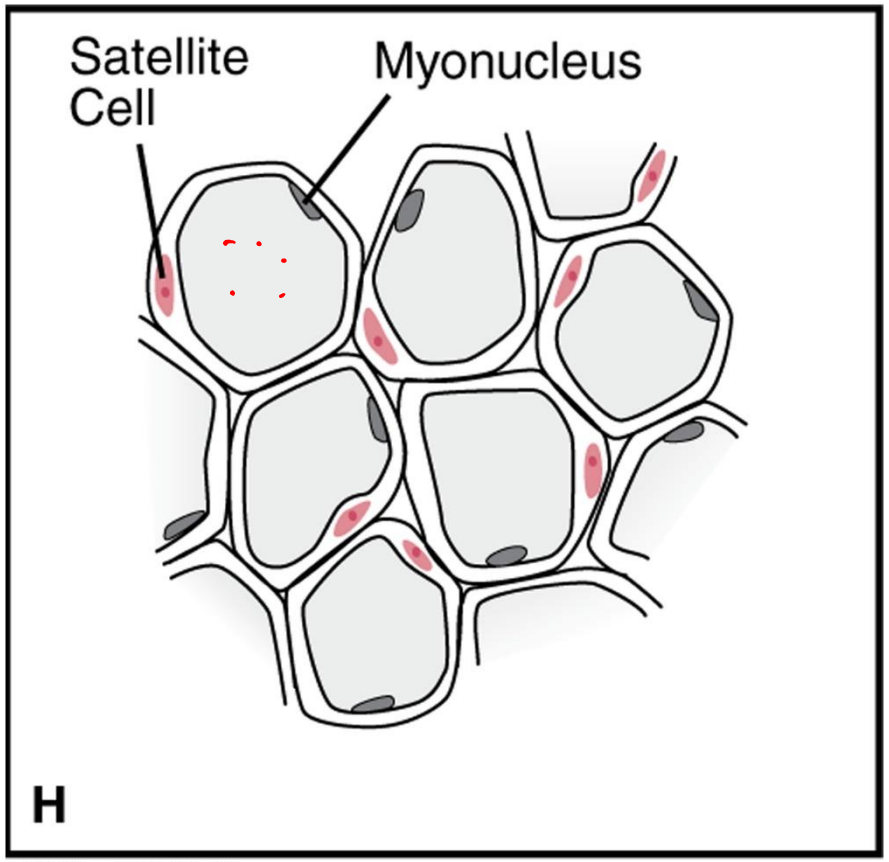

1° Myotube
2° Myotube
Nucleus
Satellite Cell
C

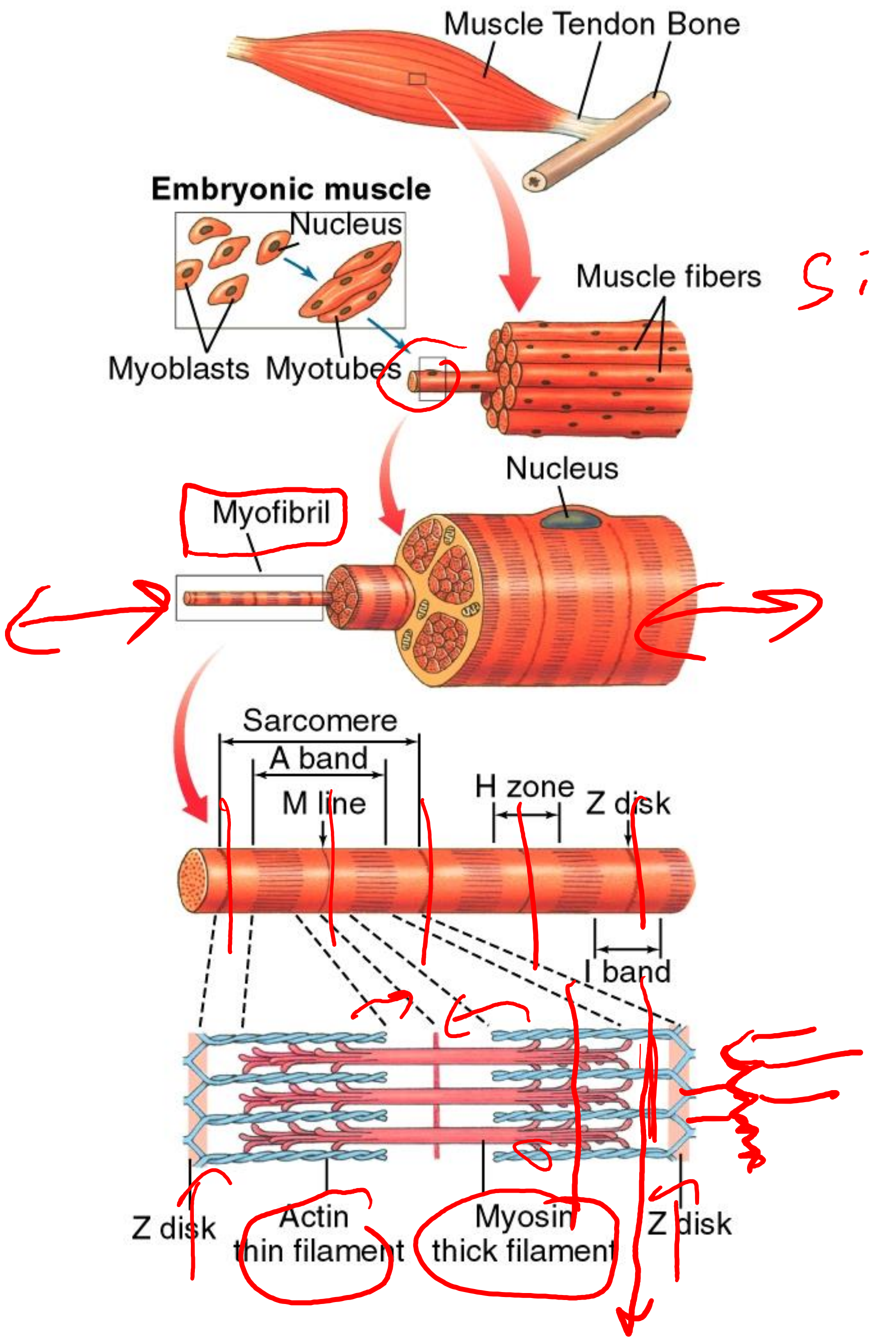

D


2° Myotube
1° Myotube
Satellite Cell
E

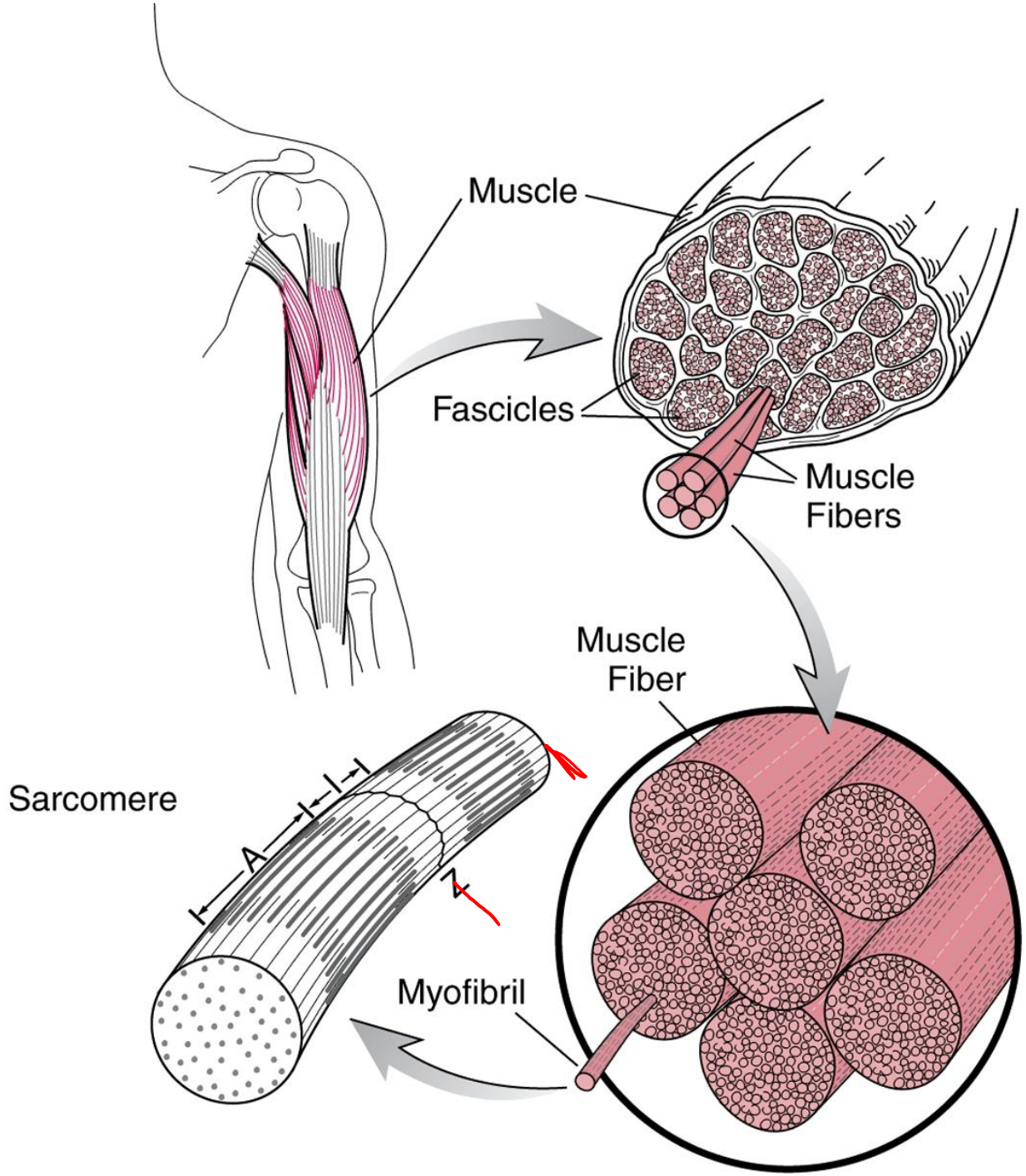

2° Myotube
Basal Lamina
1° Myotube
Satellite Cell
Myonucleus
F

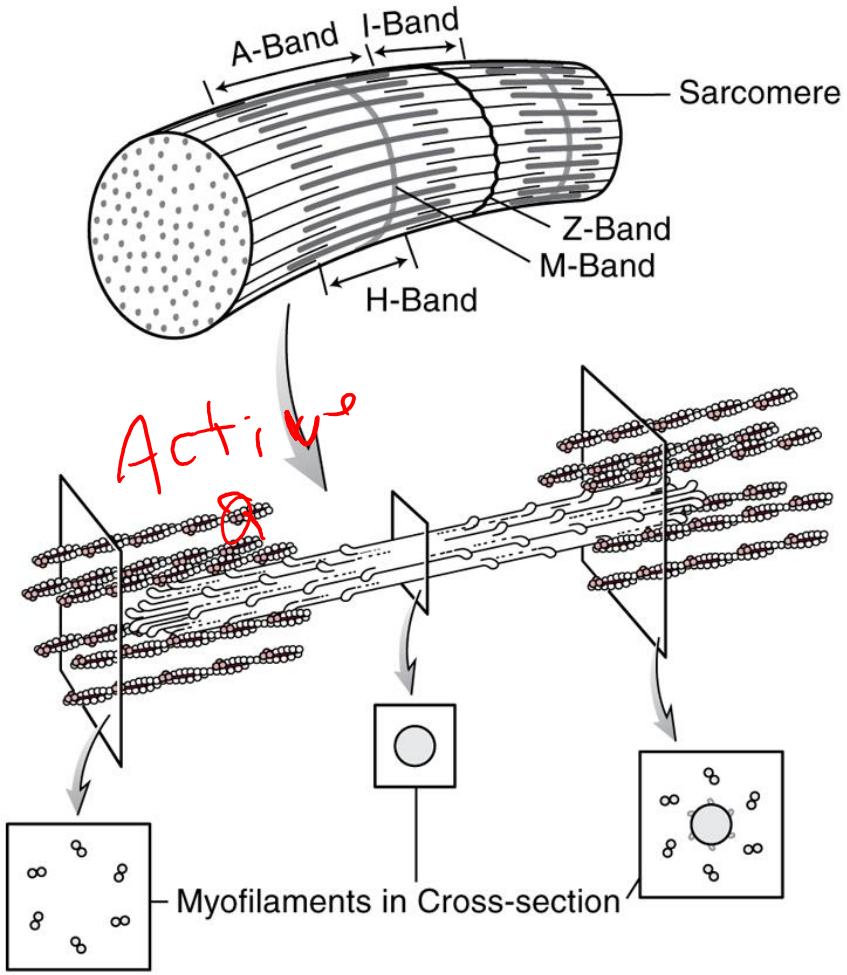


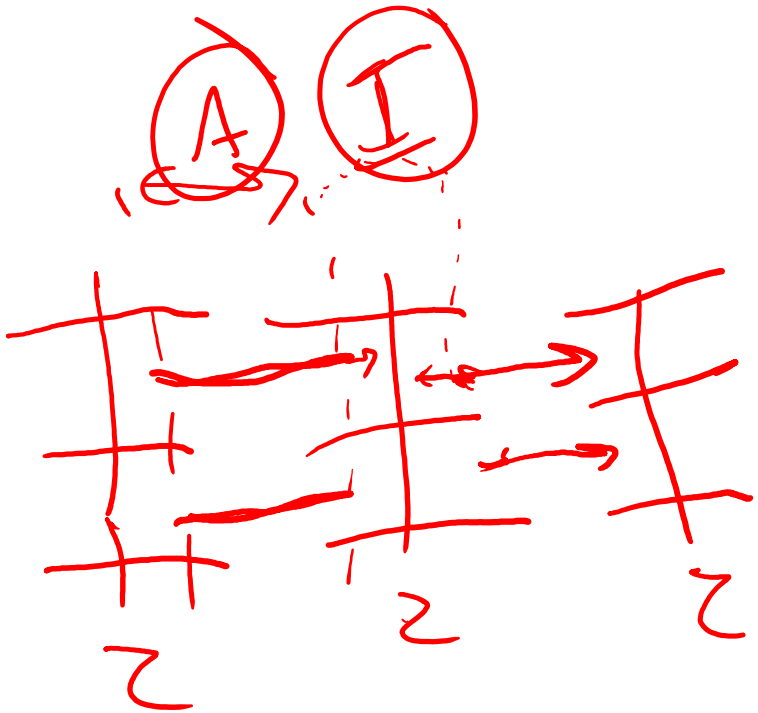


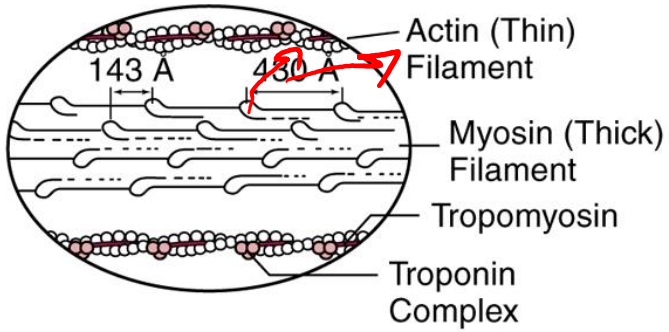


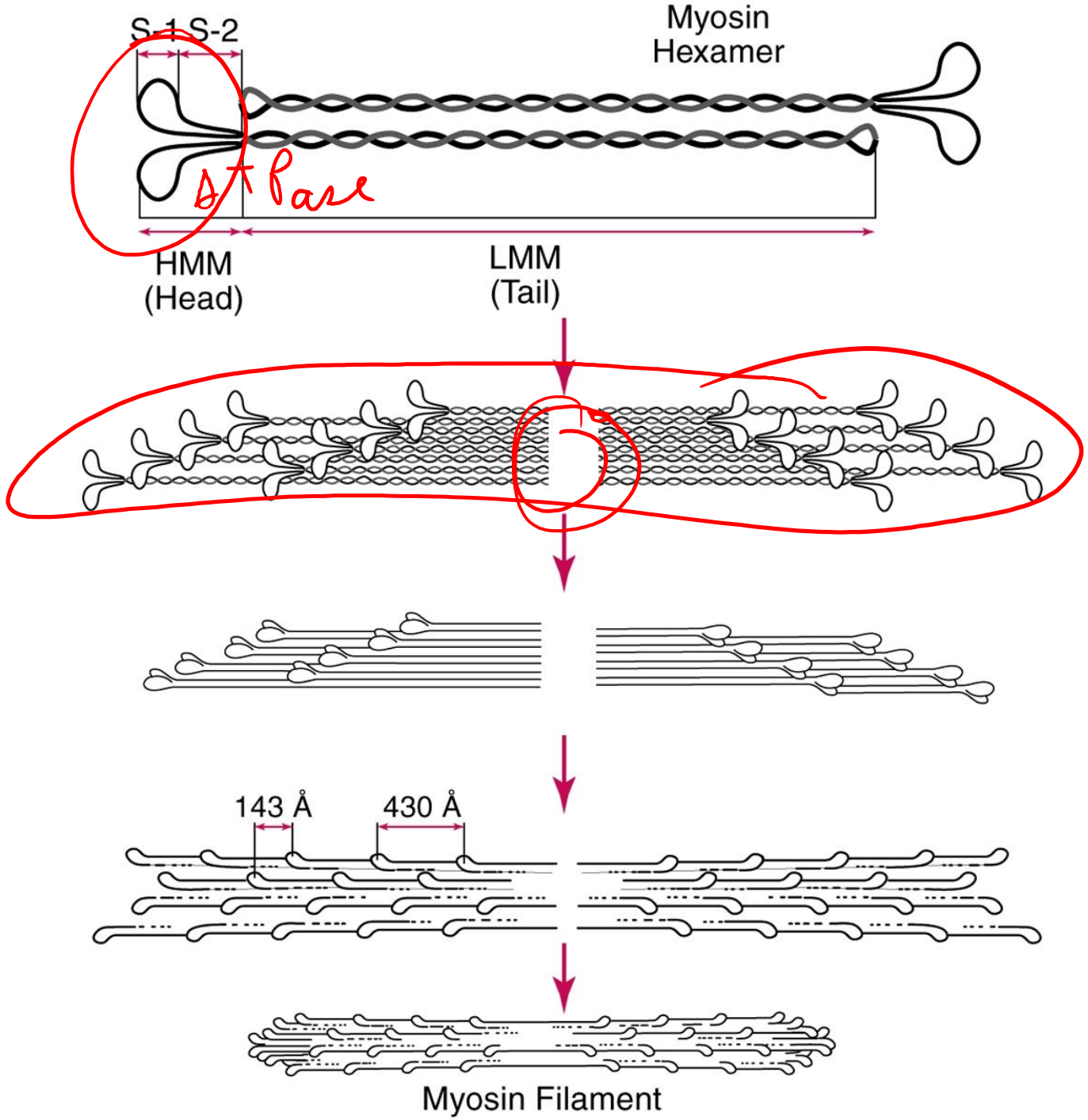
single cell w/ multiple nuc

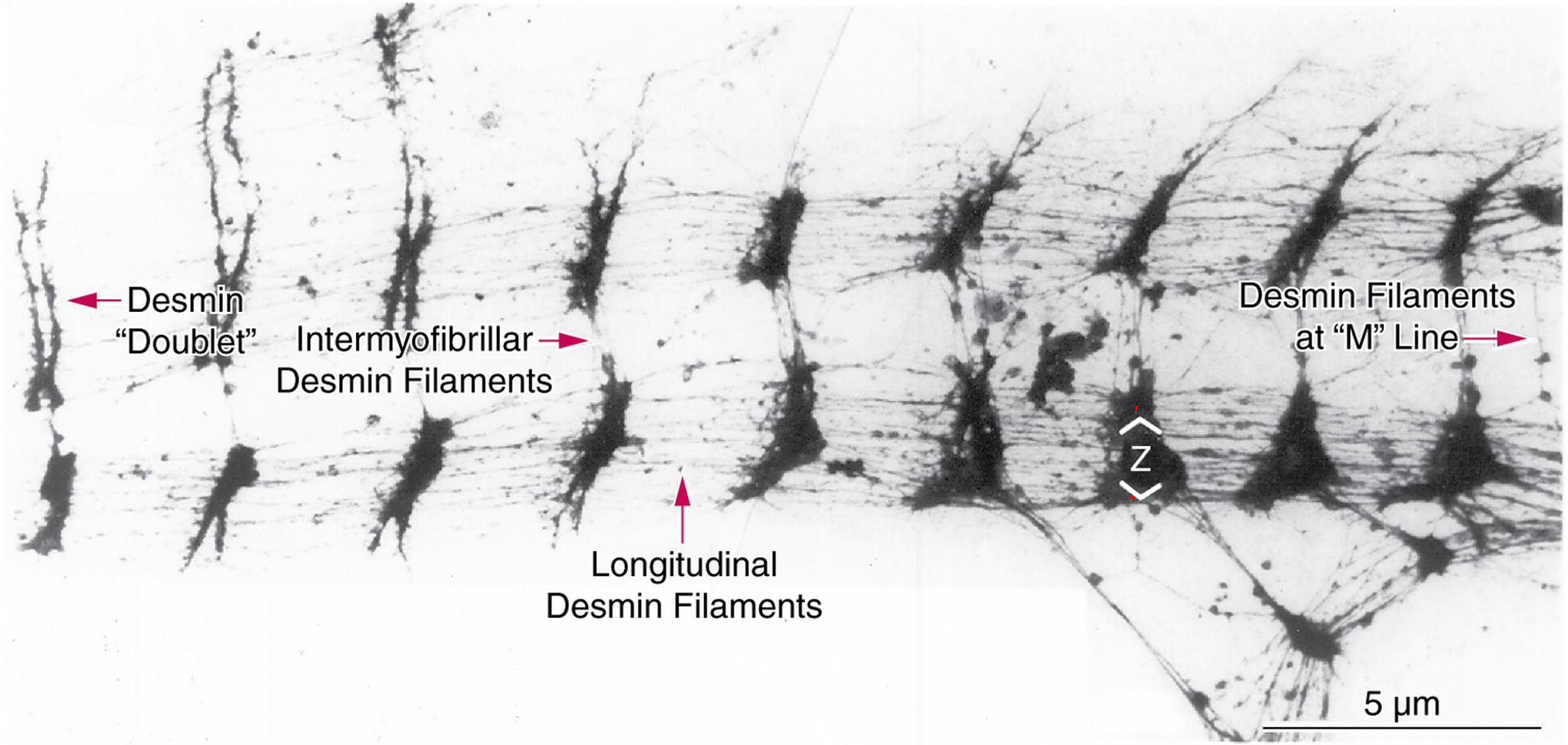


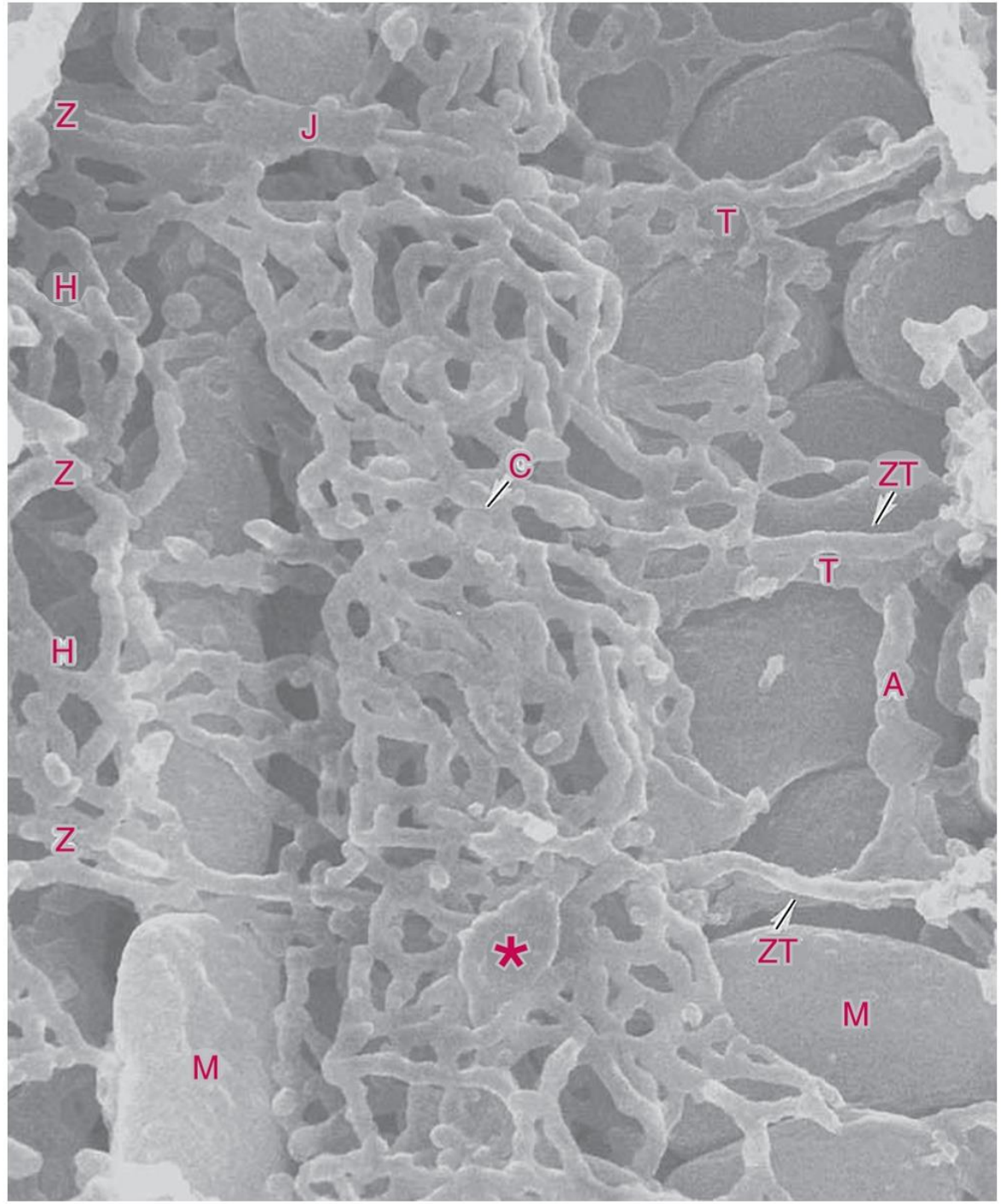


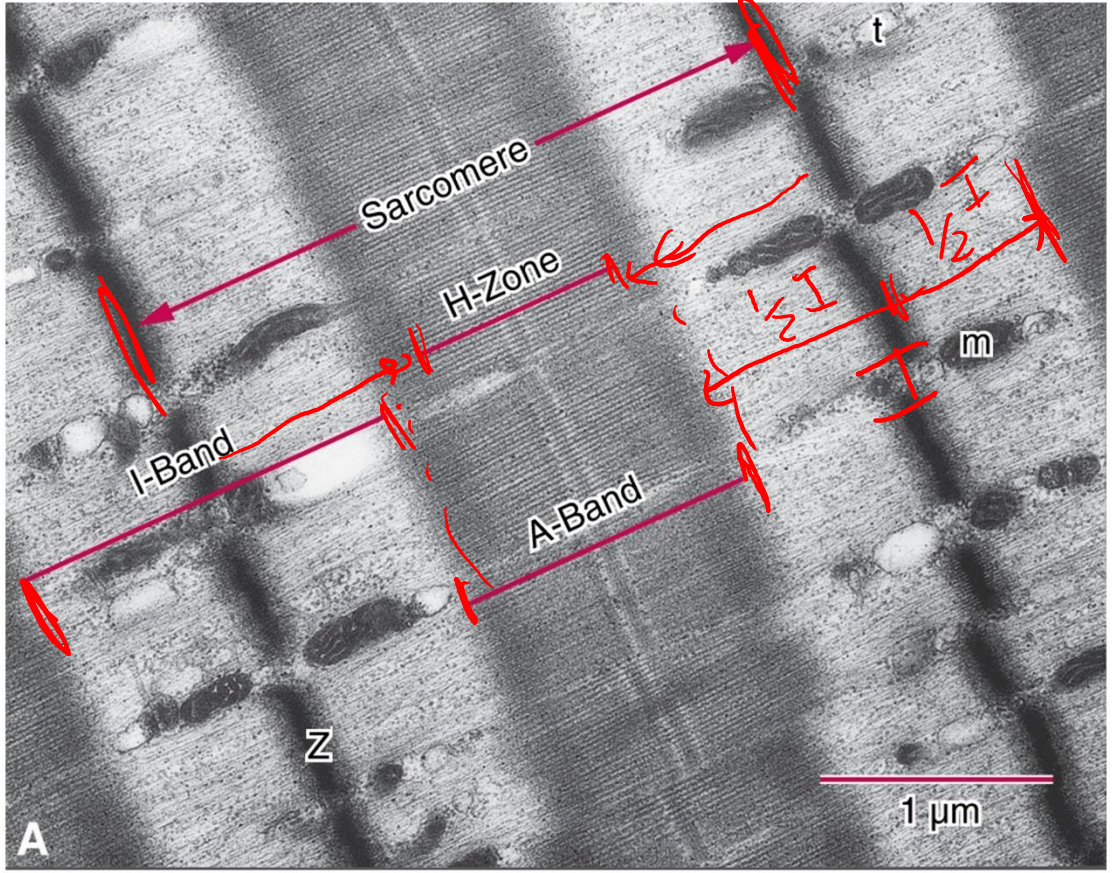


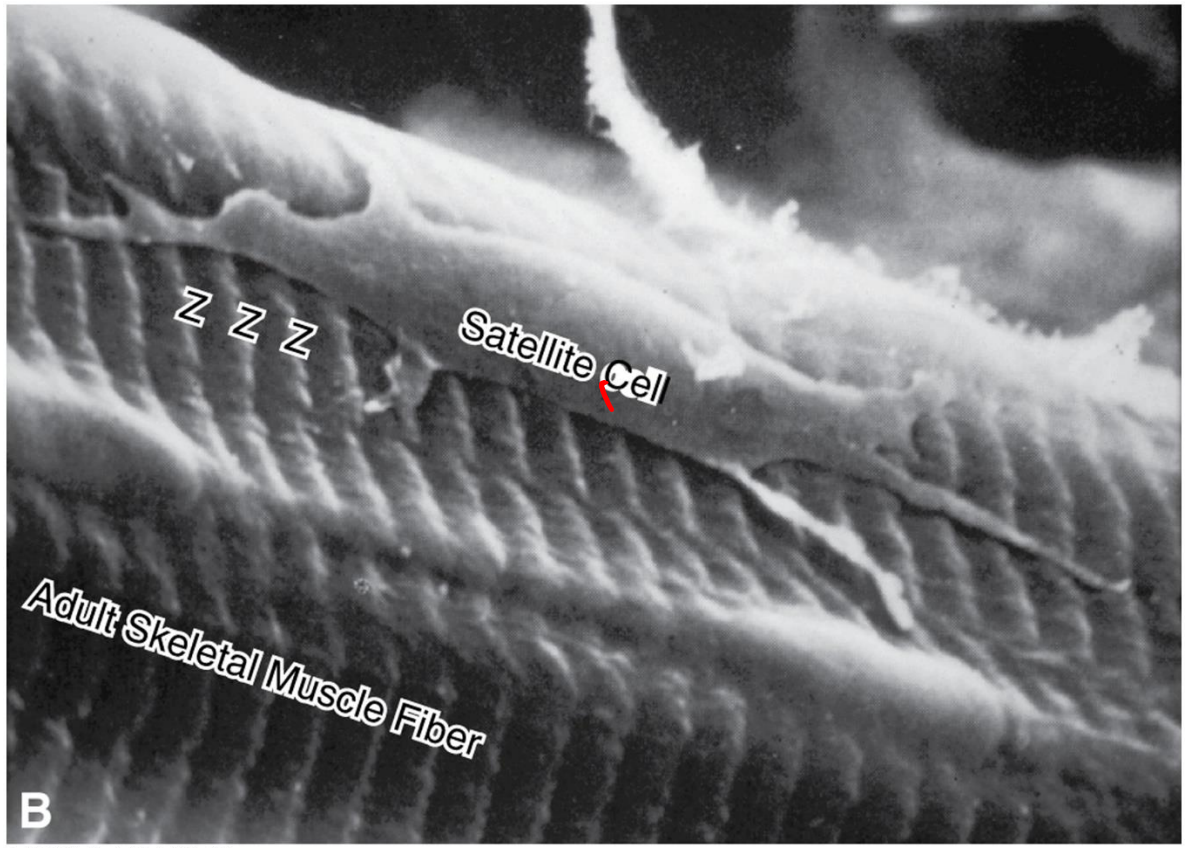


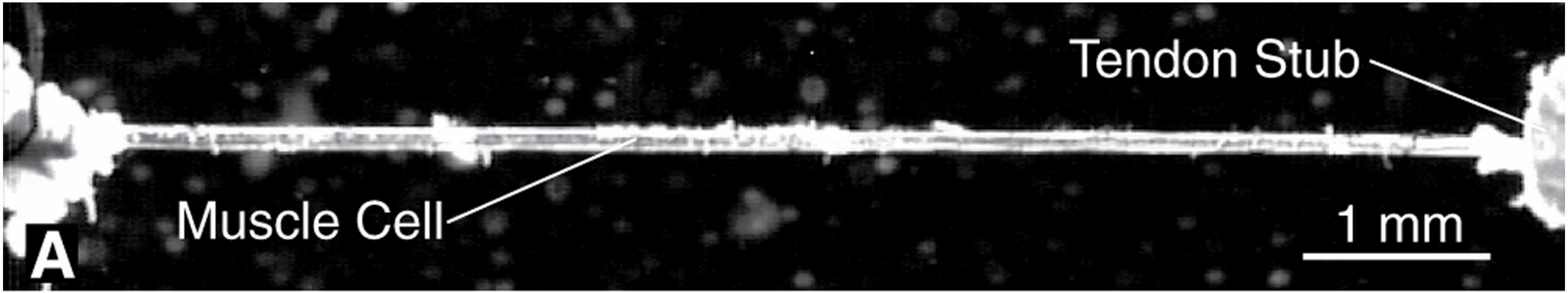


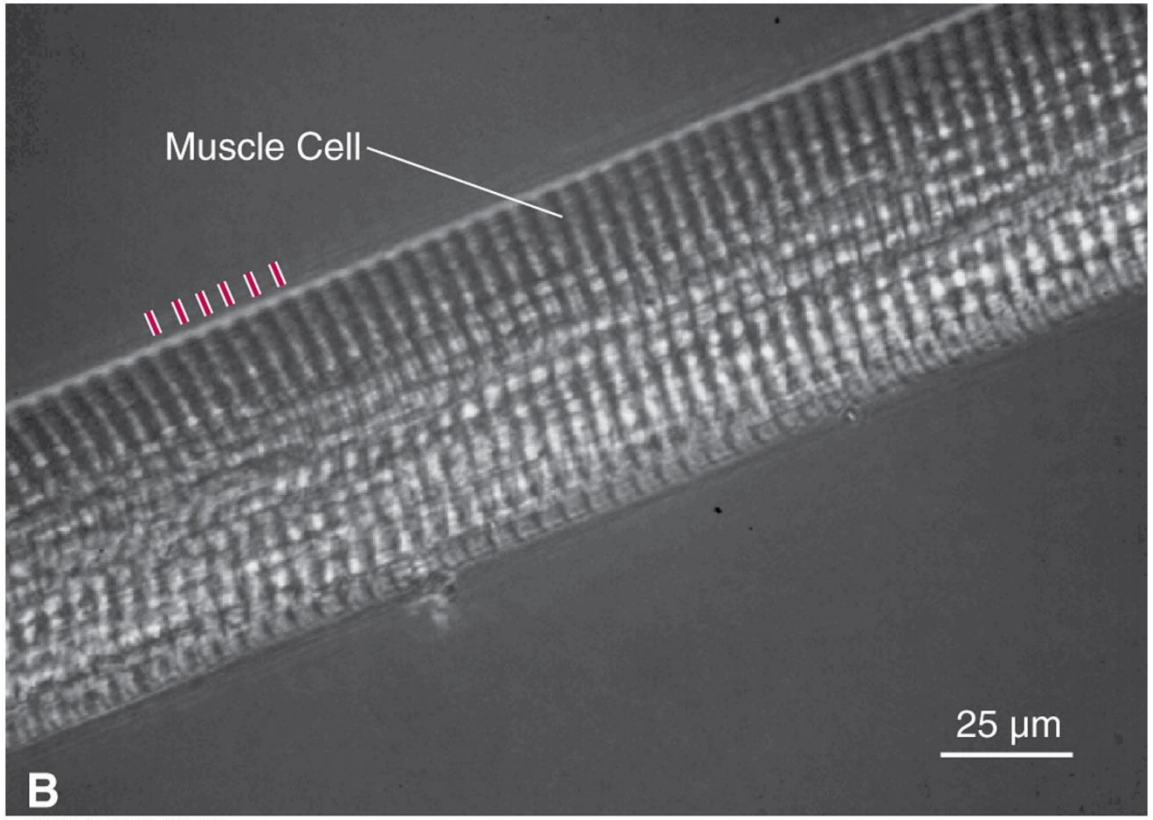


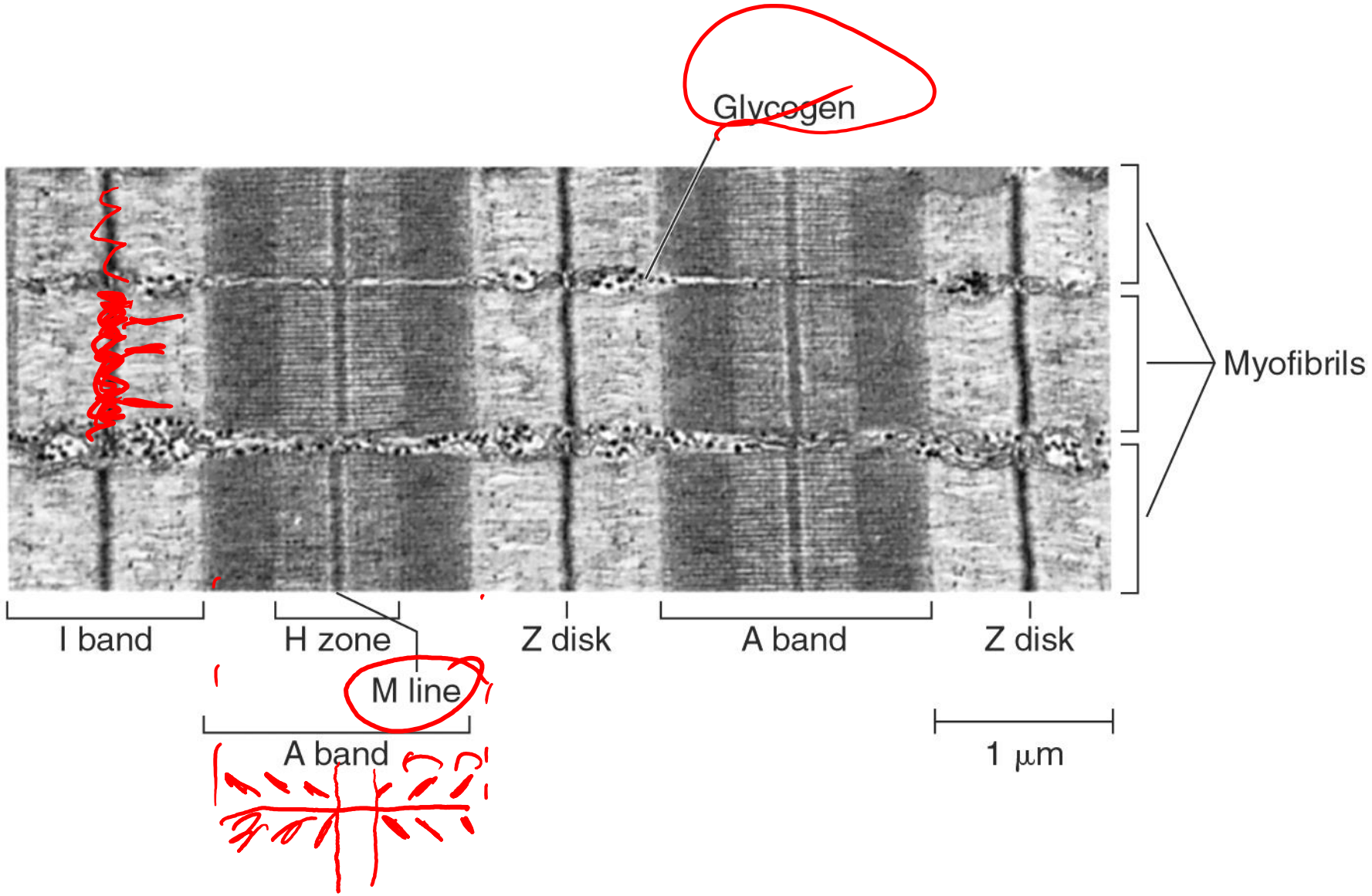


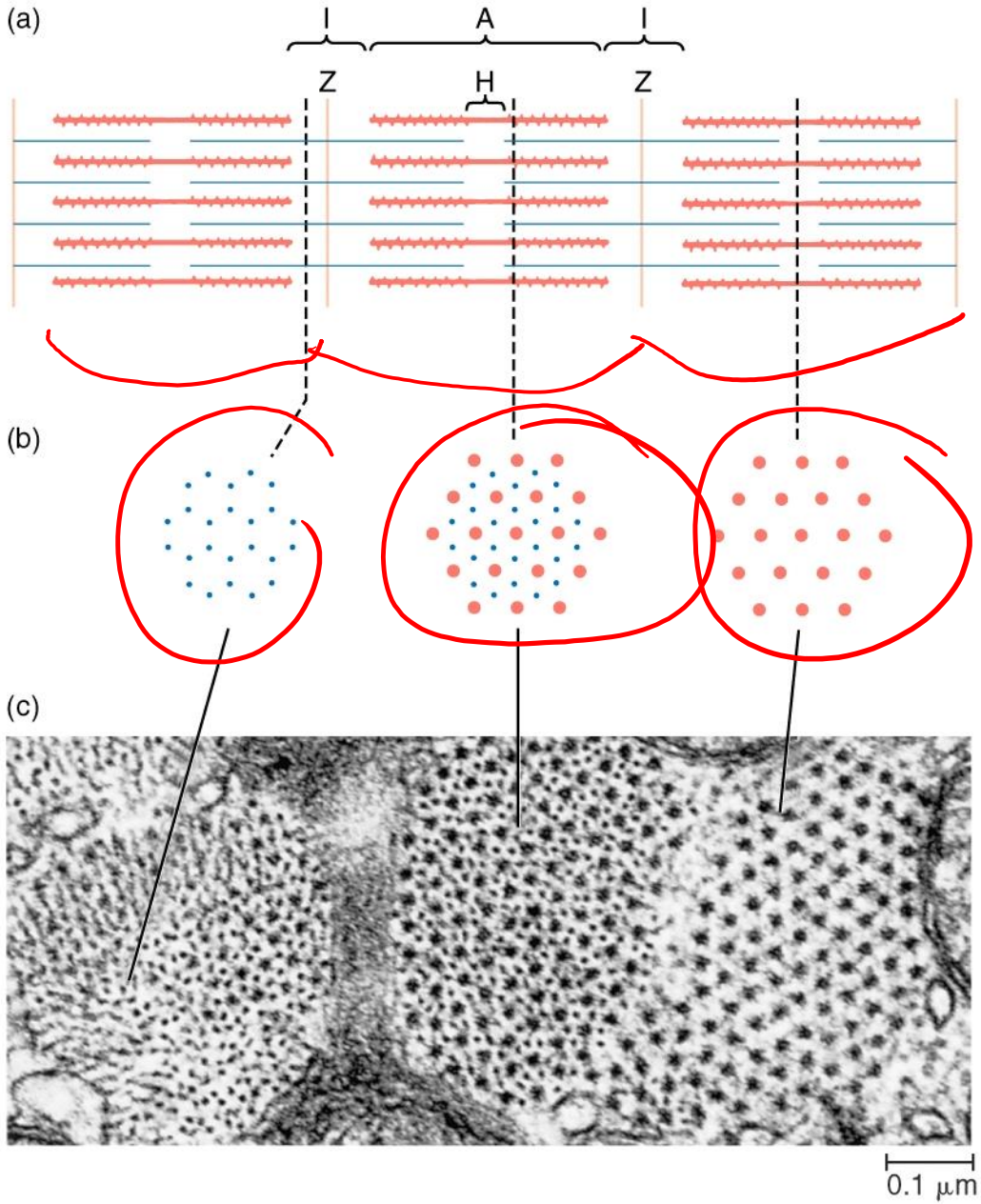


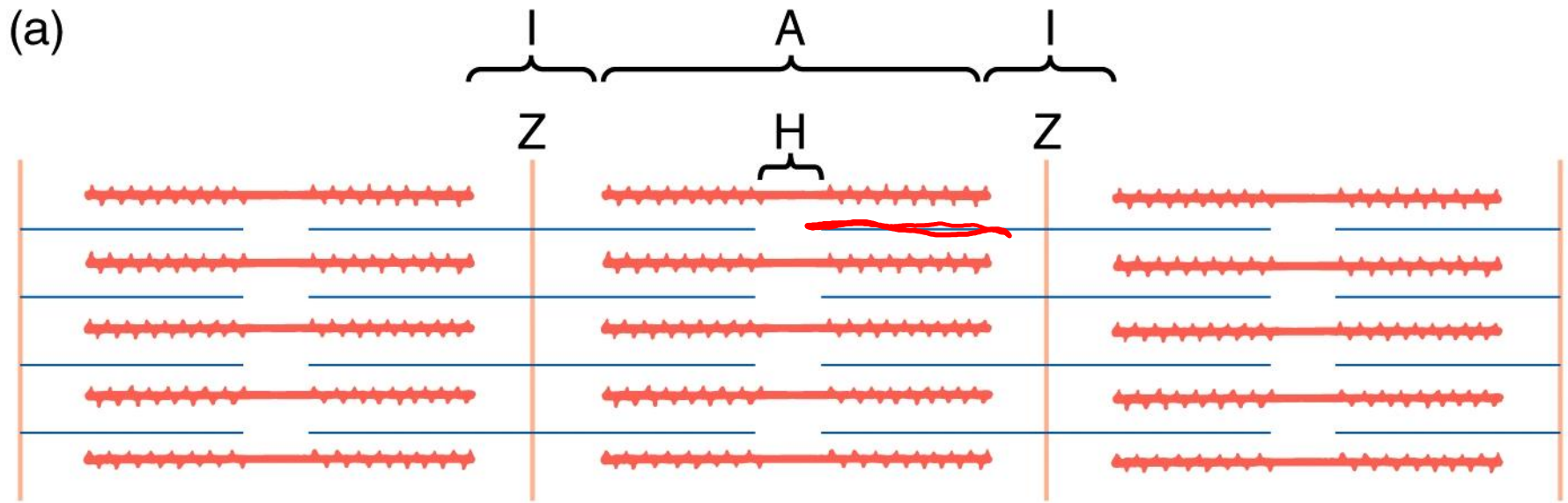




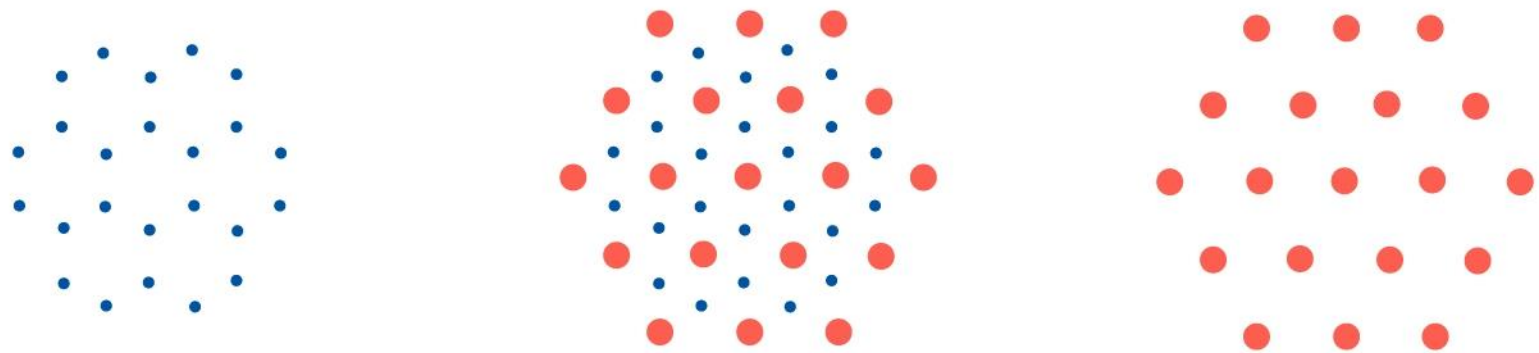


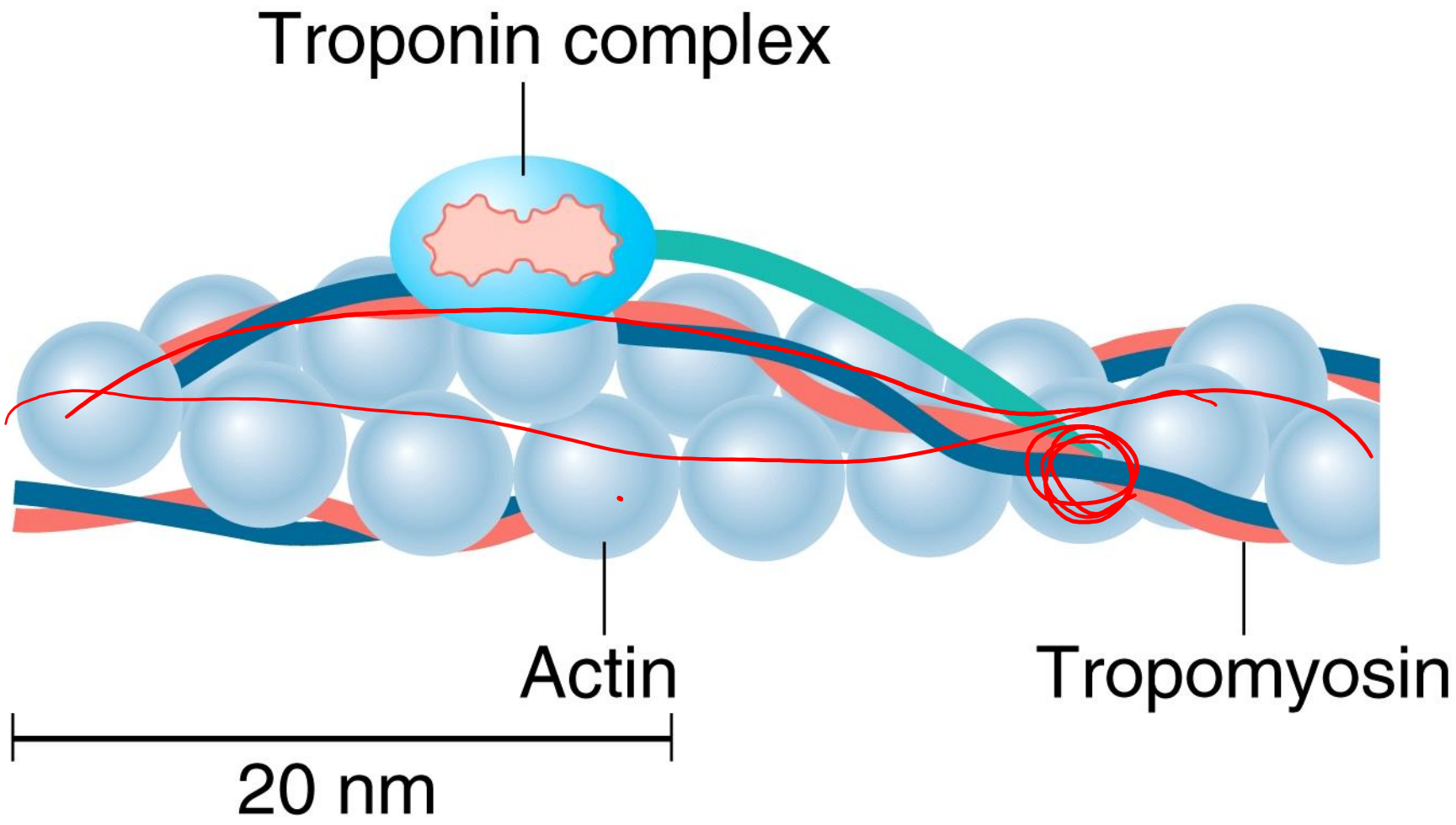

Glycogen
Myofibrils
I band
H zone
Z disk
A band
Z disk
M line
A band
1 μm

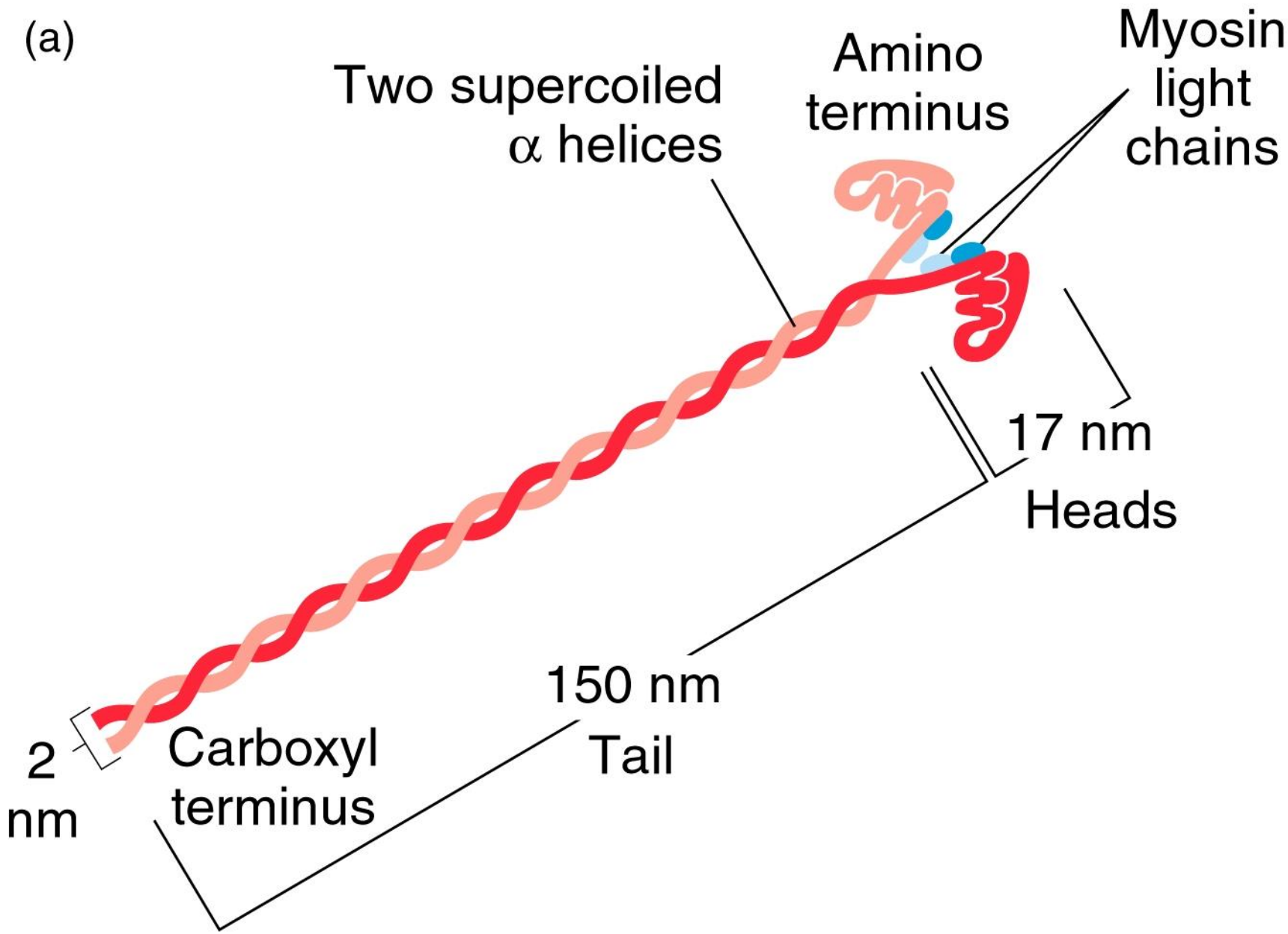

(a)
I
A
I
Z
H
Z
(b)
(c)
0.1 μm

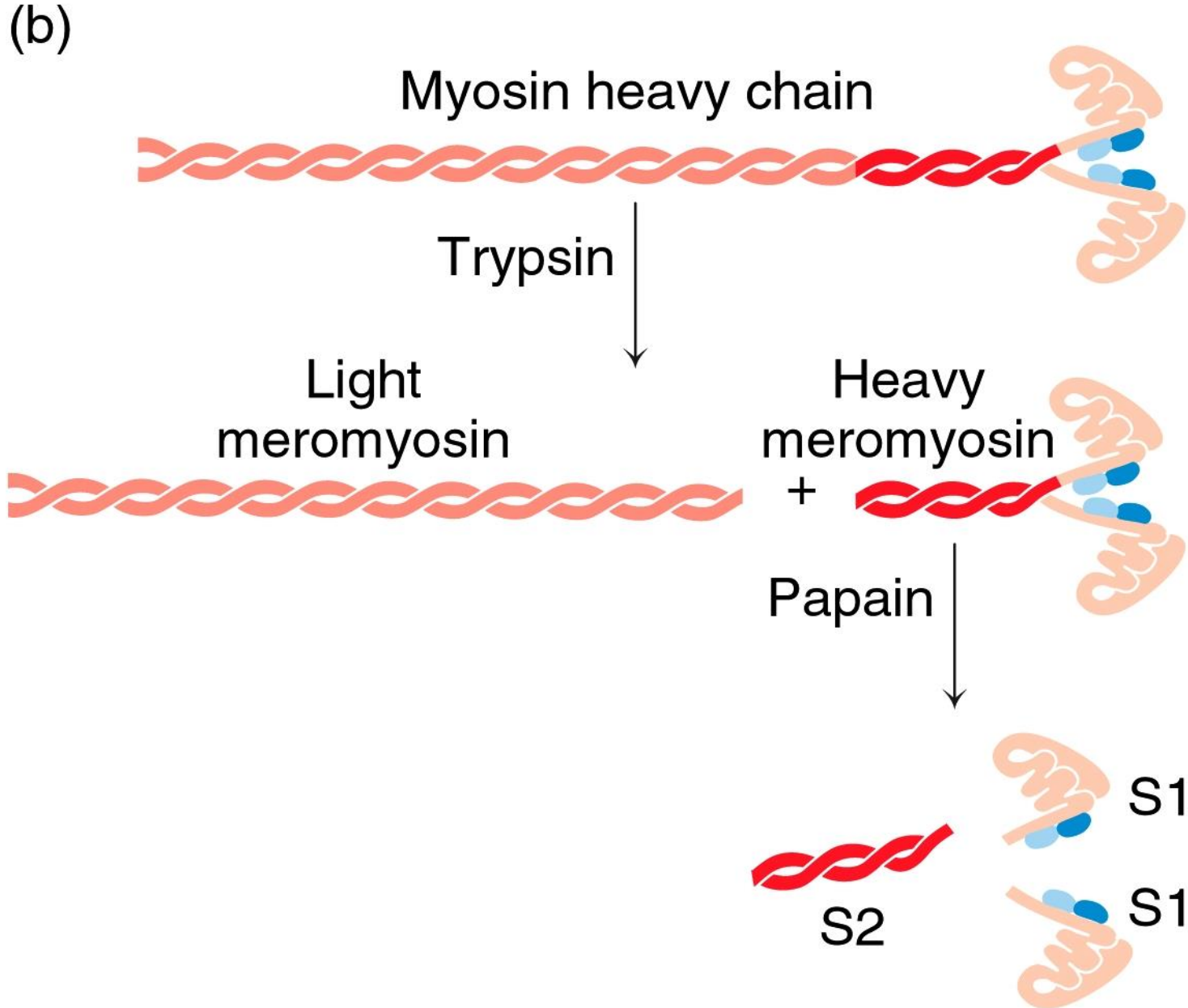

(a)
I
A
I
Z
H
Z

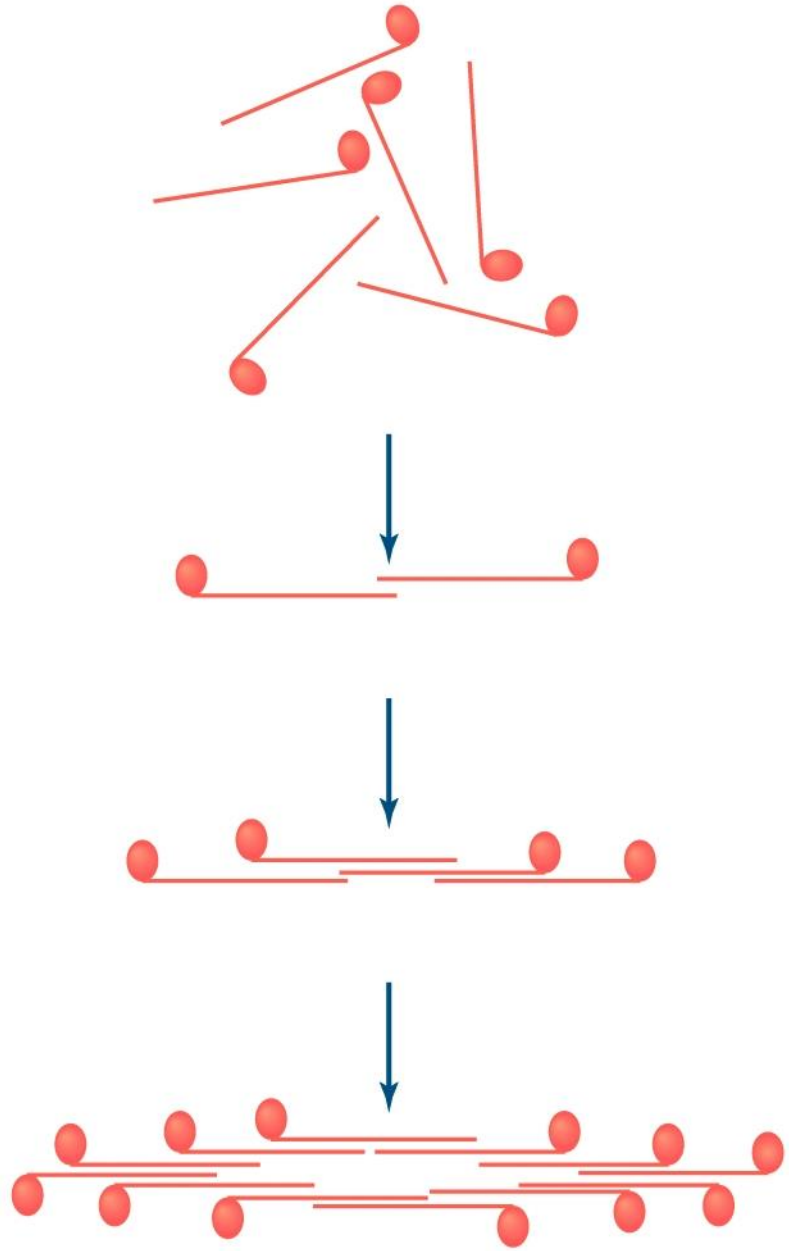
(b)




Troponin complex
Actin
Tropomyosin
20 nm

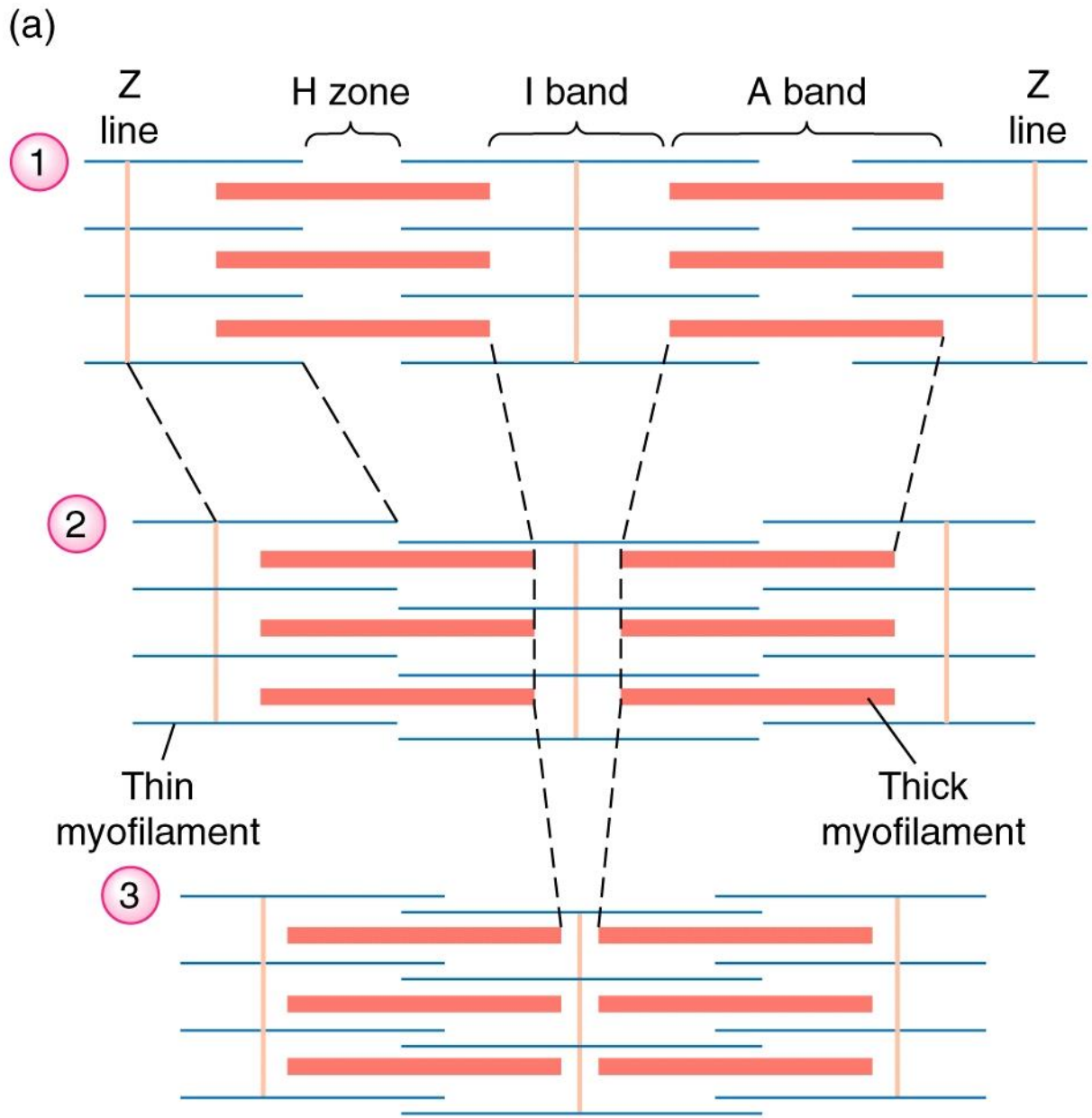

(a)
Two supercoiled α helices
Amino terminus
Myosin light chains
17 nm
Heads
150 nm
Tail
2 nm
Carboxyl terminus

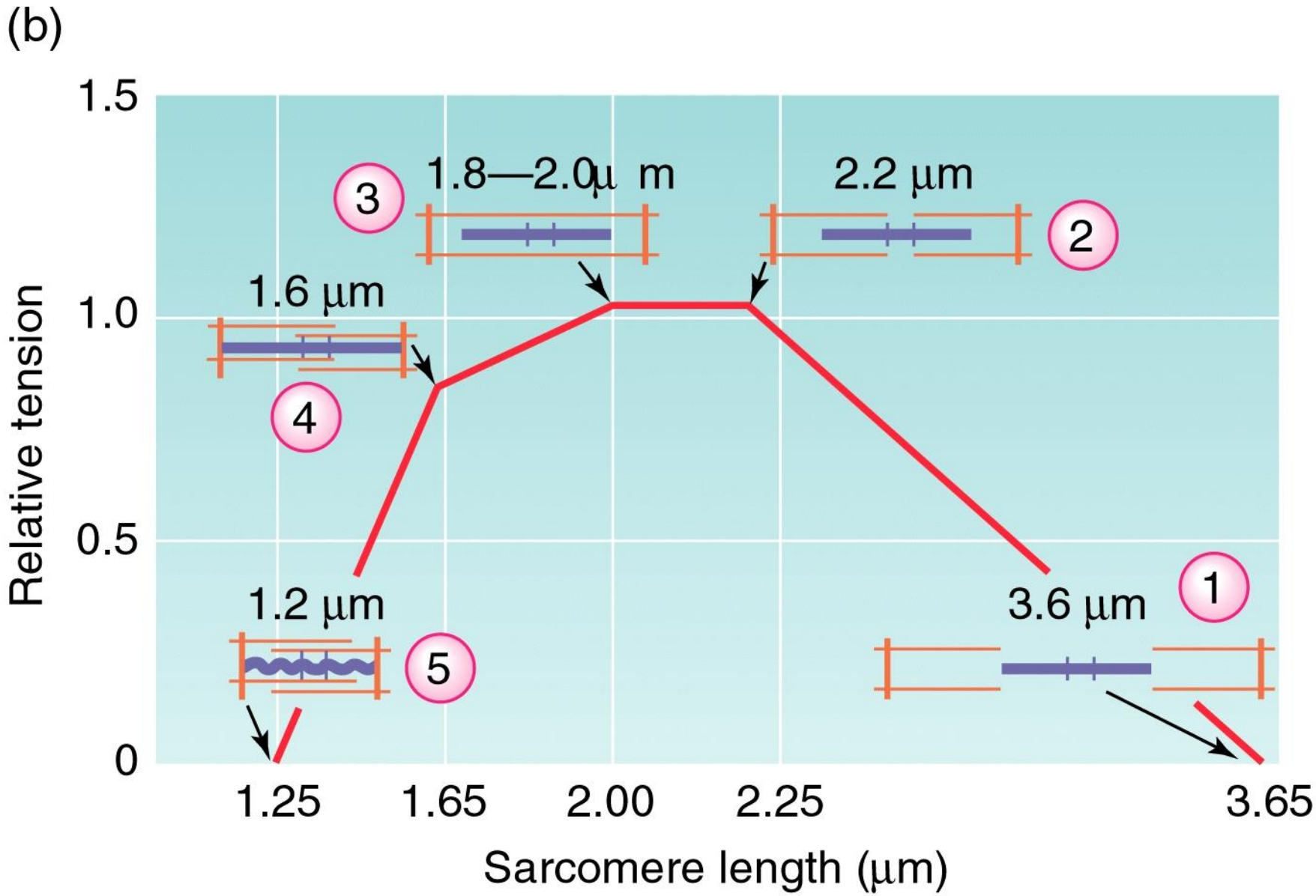

(b)
Myosin heavy chain
Trypsin
Light
meromyosin
Heavy
meromyosin
+
Papain
S1
S2
S1



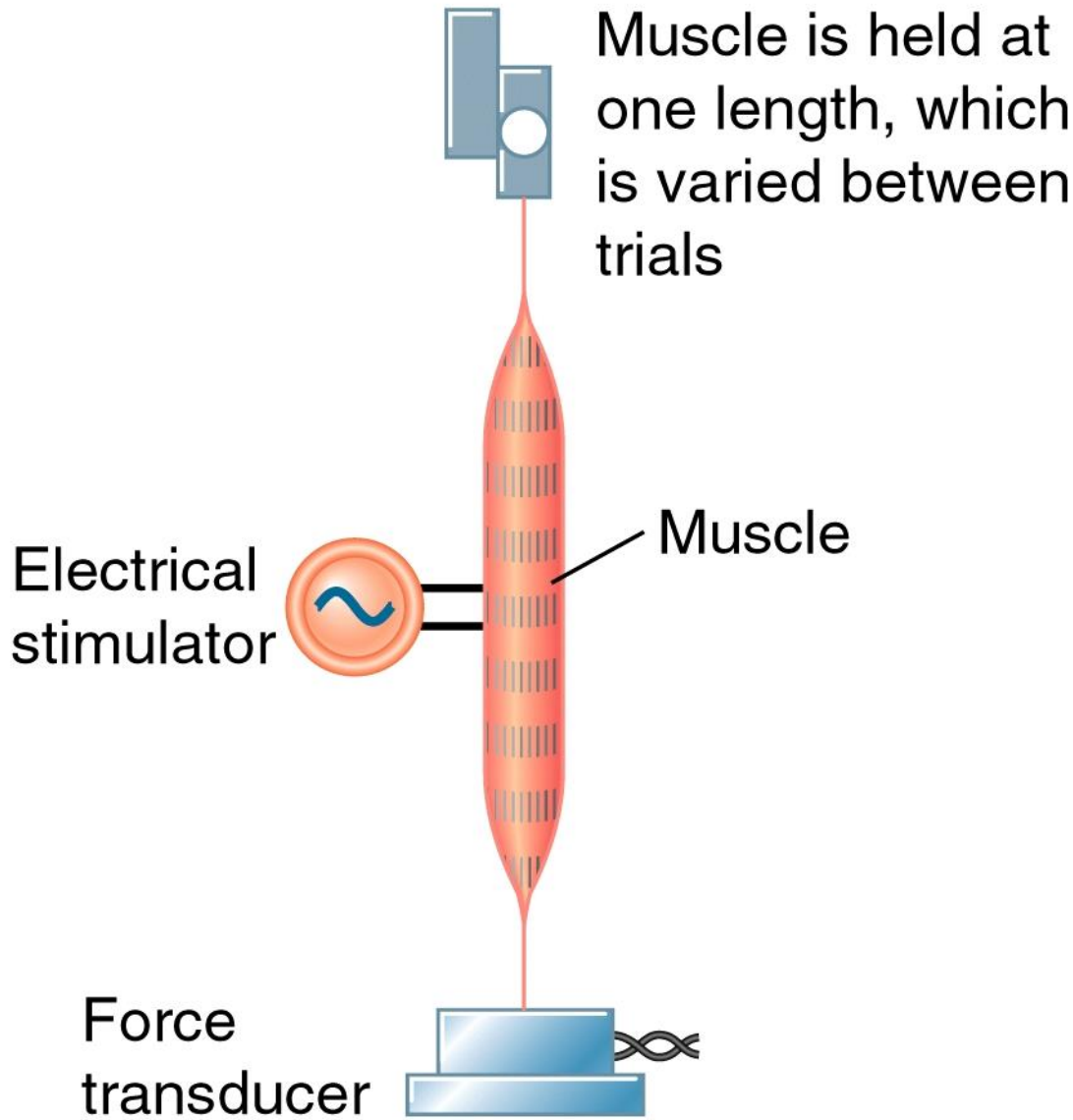
Albert Szent-Györgyi

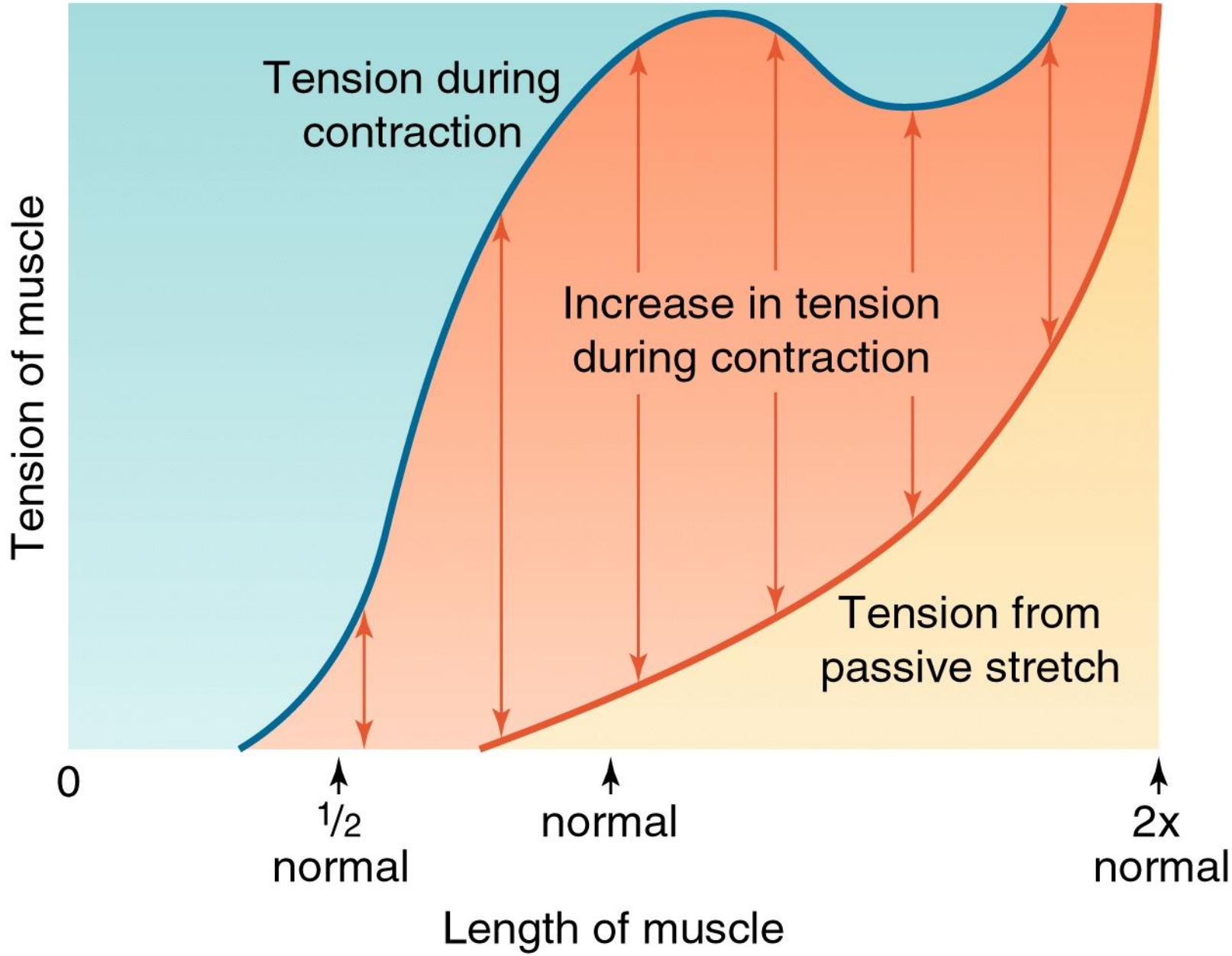
https://en.wikipedia.org/wiki/Albert_Szent-Gy%C3%B6rgyi


(a)
Z line
H zone
I band
A band
Z line
1
2
3
Thin myofilament
Thick myofilament

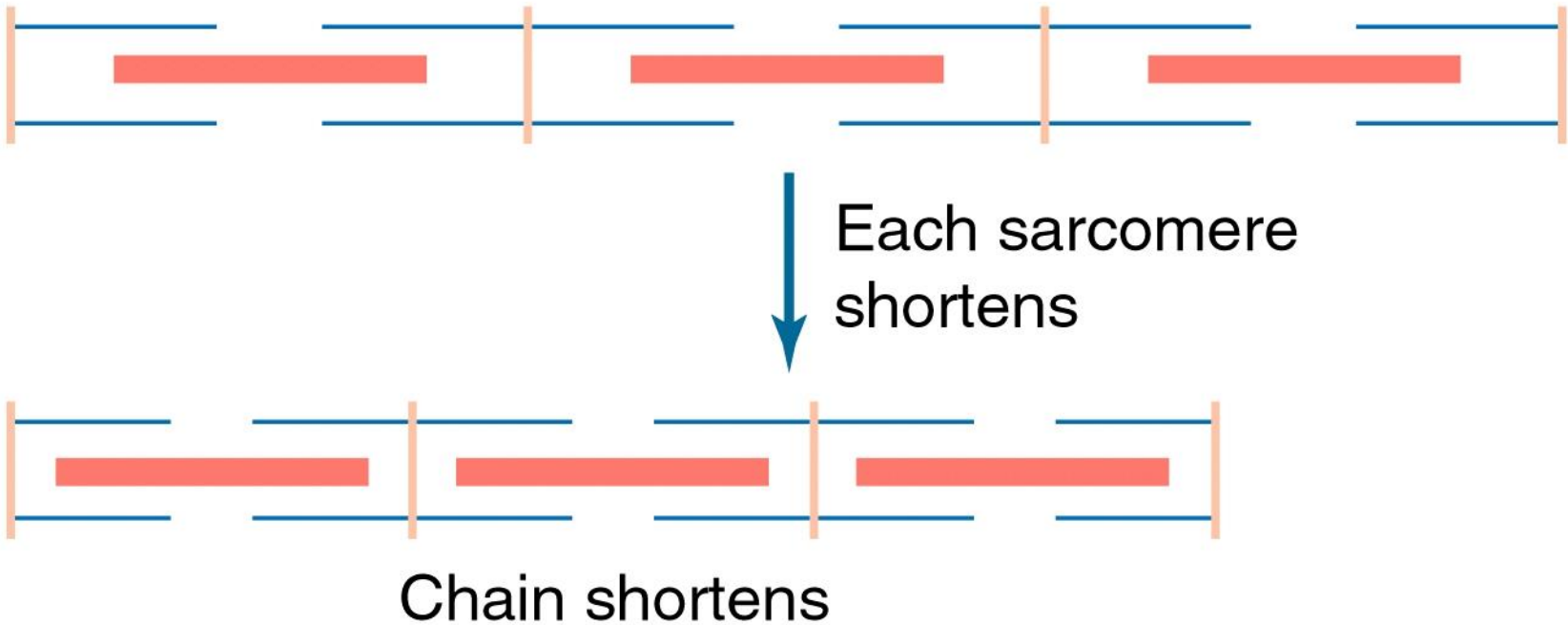

(b)
1.5
1.0
0.5
0
Relative tension
1.8—2.0µ m
2.2 µm
1.6 µm
1.2 µm
3.6 µm
3
2
4
5
1
1.25
1.65
2.00
2.25
3.65
Sarcomere length (µm)

(c)

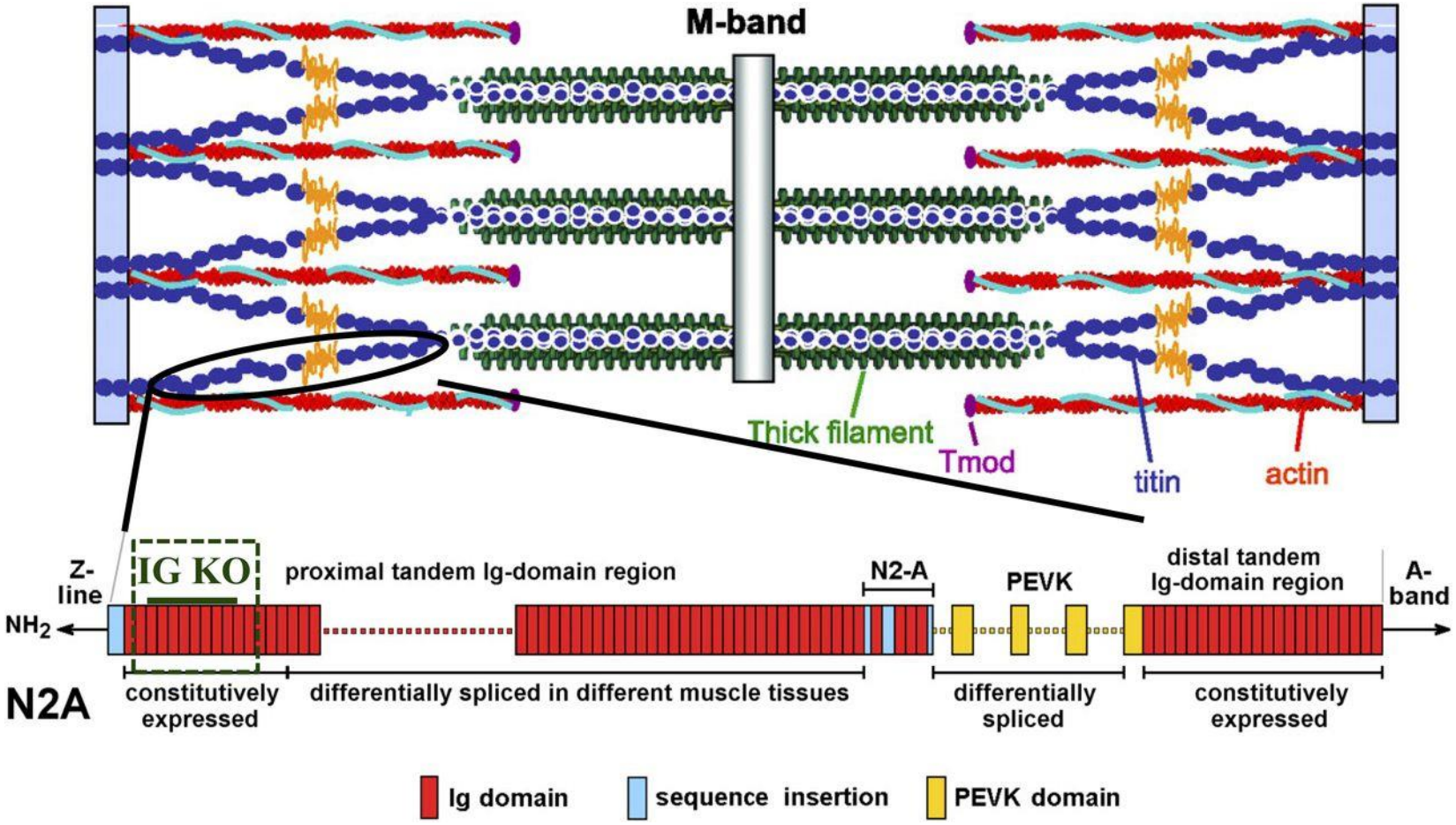

Muscle is held at one length, which is varied between trials
Muscle
Electrical stimulator
Force transducer


Tension during contraction
Increase in tension during contraction
Tension from passive stretch
Tension of muscle
0
1/2 normal
normal
2x normal
Length of muscle

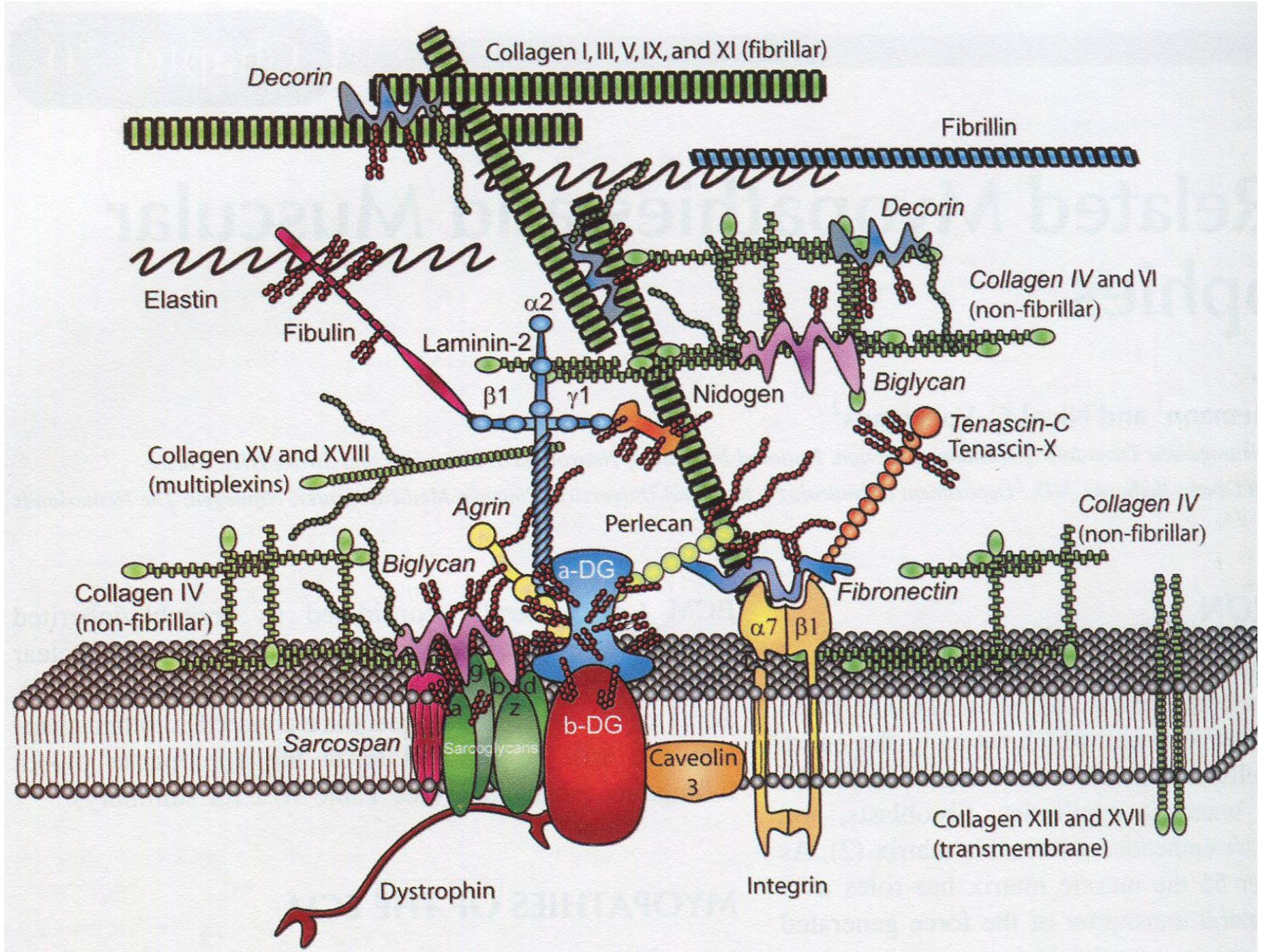
(c)

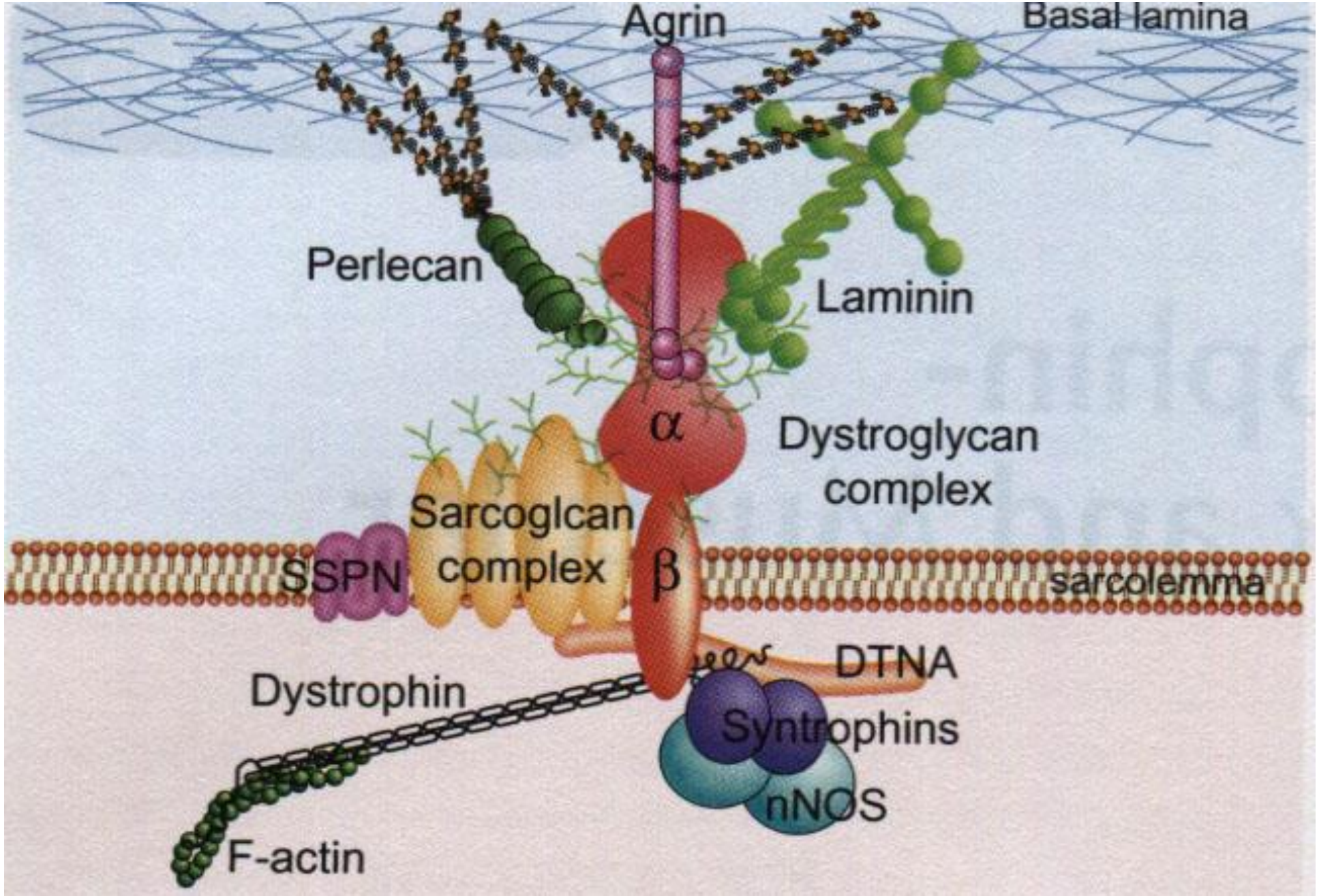


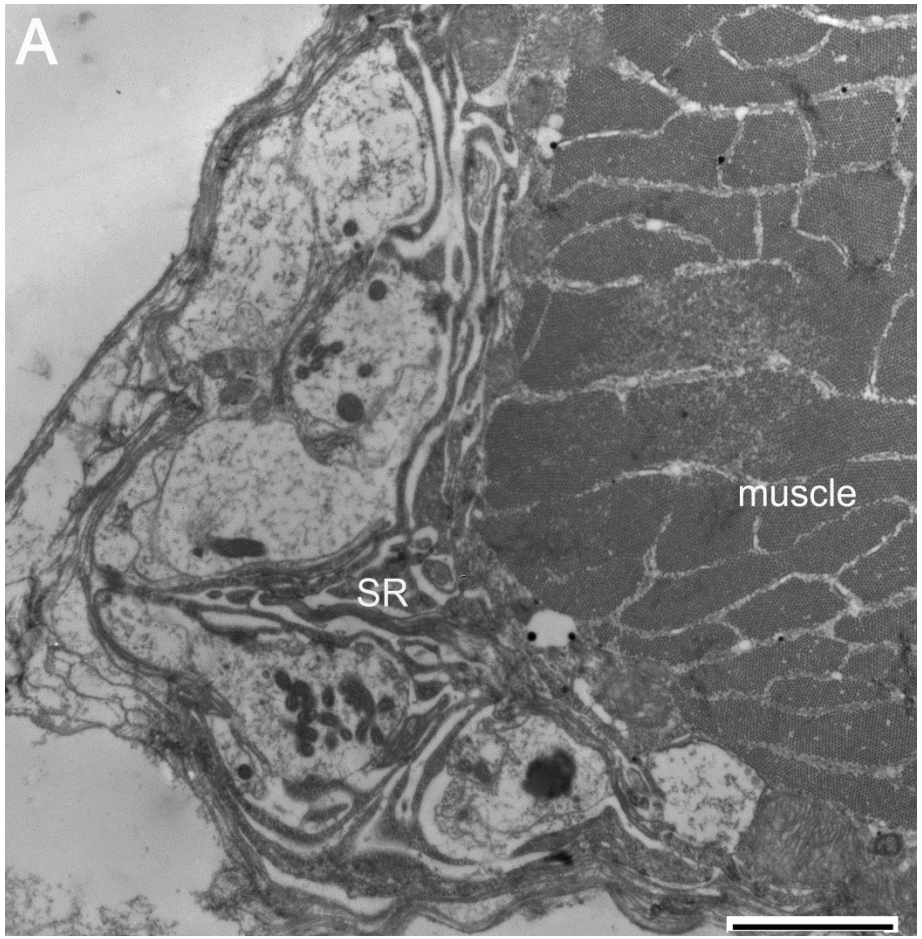
Layout of titin in the sarcomere.

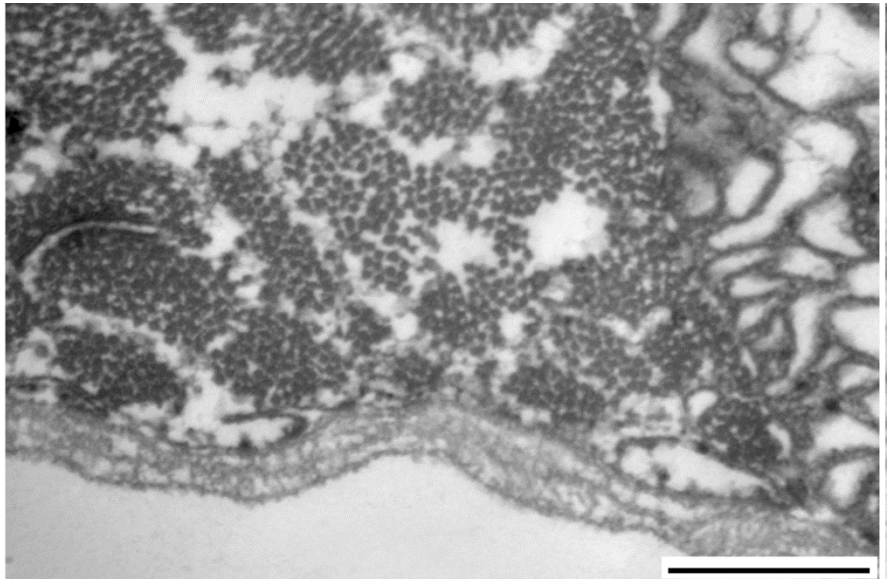


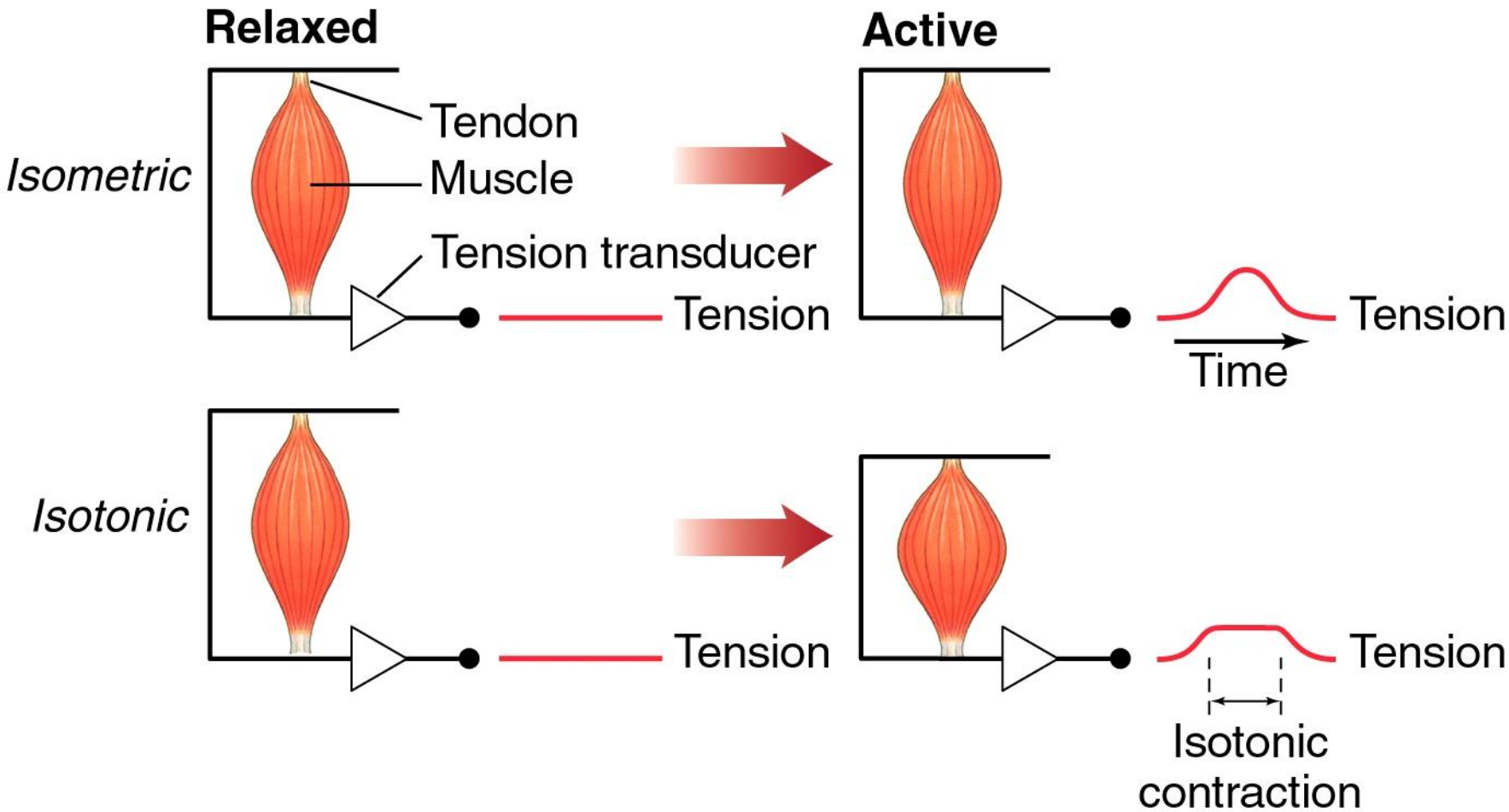
Danielle Buck et al. J Gen Physiol 2014;143:215-230

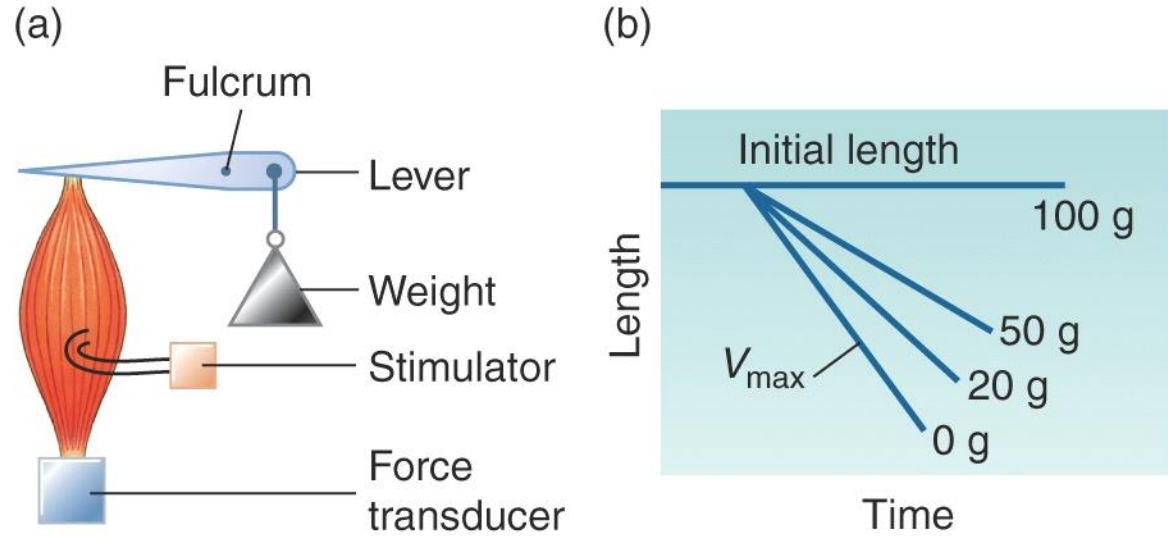

Collagen I, III, V, IX, and XI (fibrillar)
Decorin
Fibrillin
Decorin
Elastin
Collagen IV and VI
(non-fibrillar)
α2
Fibulin
Laminin-2
Biglycan
β1
γ1
Nidogen
Tenascin-C
Tenascin-X
Collagen XV and XVIII
(multiplexins)
Agrin
Perlecan
Collagen IV
(non-fibrillar)
Biglycan
a-DG
Collagen IV
(non-fibrillar)
Fibronectin
α7
β1
g
b
d
a
z
b-DG
Sarcospan
Sarcoglycans
Caveolin
3
Collagen XIII and XVII
(transmembrane)
Dystrophin
Integrin

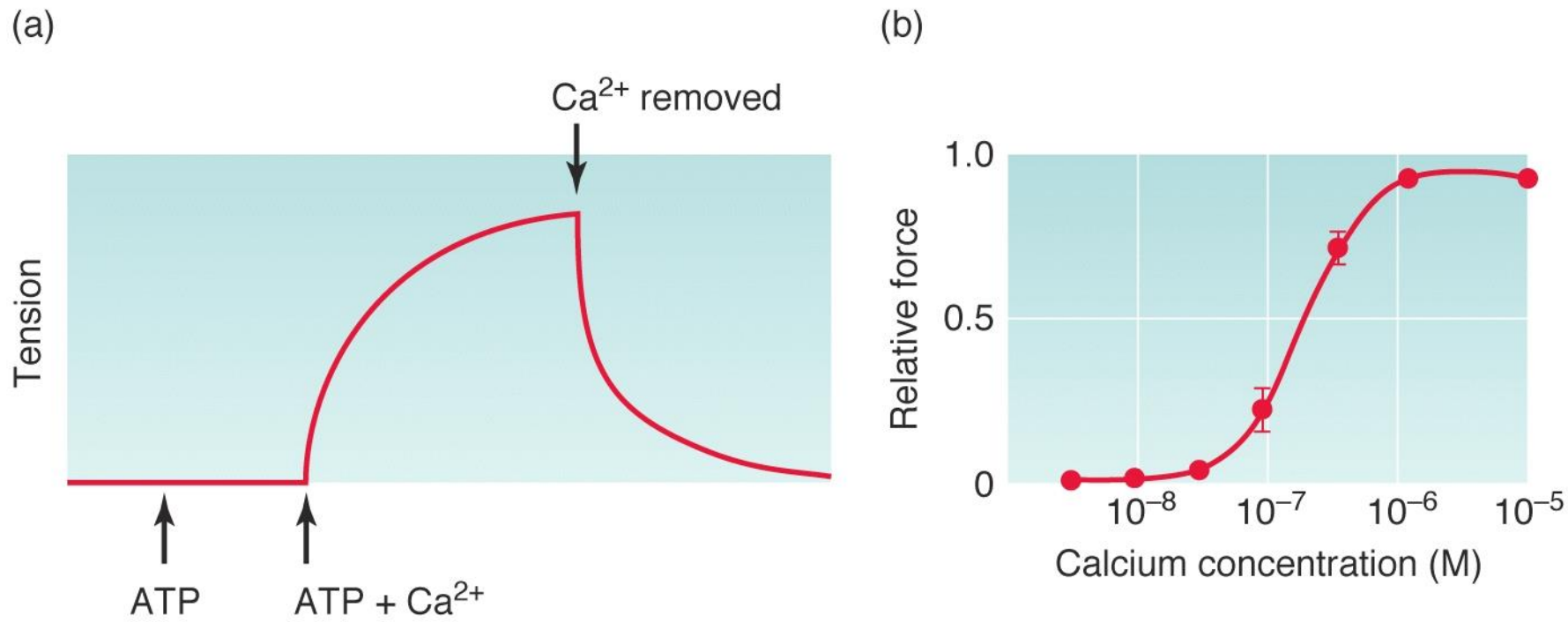

Agrin
Basal lamina
Perlecan
Laminin
α
Dystroglycan
complex
Sarcoglcan
complex
β
SSPN
sarcolemma
DTNA
Dystrophin
Syntrophins
nNOS
F-actin

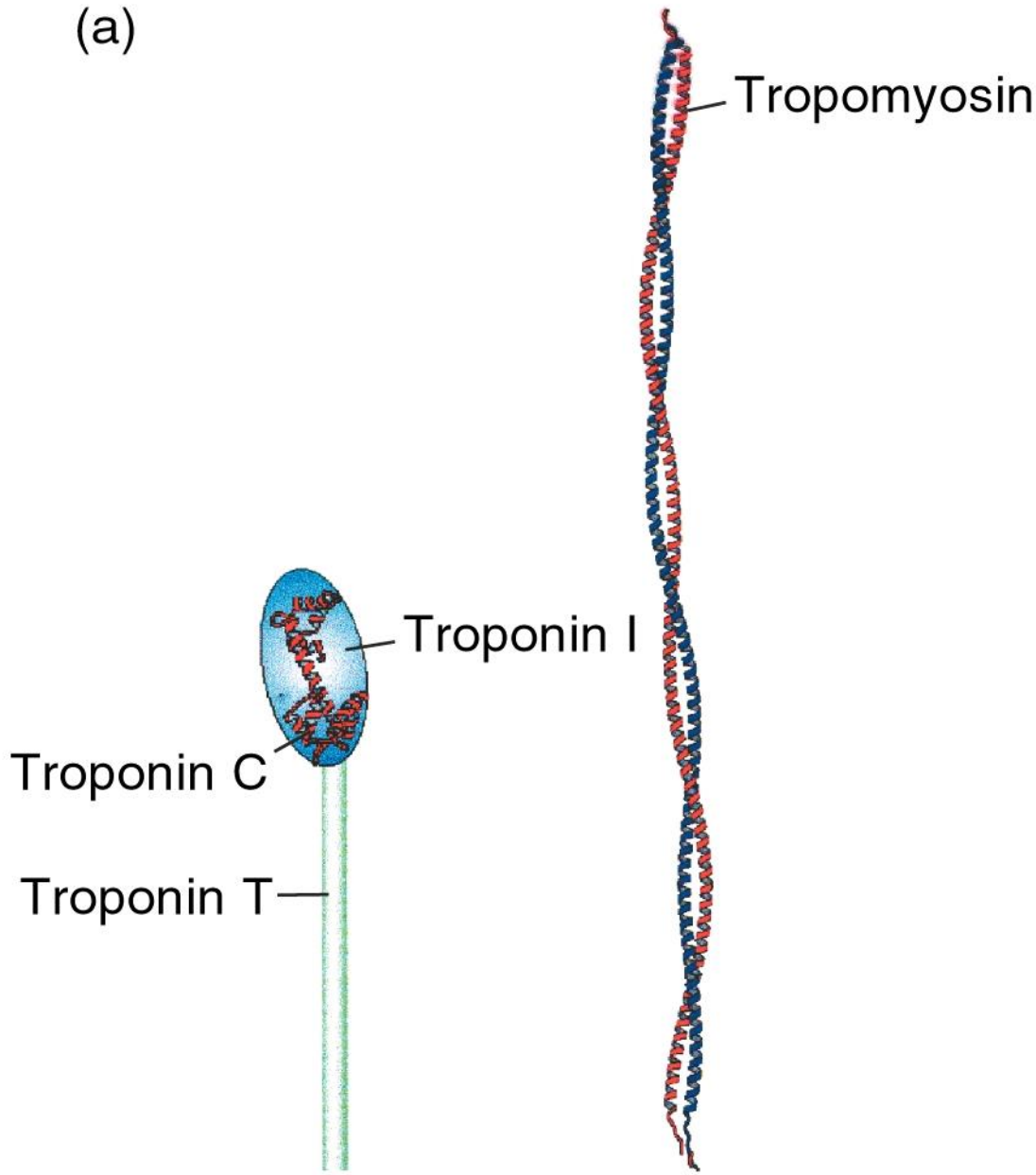

A
muscle
SR

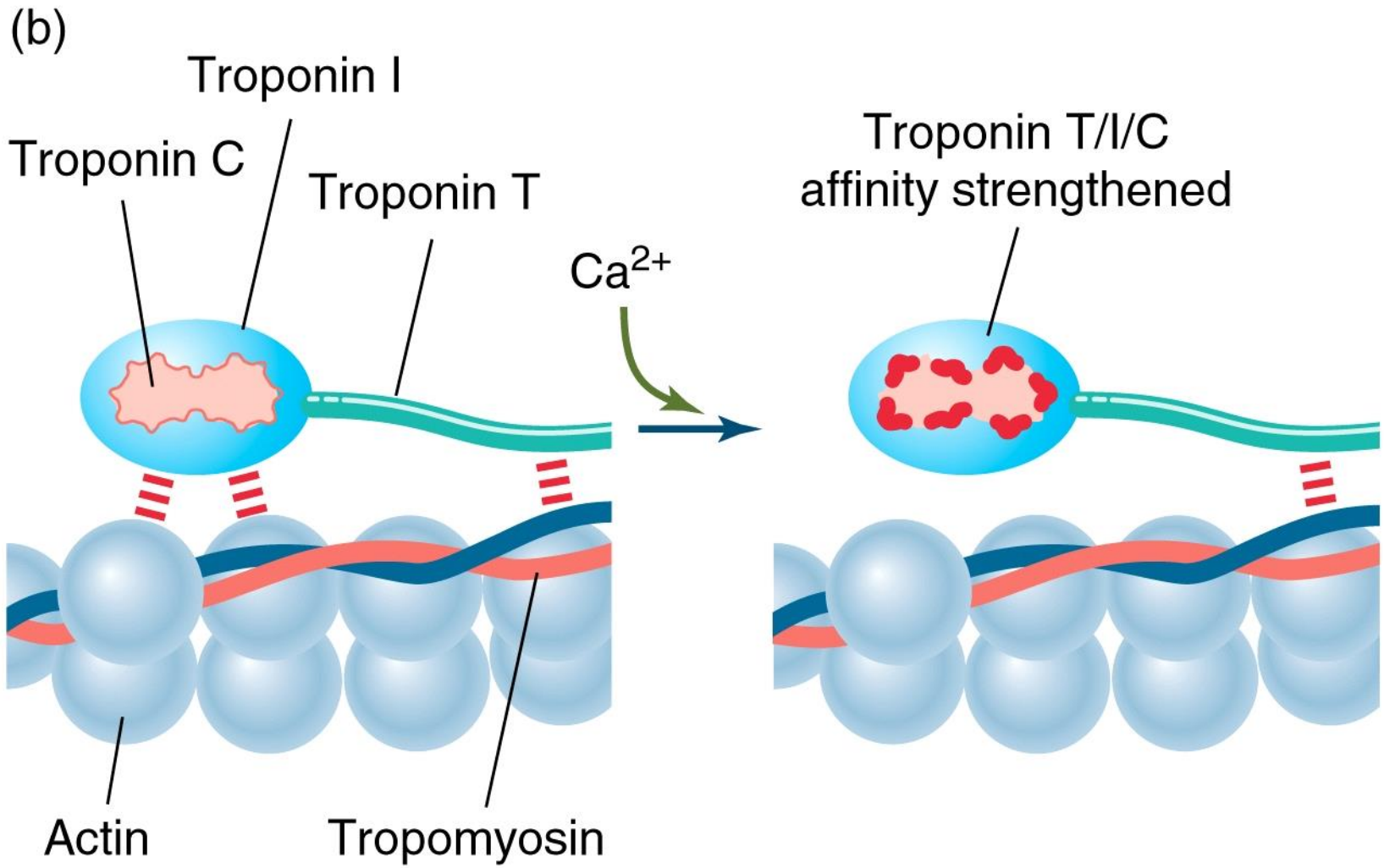


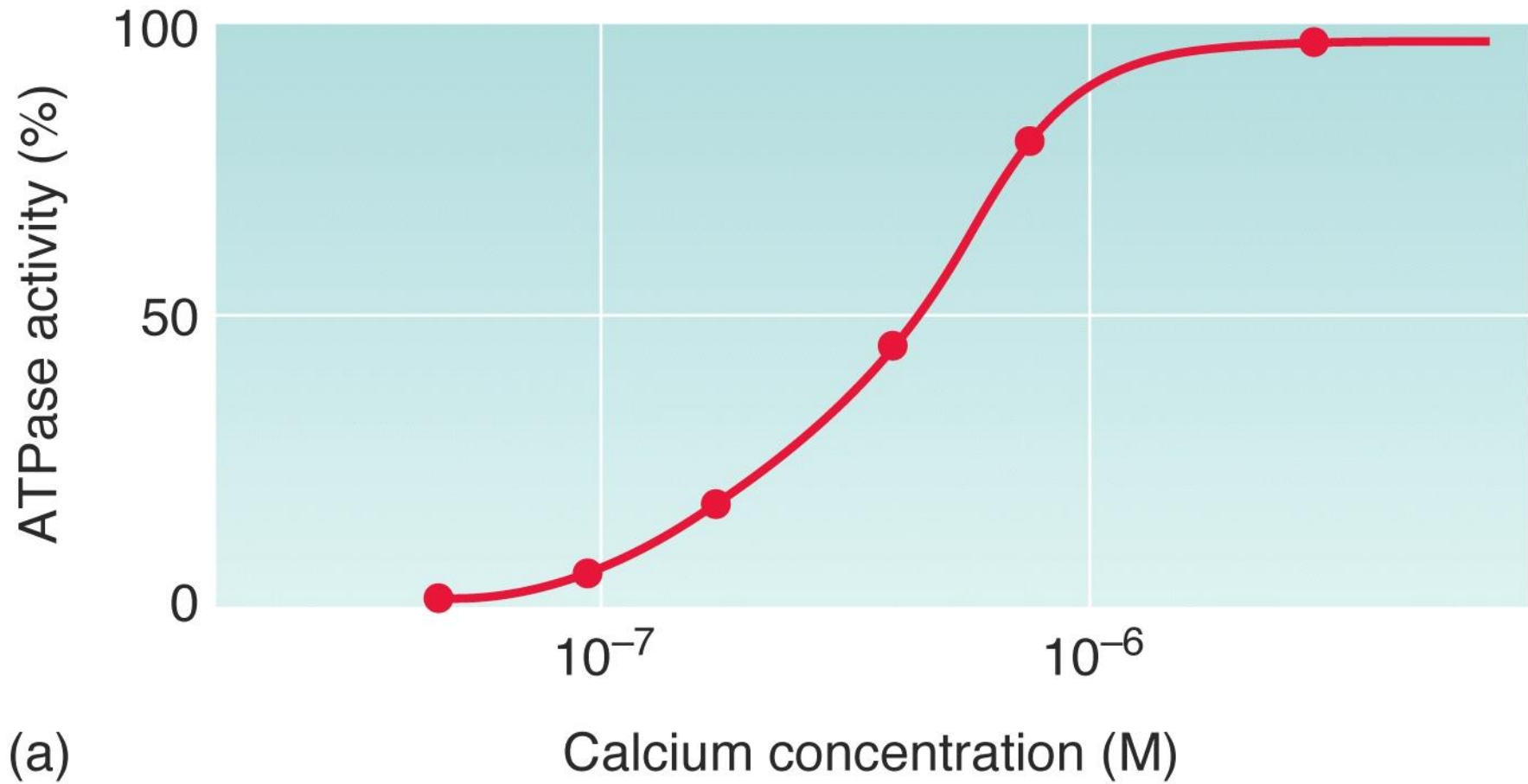

Relaxed
Active
Isometric
Tendon
Muscle
Tension transducer
Tension
Tension
Time
Isotonic
Tension
Tension
Isotonic
contraction


(a)
Fulcrum
Lever
Weight
Stimulator
Force transducer
(b)
Initial length
100 g
50 g
20 g
0 g
V_{max}
Length
Time


(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)

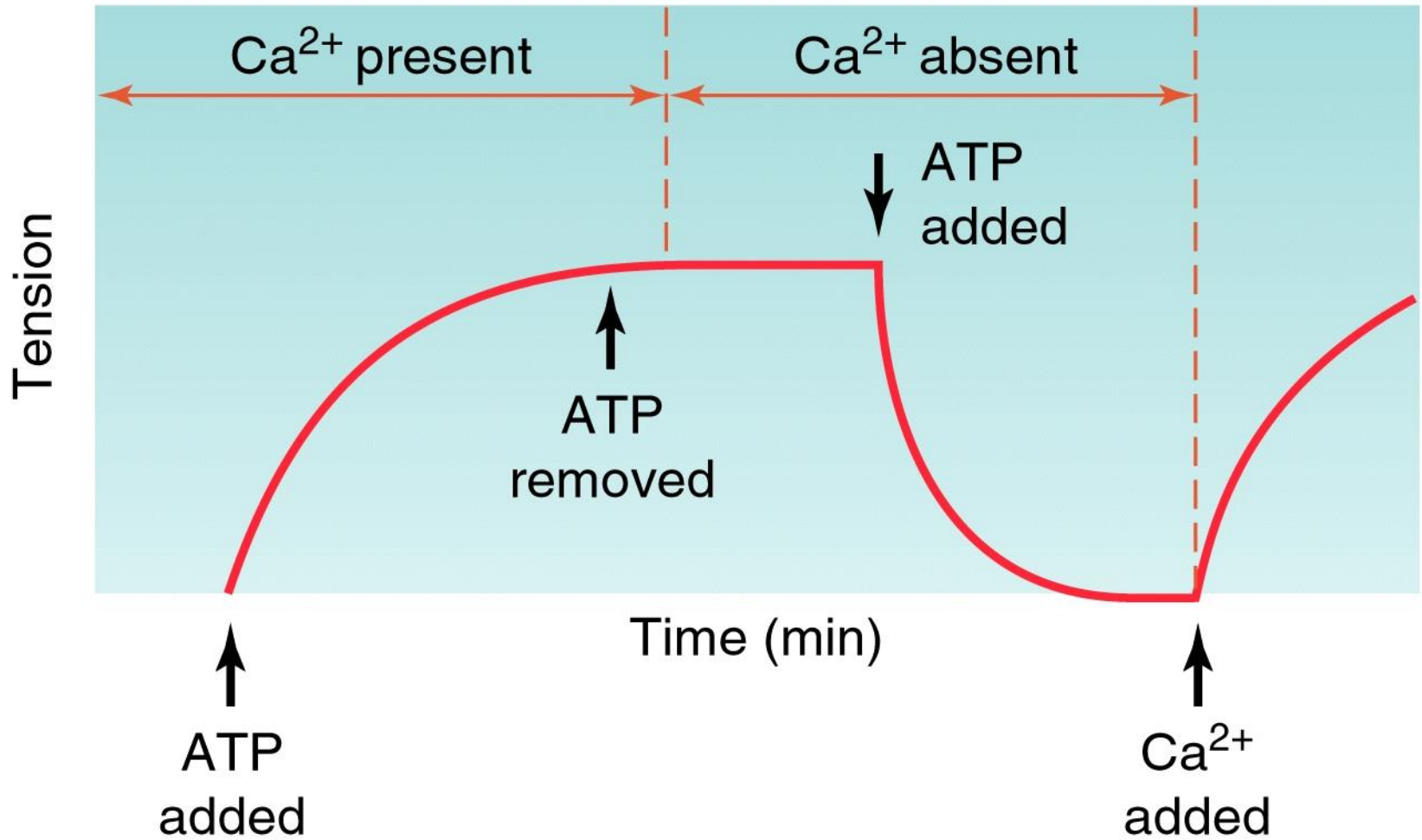

(a)
Tropomyosin
Troponin I
Troponin C
Troponin T


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

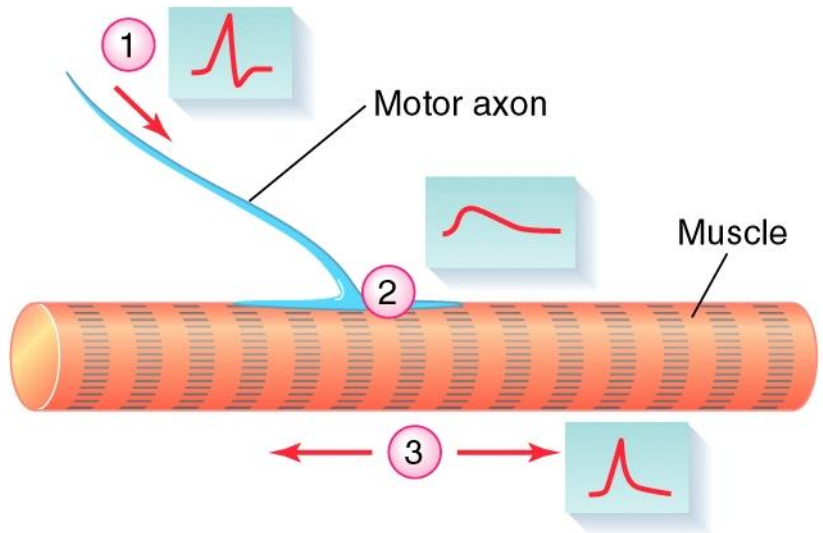


(a)

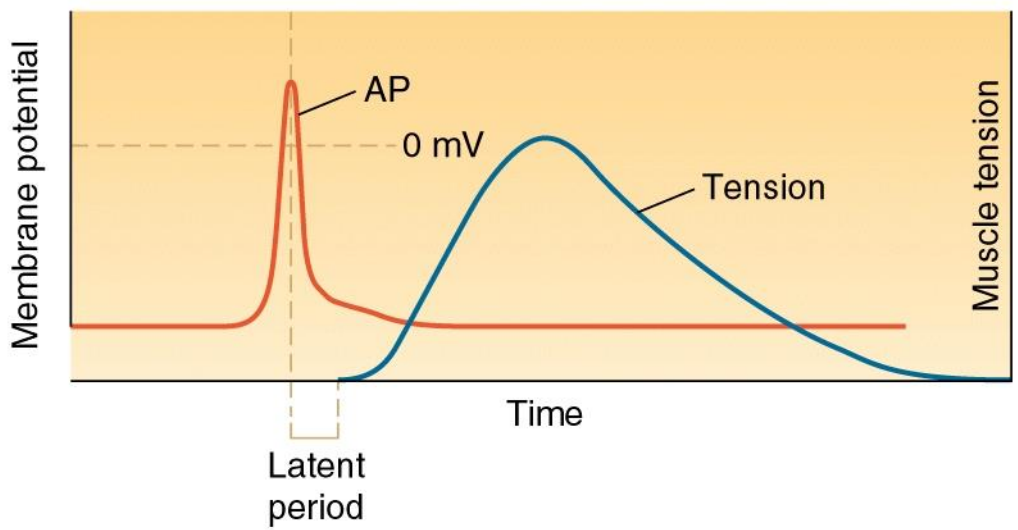
(b)


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

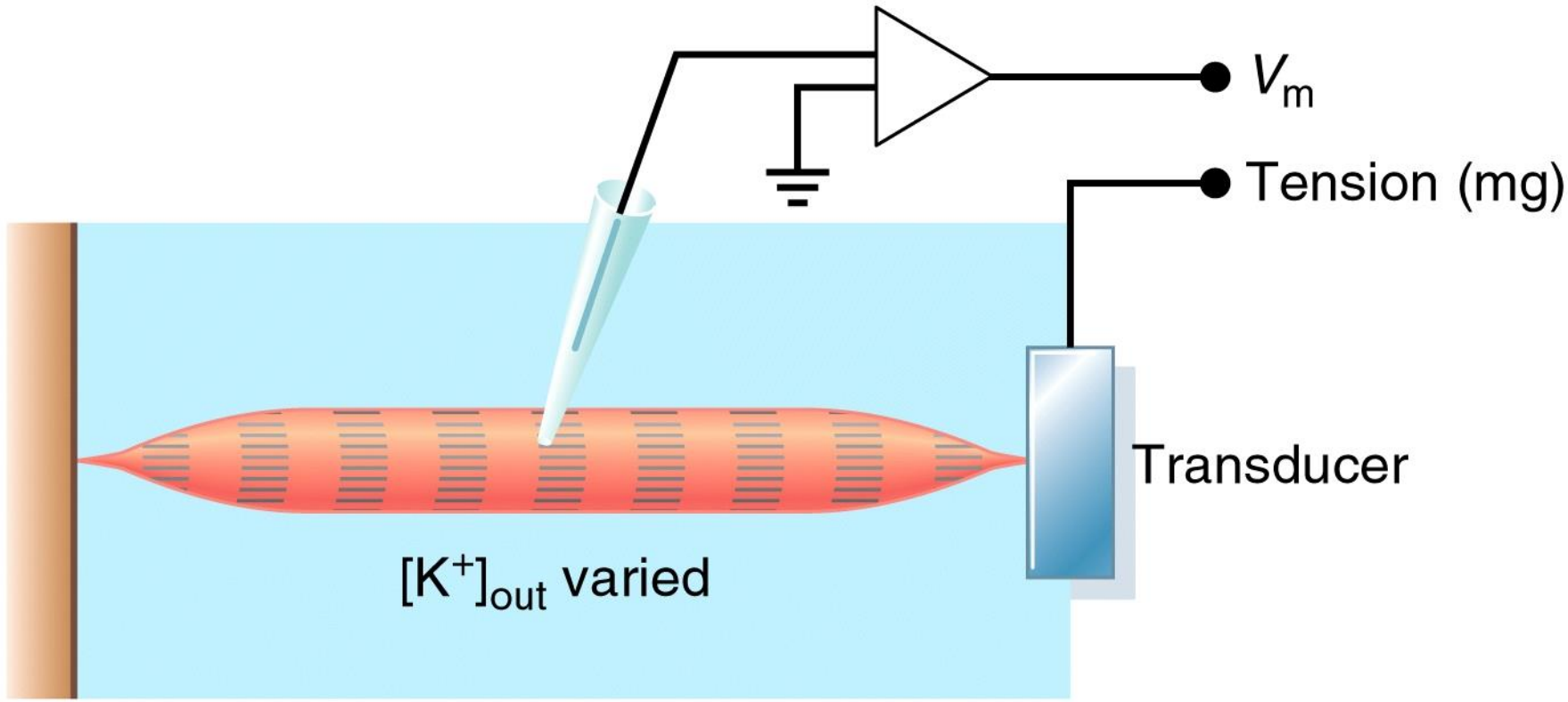
(a)

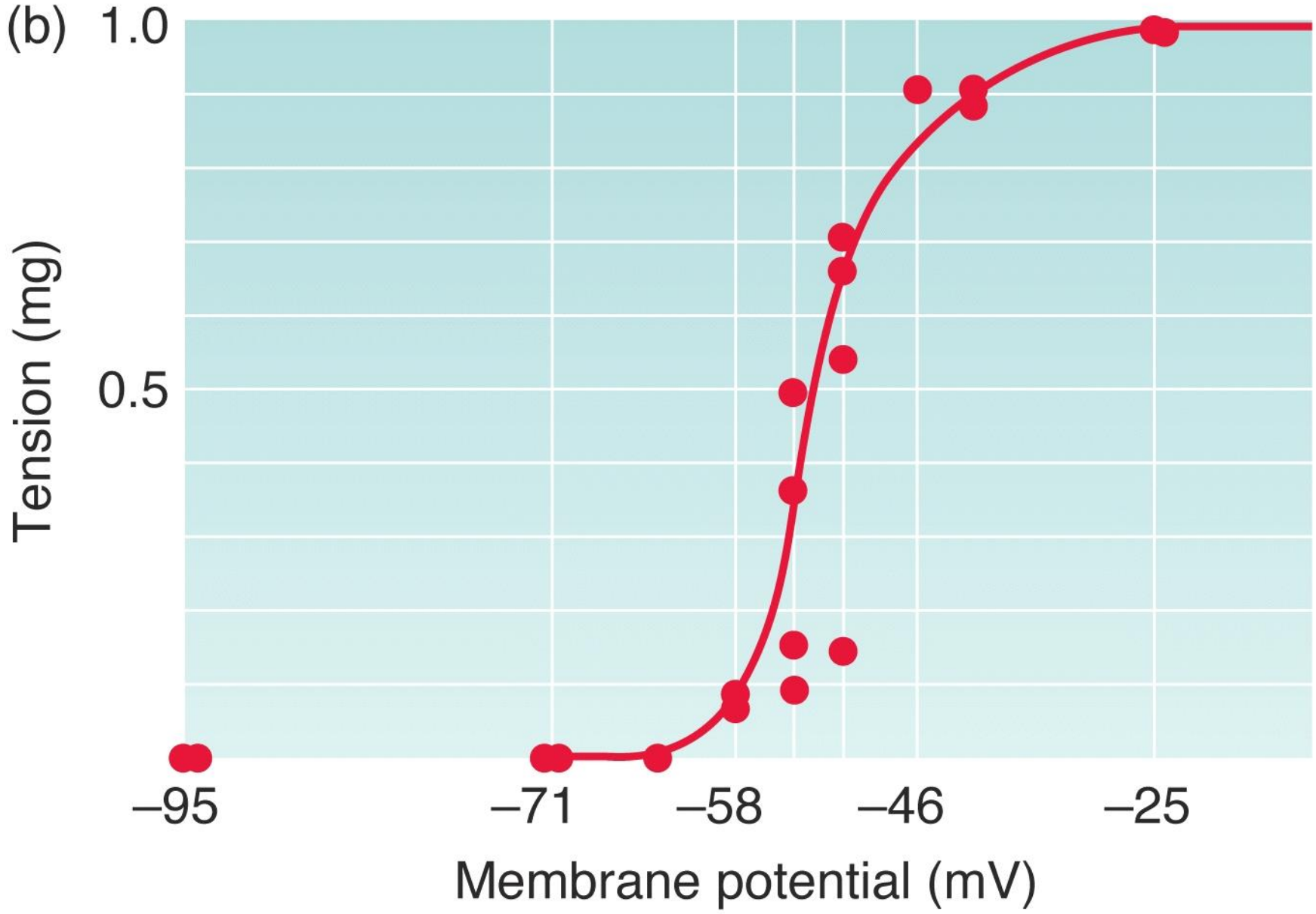

1
Motor axon
Muscle
2
3

(b)

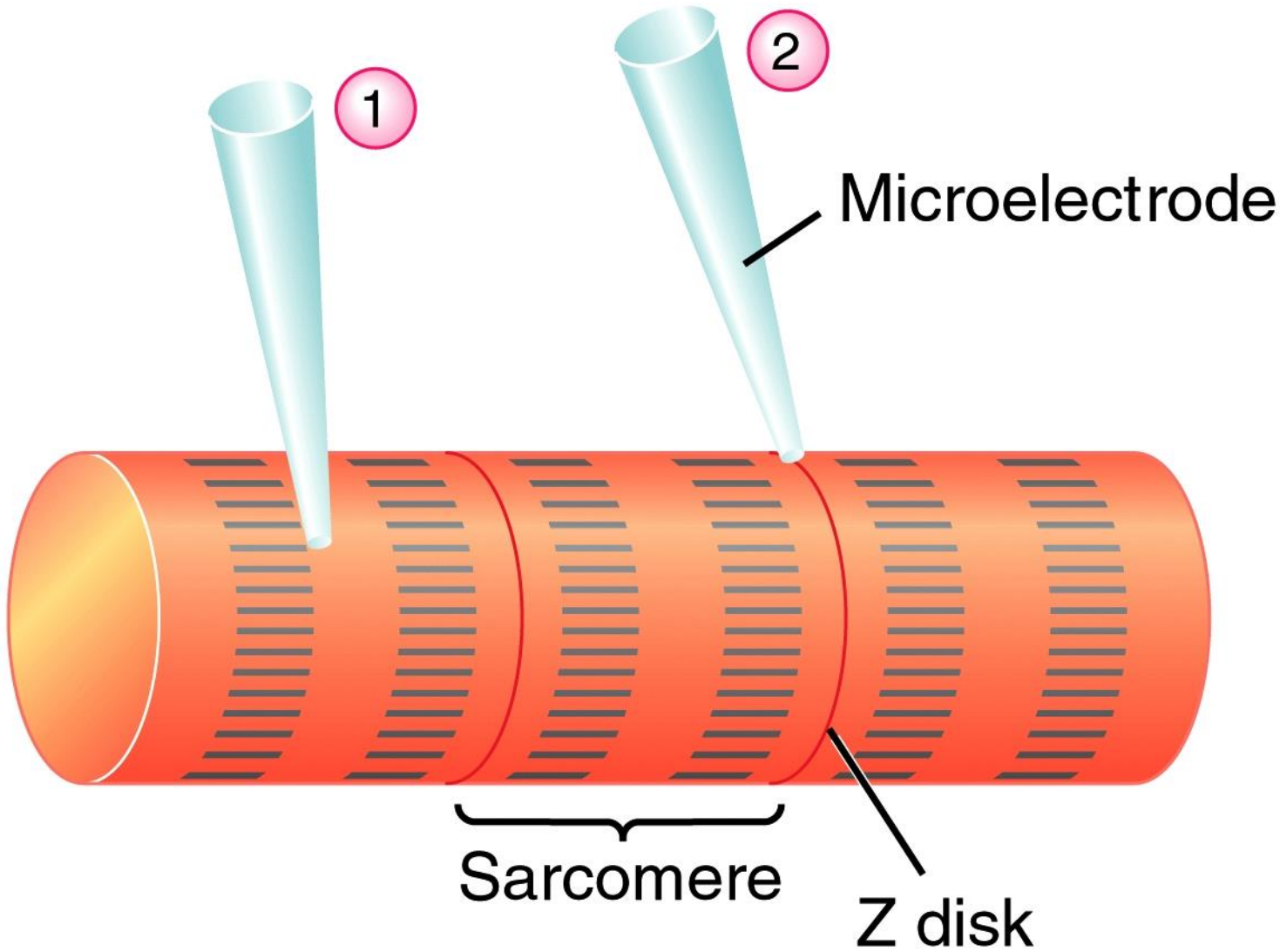

Membrane potential
AP
0 mV
Tension
Muscle tension
Time
Latent
period

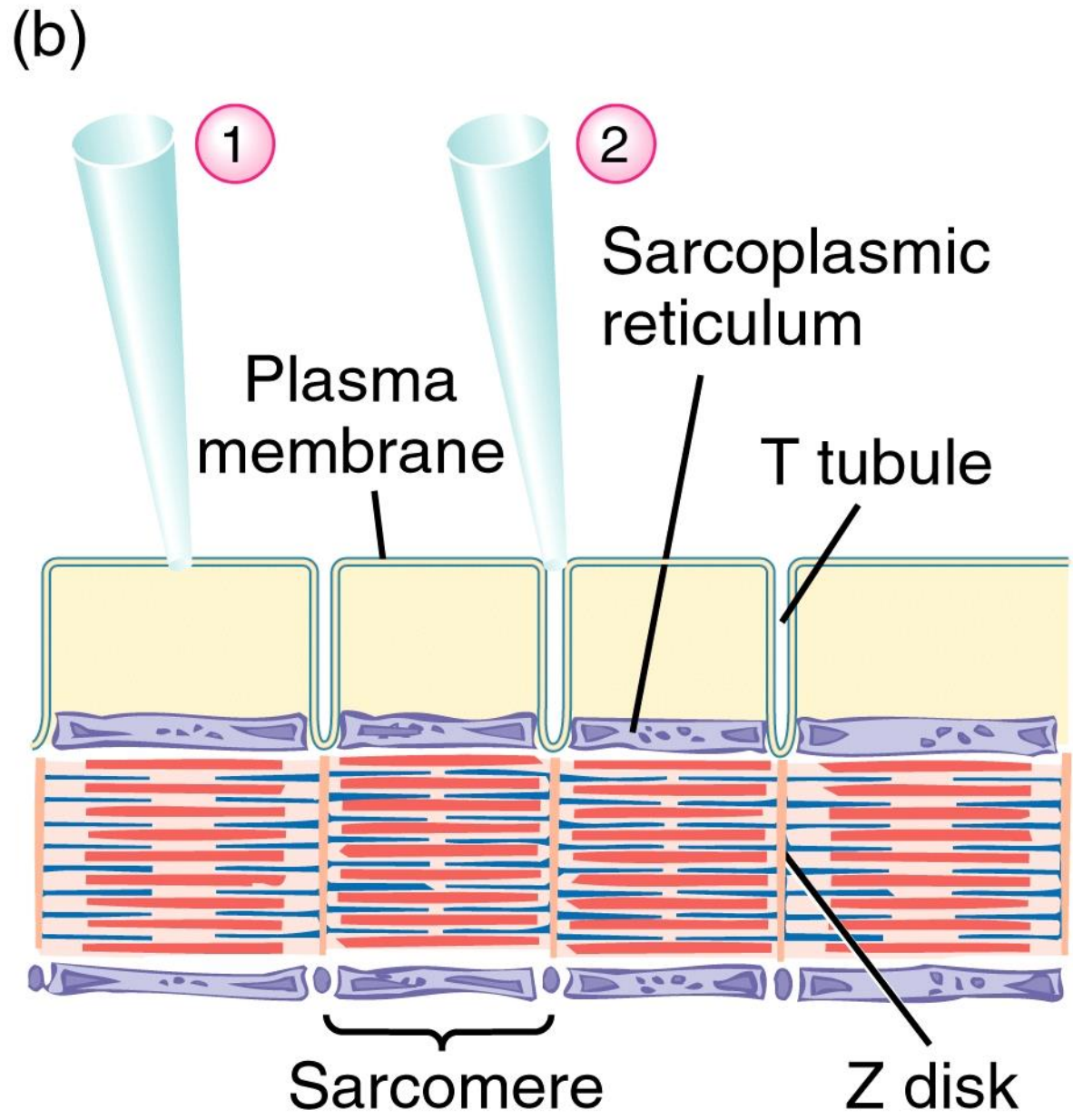
(a)

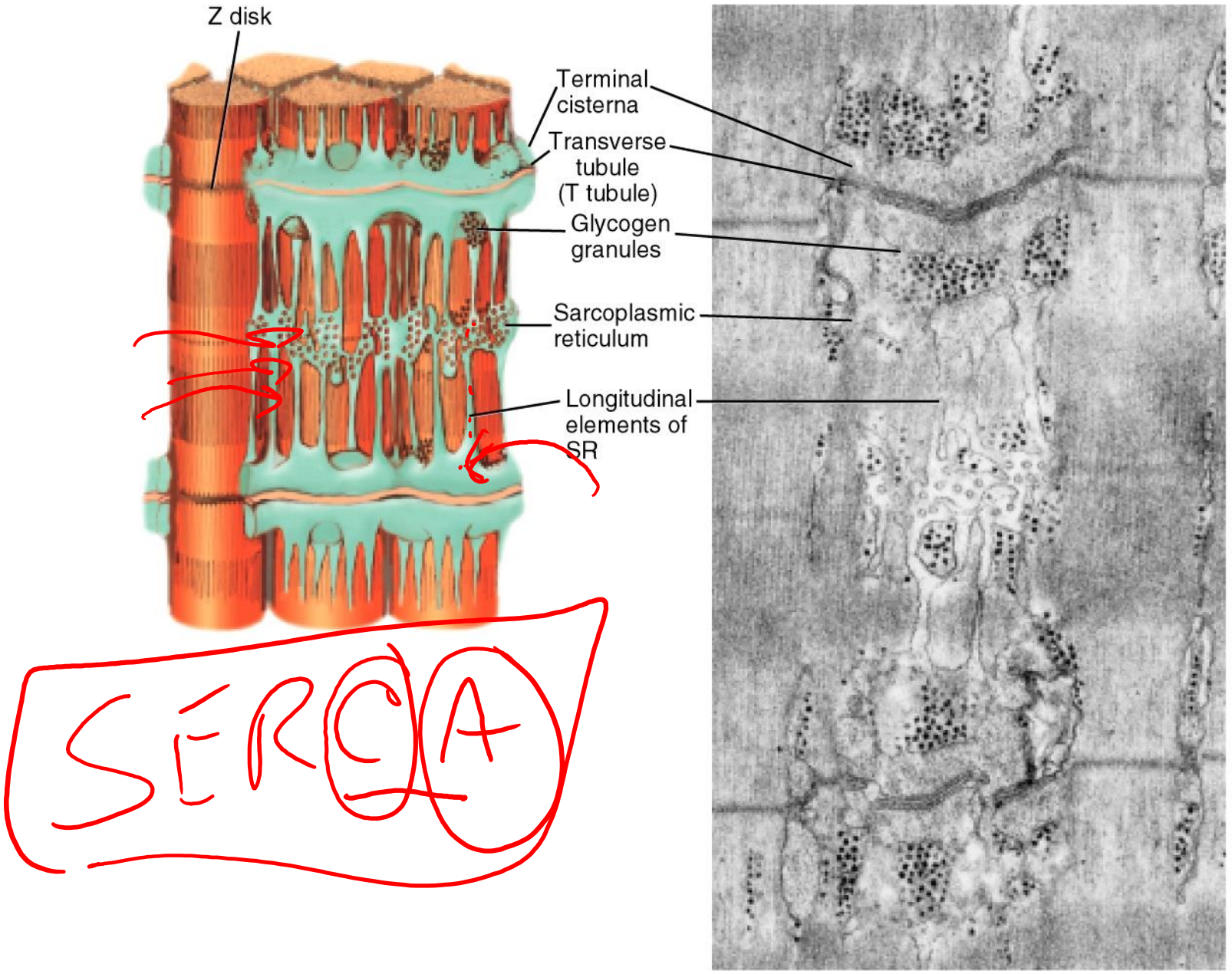


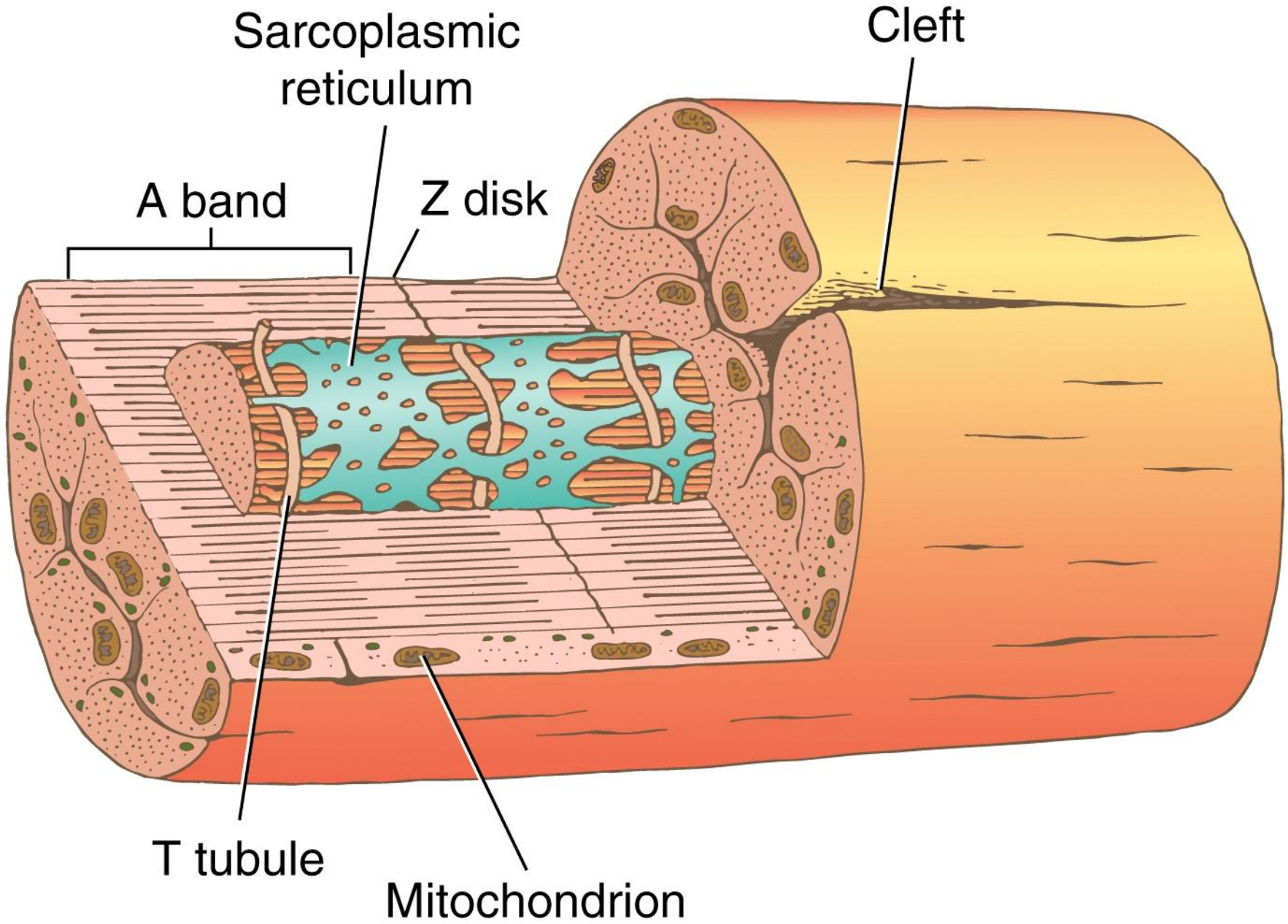

(b)
1.0
0.5
Tension (mg)
–95
–71
–58
–46
–25
Membrane potential (mV)

(a)

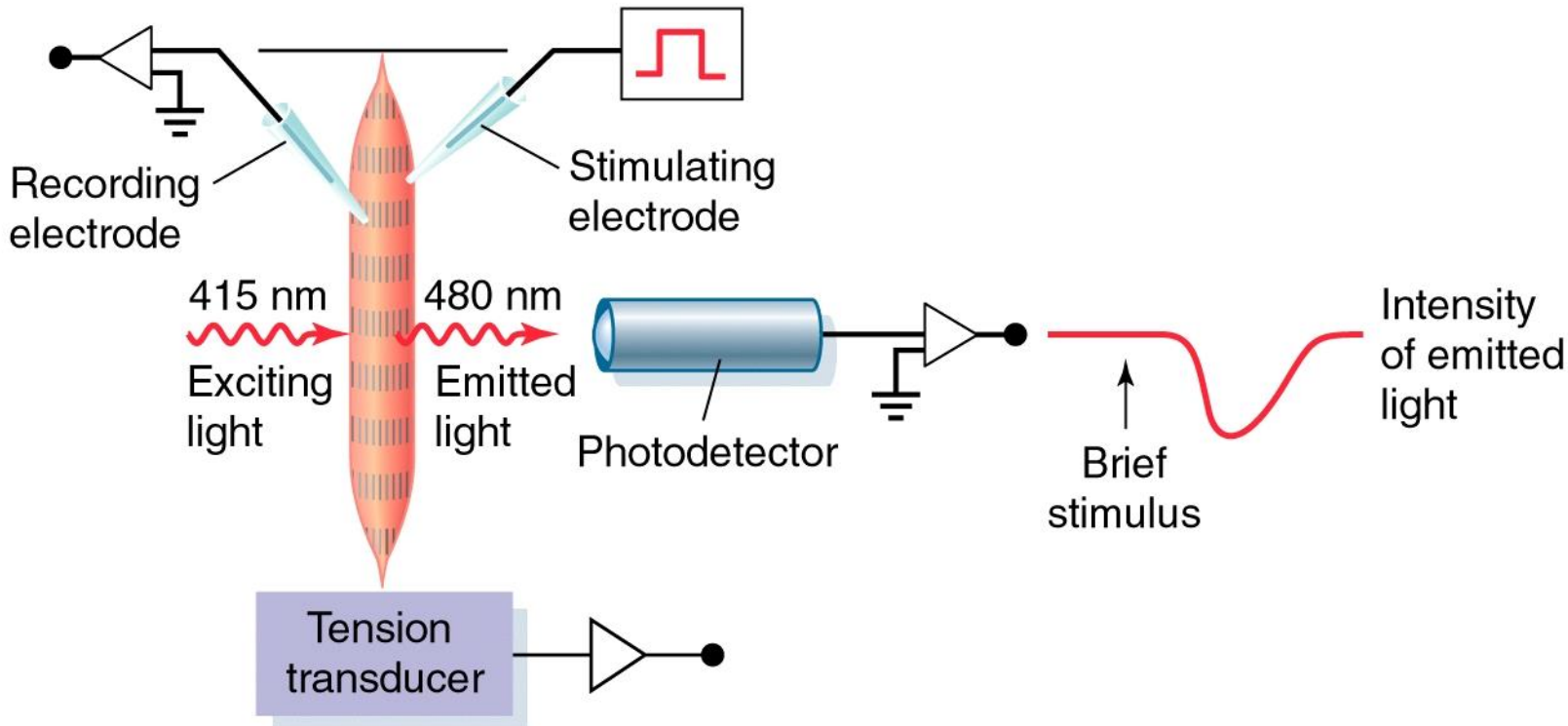


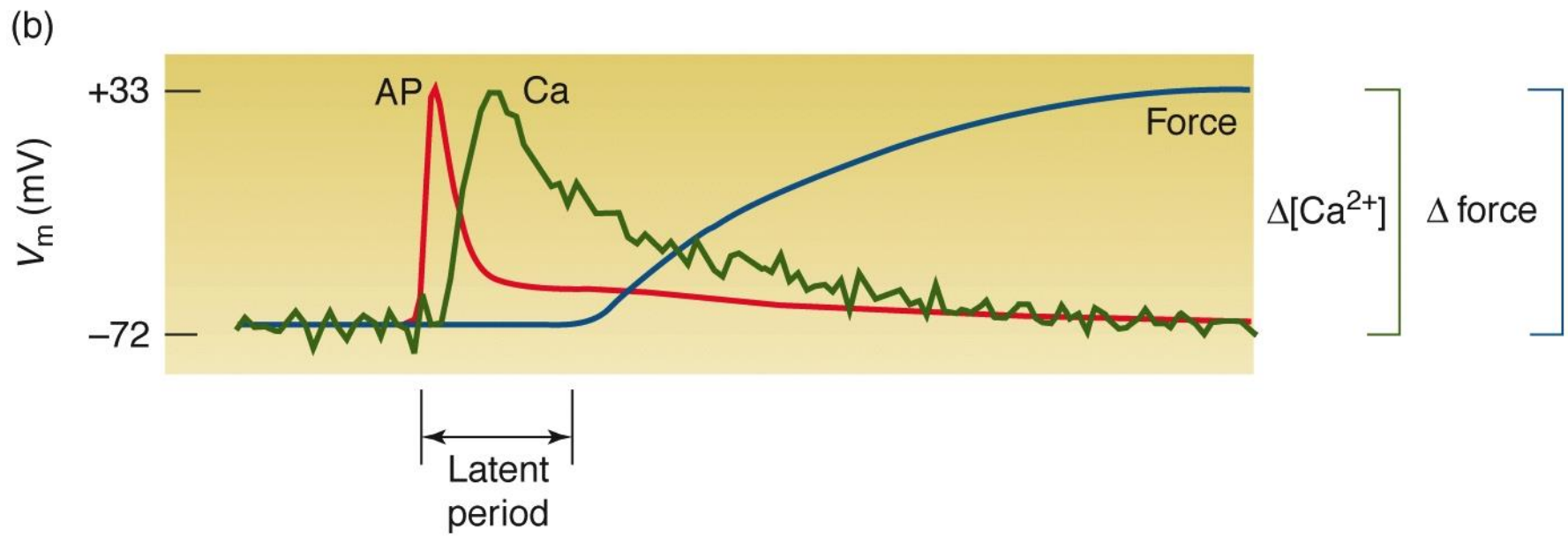

(b)
1
2
Sarcoplasmic reticulum
Plasma membrane
T tubule
Sarcomere
Z disk


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

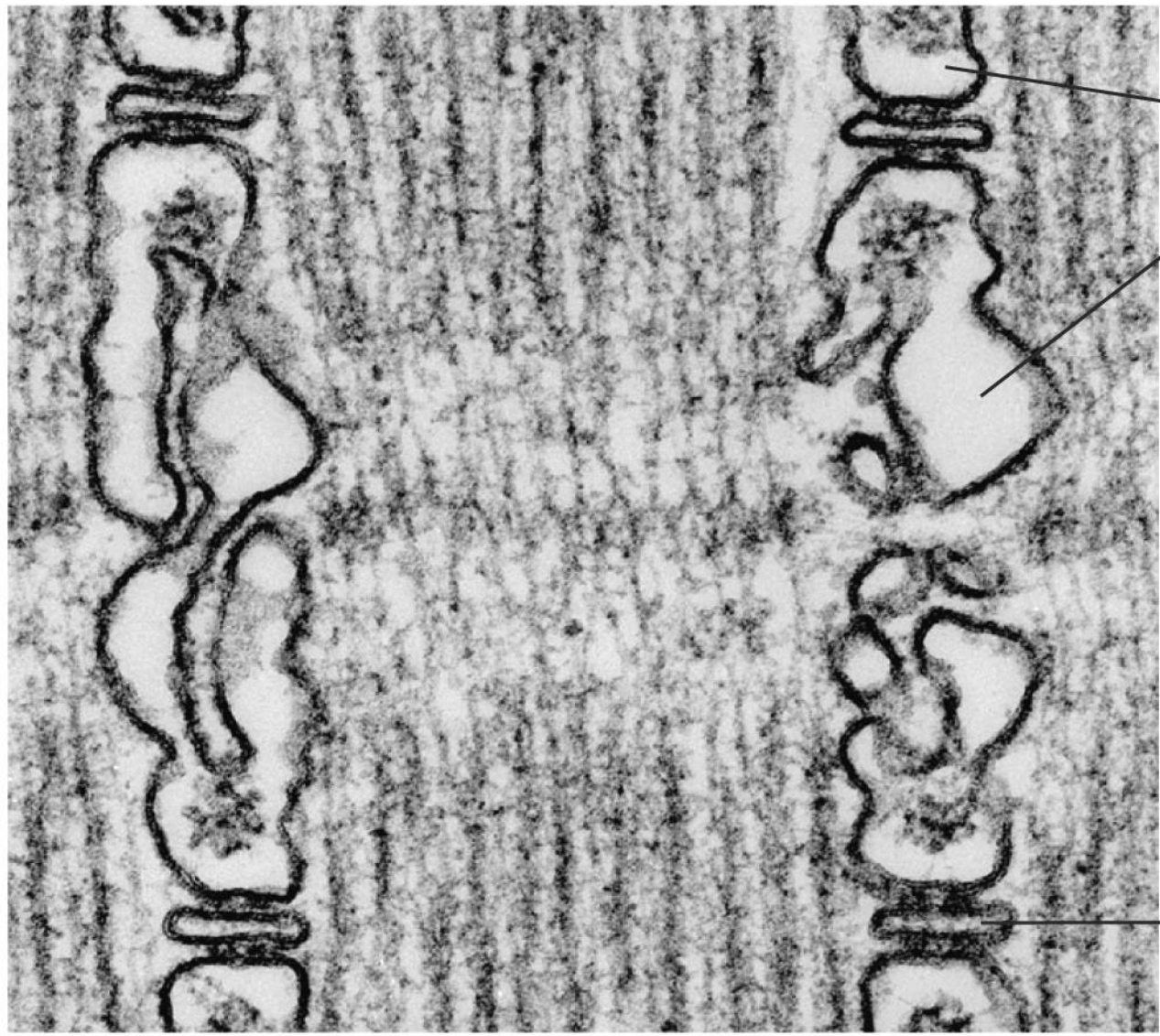

Sarcoplasmic reticulum
Cleft
A band
Z disk
T tubule
Mitochondrion

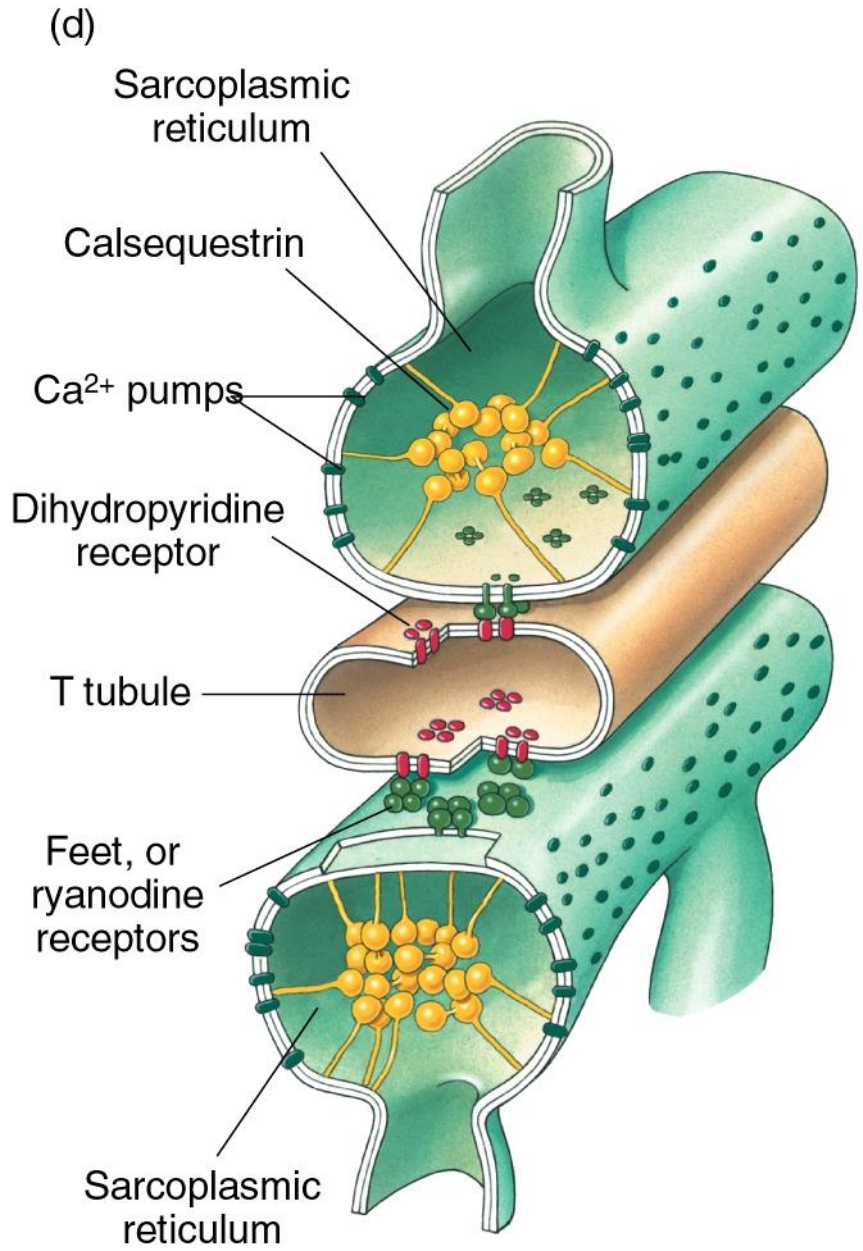
(a)

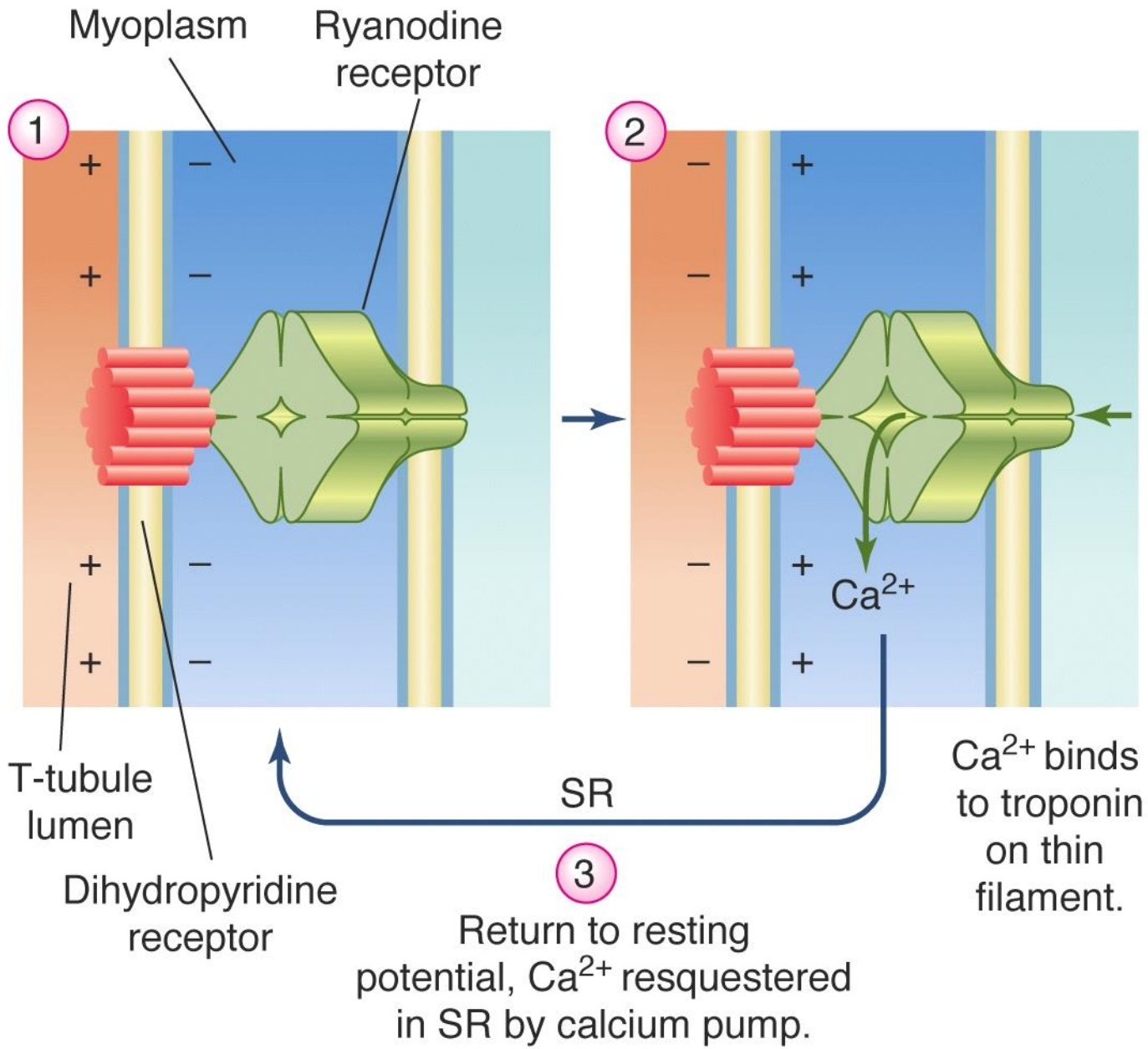

Recording electrode
Stimulating electrode
415 nm
Exciting light
480 nm
Emitted light
Photodetector
Intensity of emitted light
Brief stimulus
Tension transducer

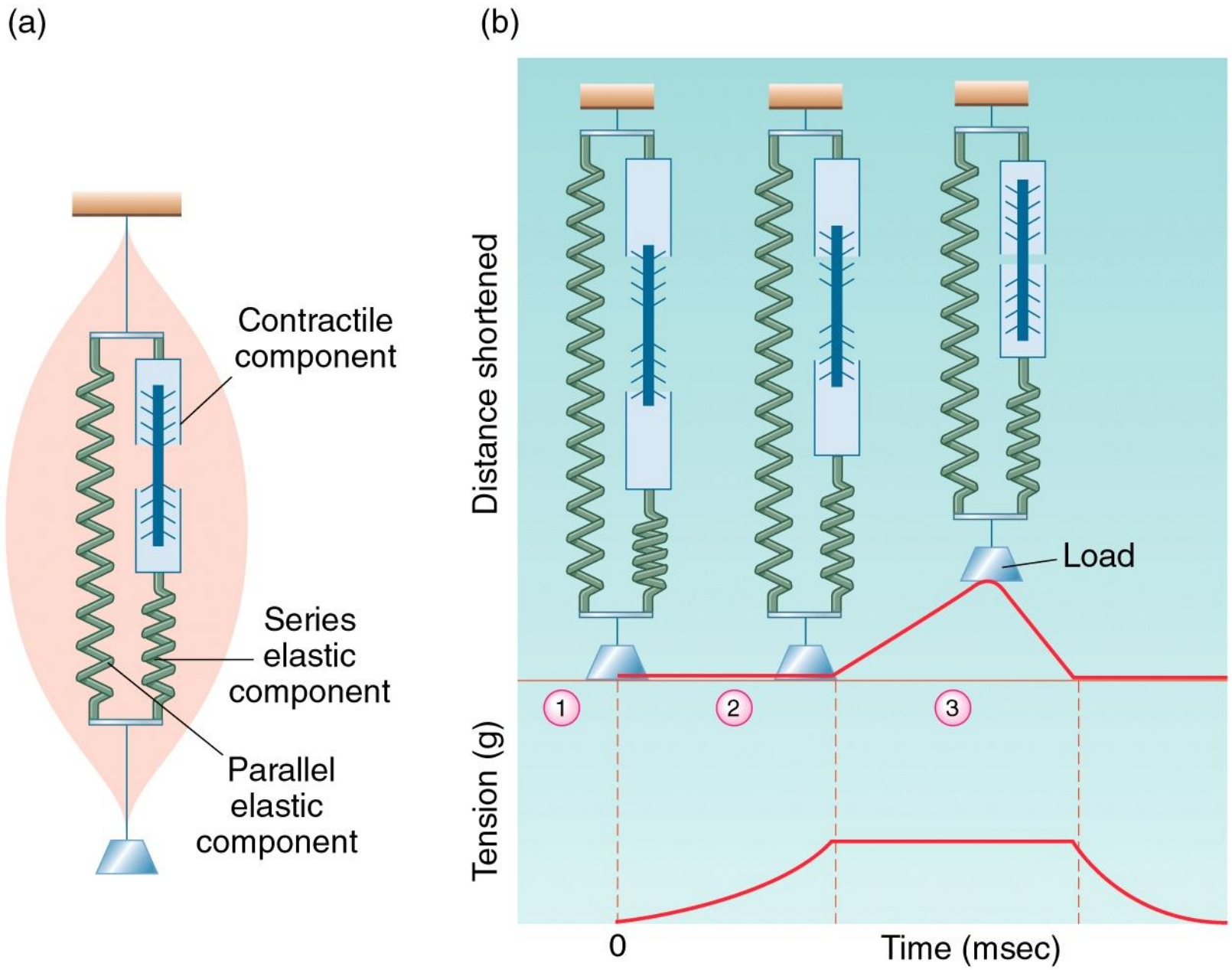

(b)
+33
–72
V_m (mV)
AP
Ca
Force
Δ[Ca2+]
Δ force
Latent
period

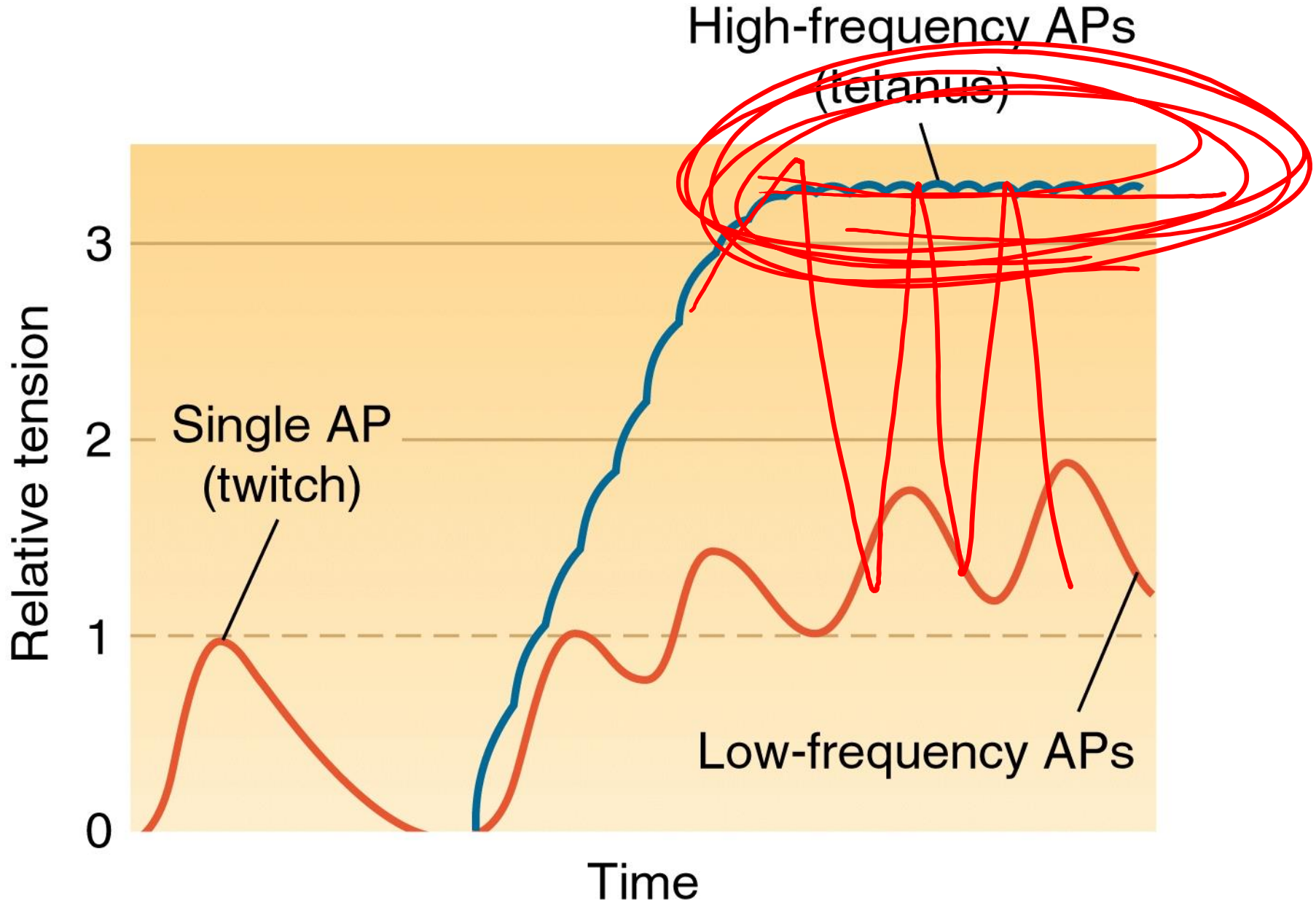
(a)




(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+} resequestered in SR by calcium pump.
Ca^{2+} binds to troponin on thin filament.


(a)
Contractile component
Series elastic component
Parallel elastic component
(b)
Distance shortened
Load
1
2
3
Tension (g)
0
Time (msec)


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

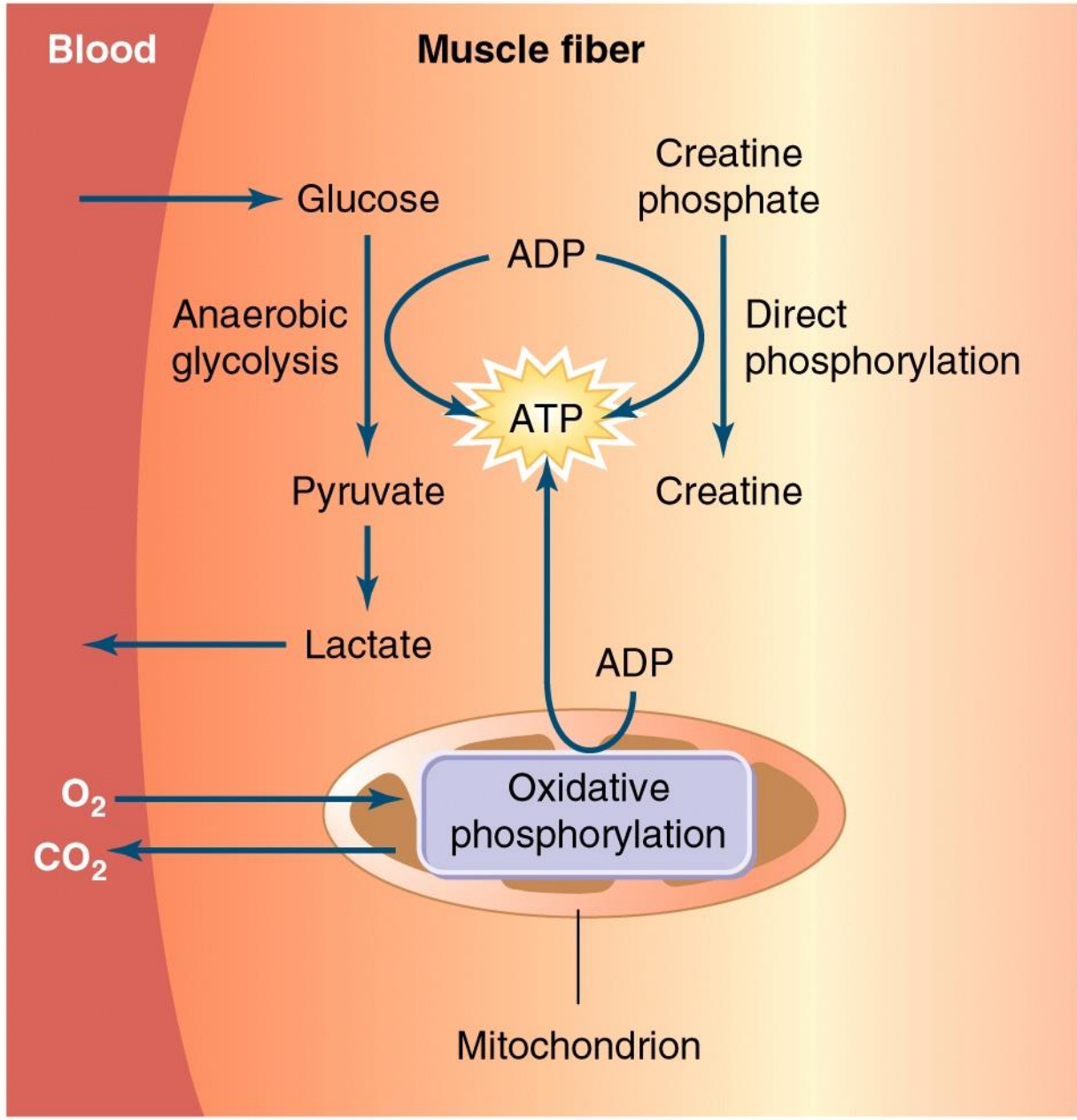
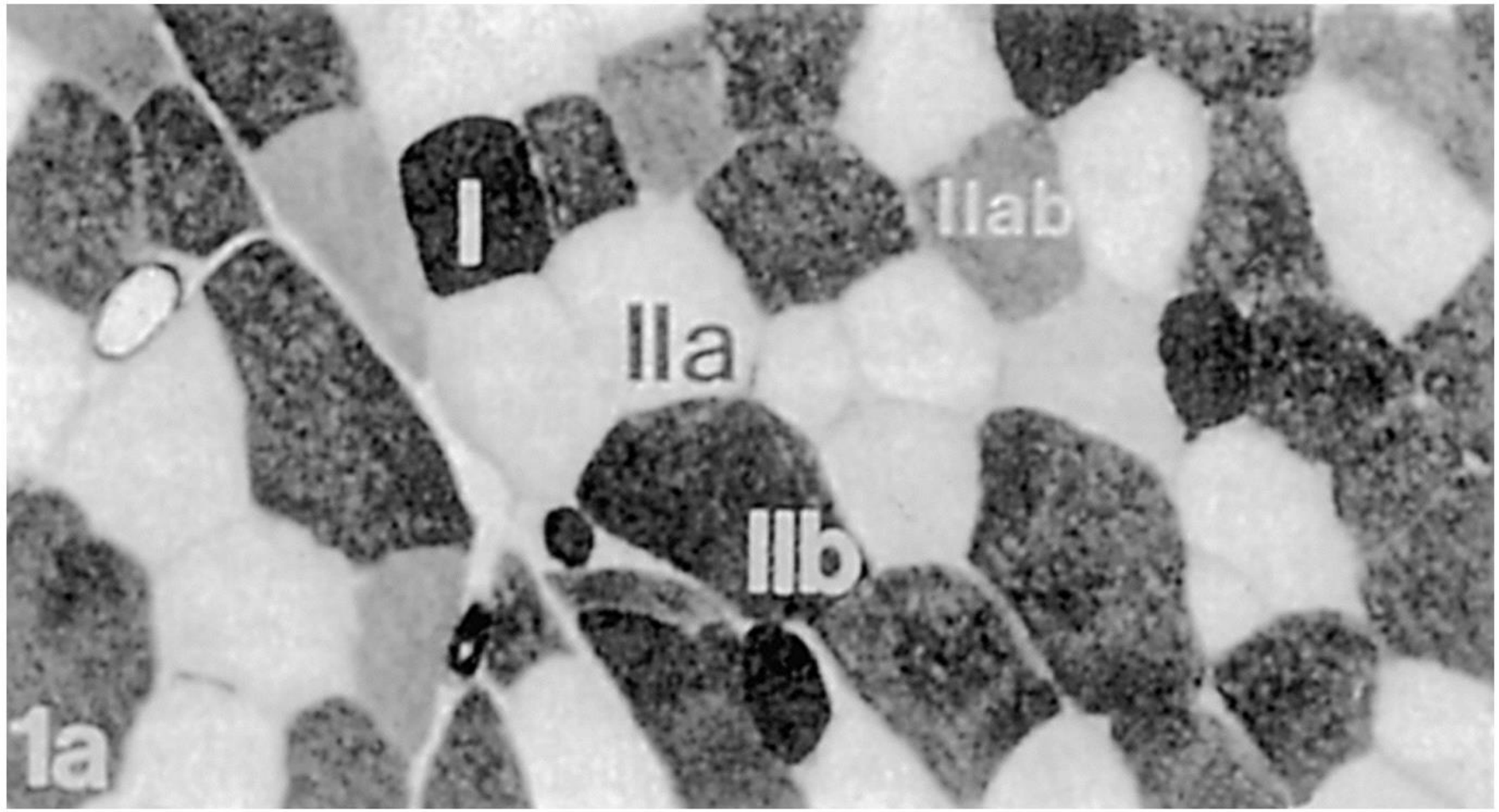

Blood
Muscle fiber
Glucose
Creatine phosphate
ADP
Anaerobic glycolysis
Direct phosphorylation
ATP
Pyruvate
Creatine
Lactate
ADP
O_2
CO_2
Oxidative phosphorylation
Mitochondrion

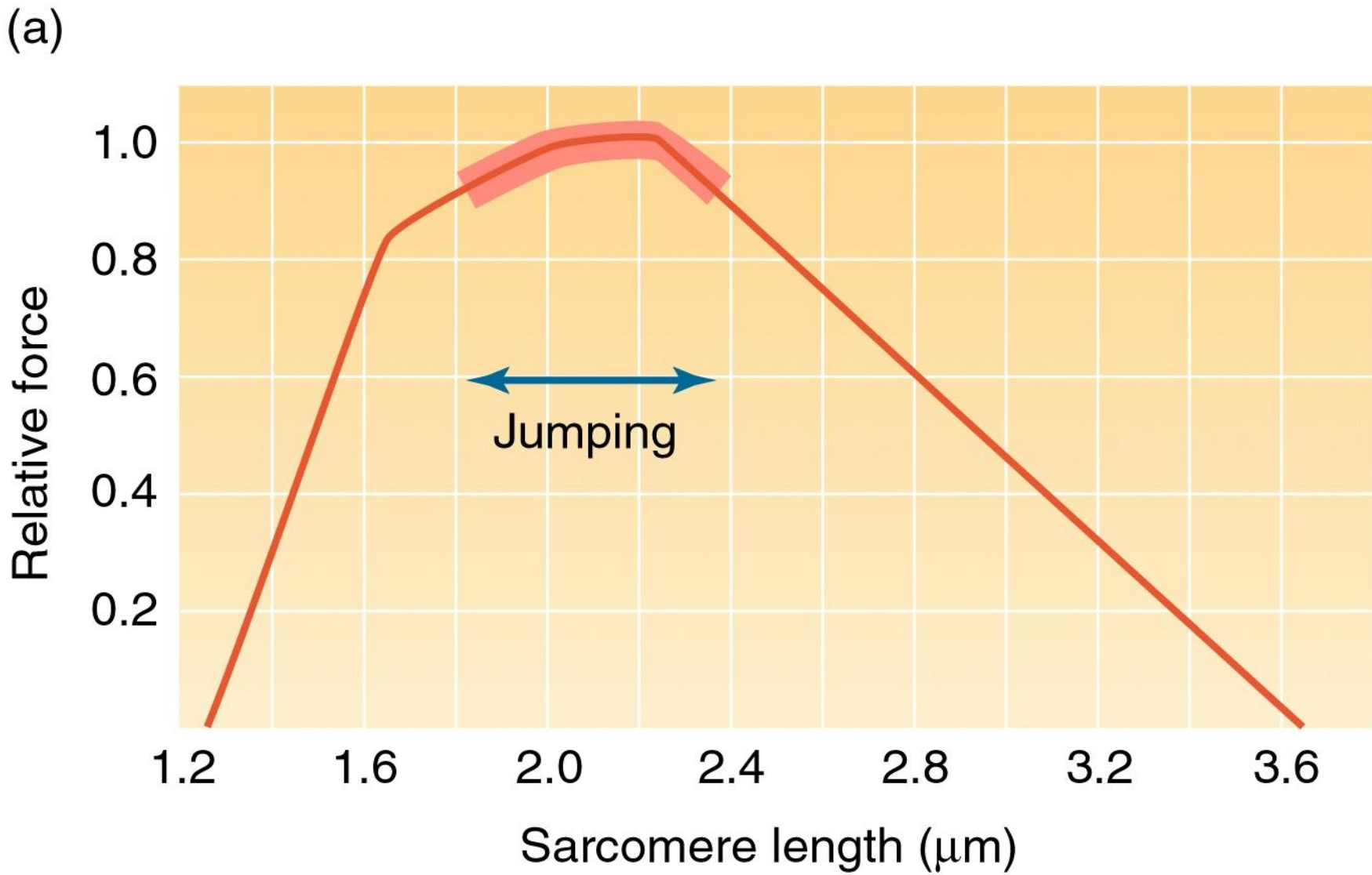
Table 10-1 Properties of twitch (phasic) fibers in mammalian skeletal muscles

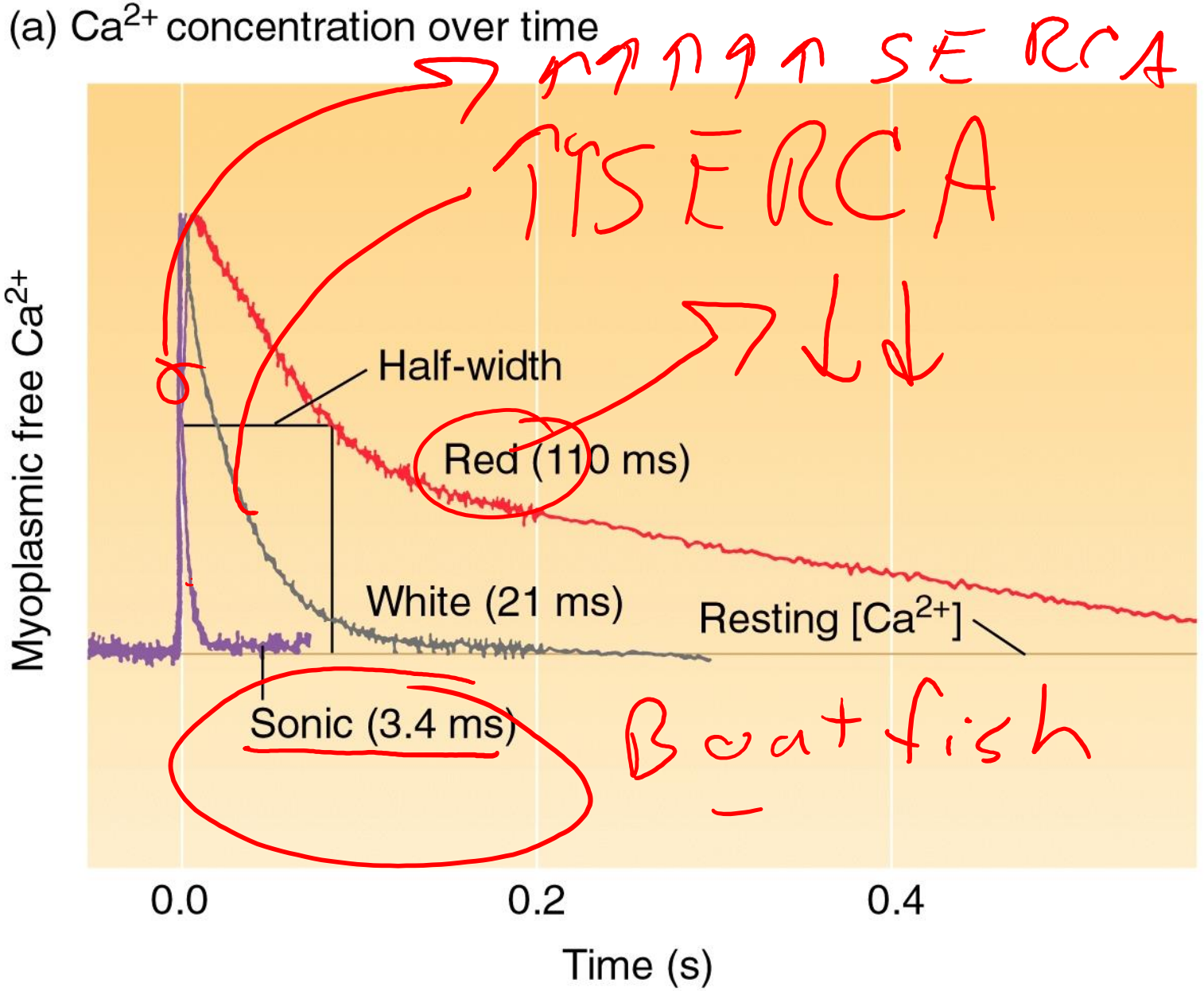
Property	Slow oxidative (type I)	Fast oxidative (type IIa)	Fast glycolytic (type IIb)
Fiber diameter	↓	↔	↑
Force per cross-sectional area	↓	↔	↑
Rate of contraction (V_{max})	↓	↑	↑
Myosin ATPase activity	↓	↑	↑
Resistance to fatigue	↑	↔	↓
Number of mitochondria	↑	↑	↓
Capacity for oxidative phosphorylation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

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

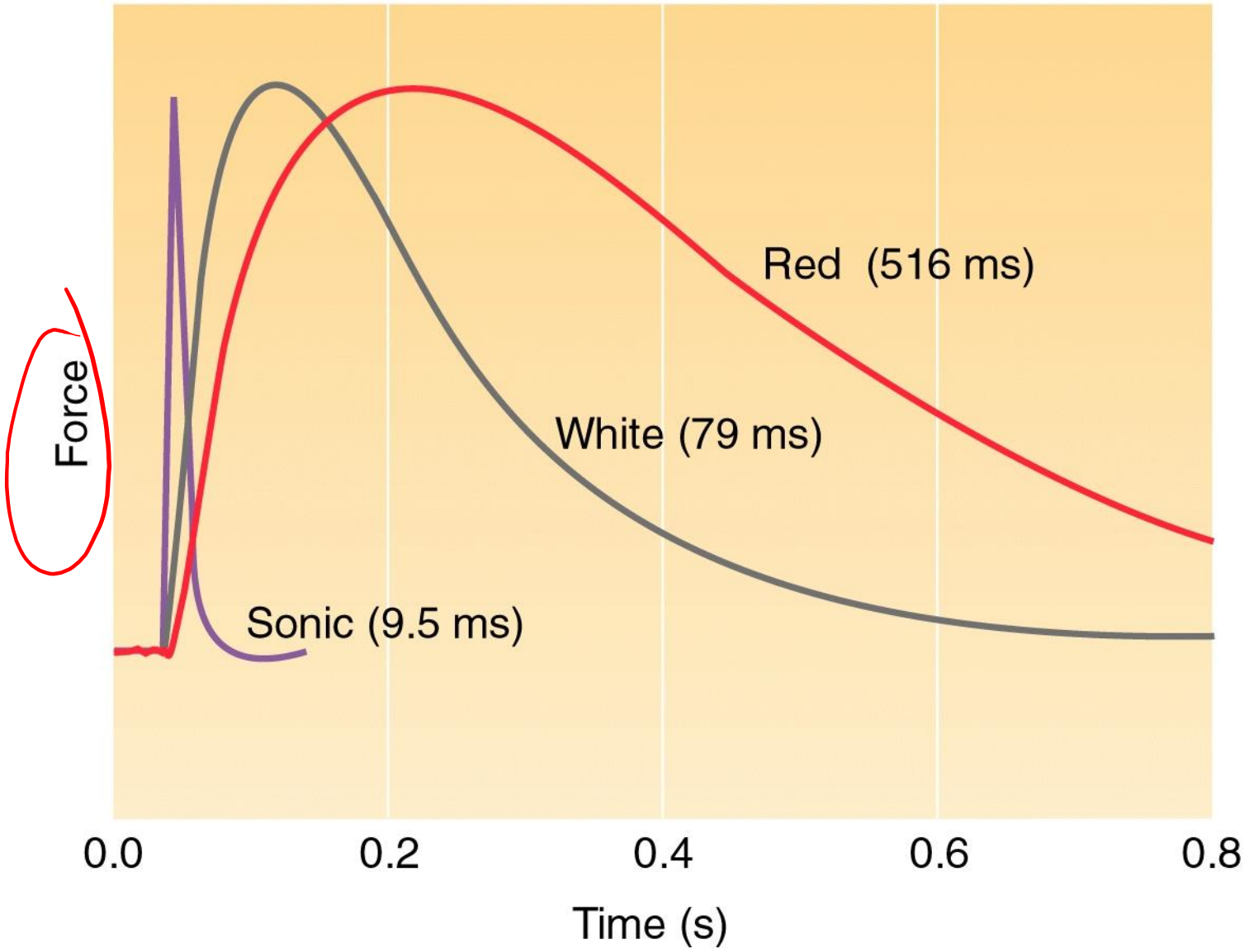

I
IIab
IIa
IIb
1a

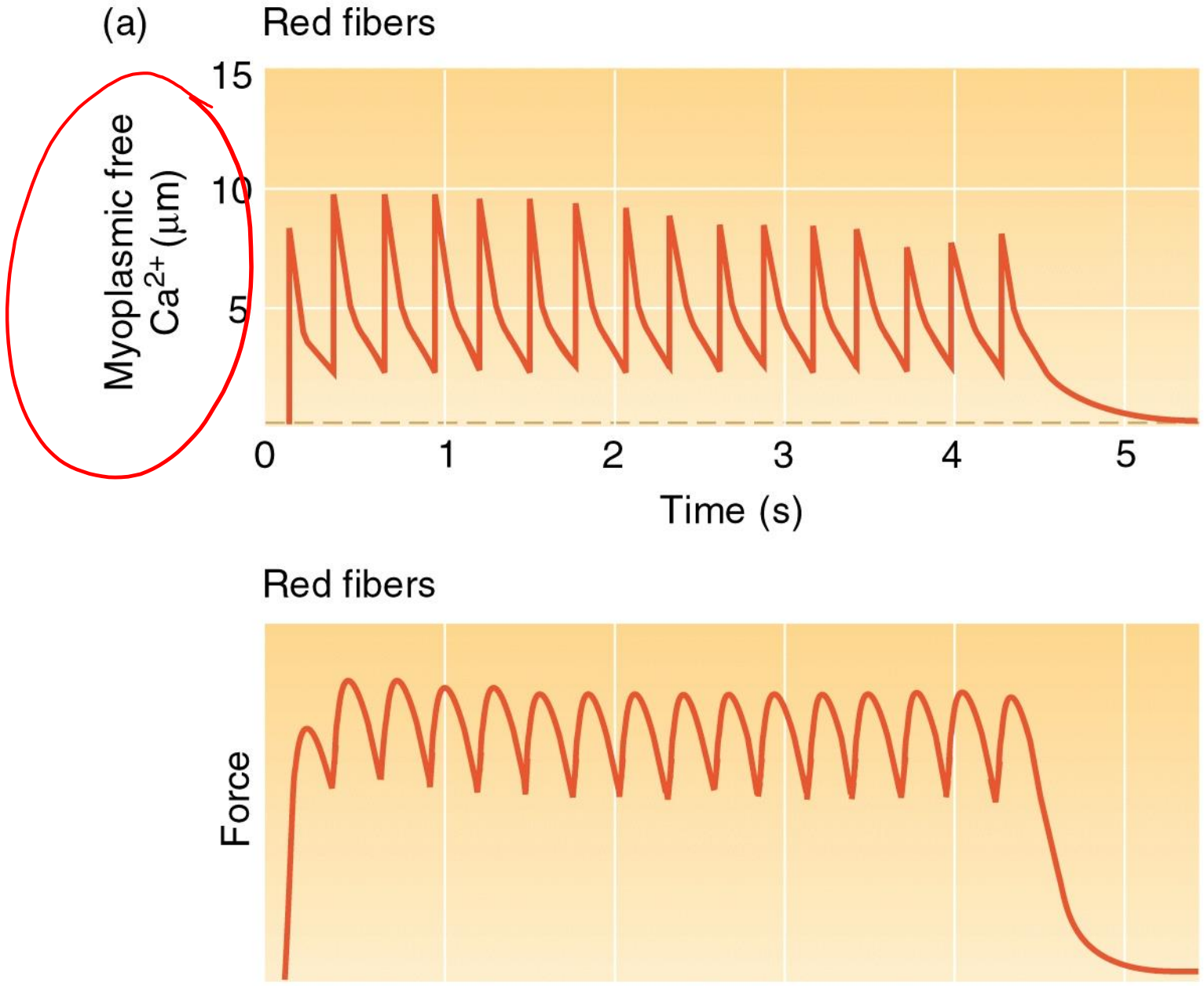
(a)

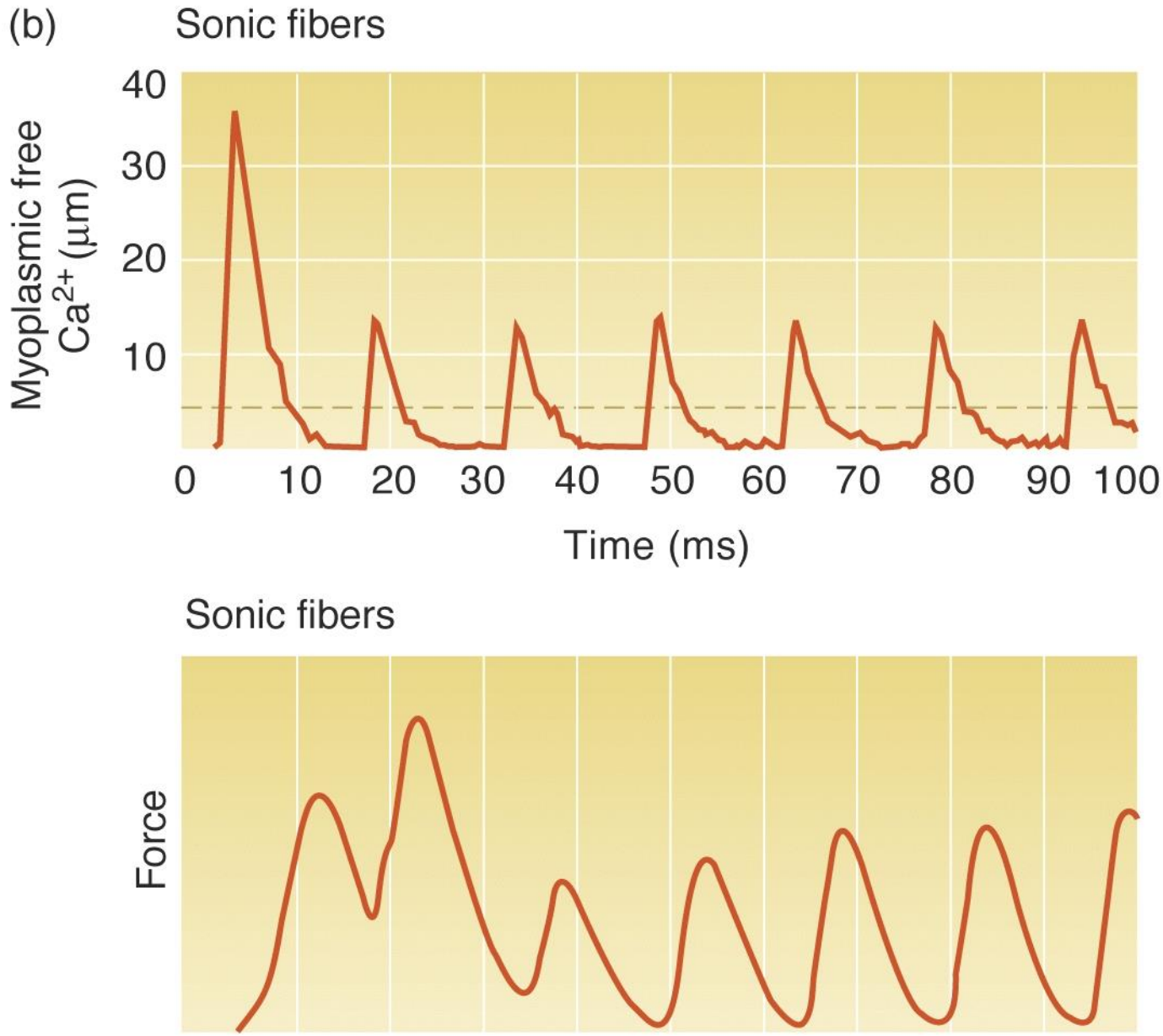

(a)
1.0
0.8
0.6
0.4
0.2
Relative force
Jumping
1.2
1.6
2.0
2.4
2.8
3.2
3.6
Sarcomere length (μm)

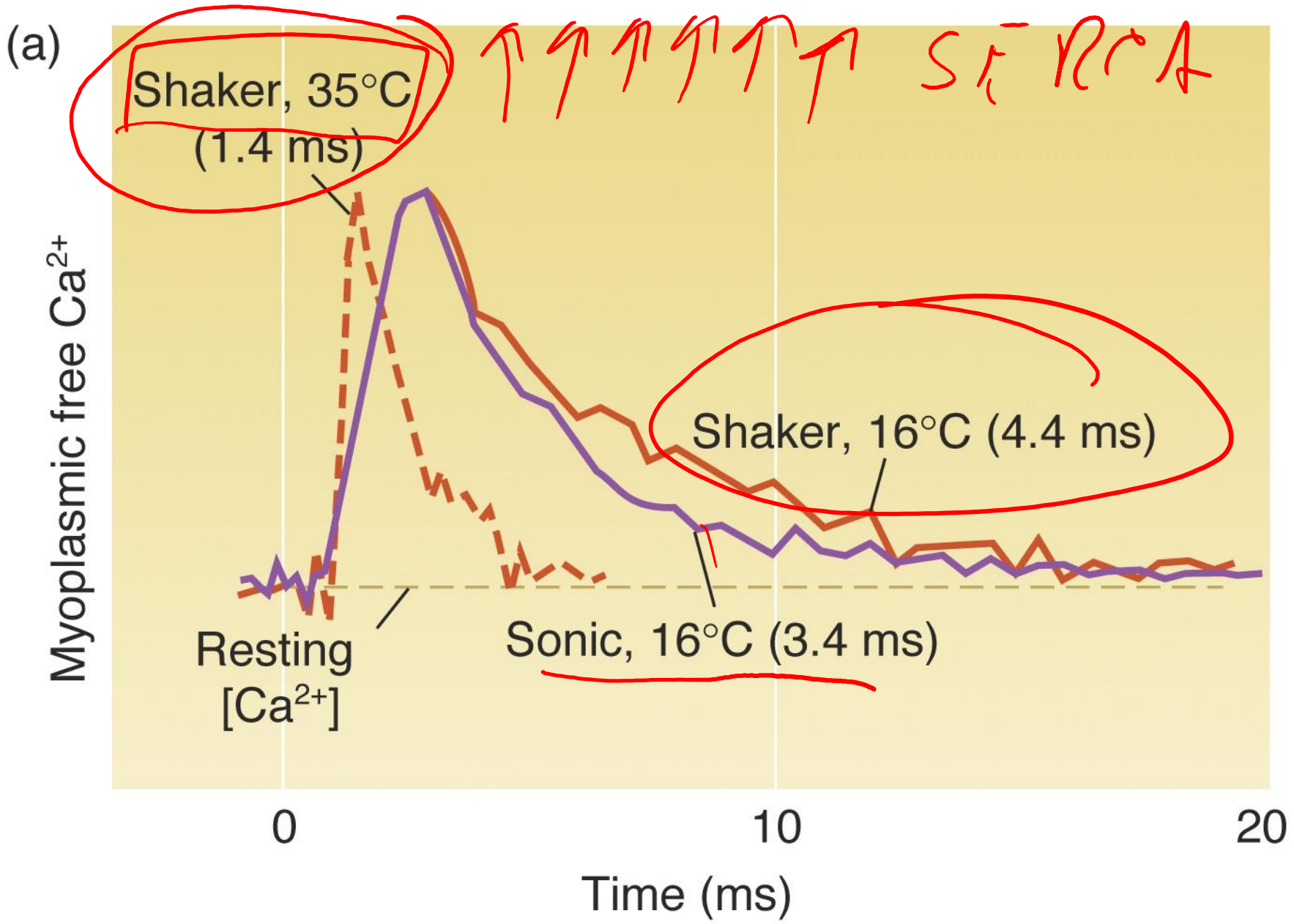

(a) Ca^{2+} concentration over time
Myoplasmic free Ca^{2+}
Half-width
Red (110 ms)
White (21 ms)
Resting $[Ca^{2+}]$
Sonic (3.4 ms)
0.0
0.2
0.4
Time (s)

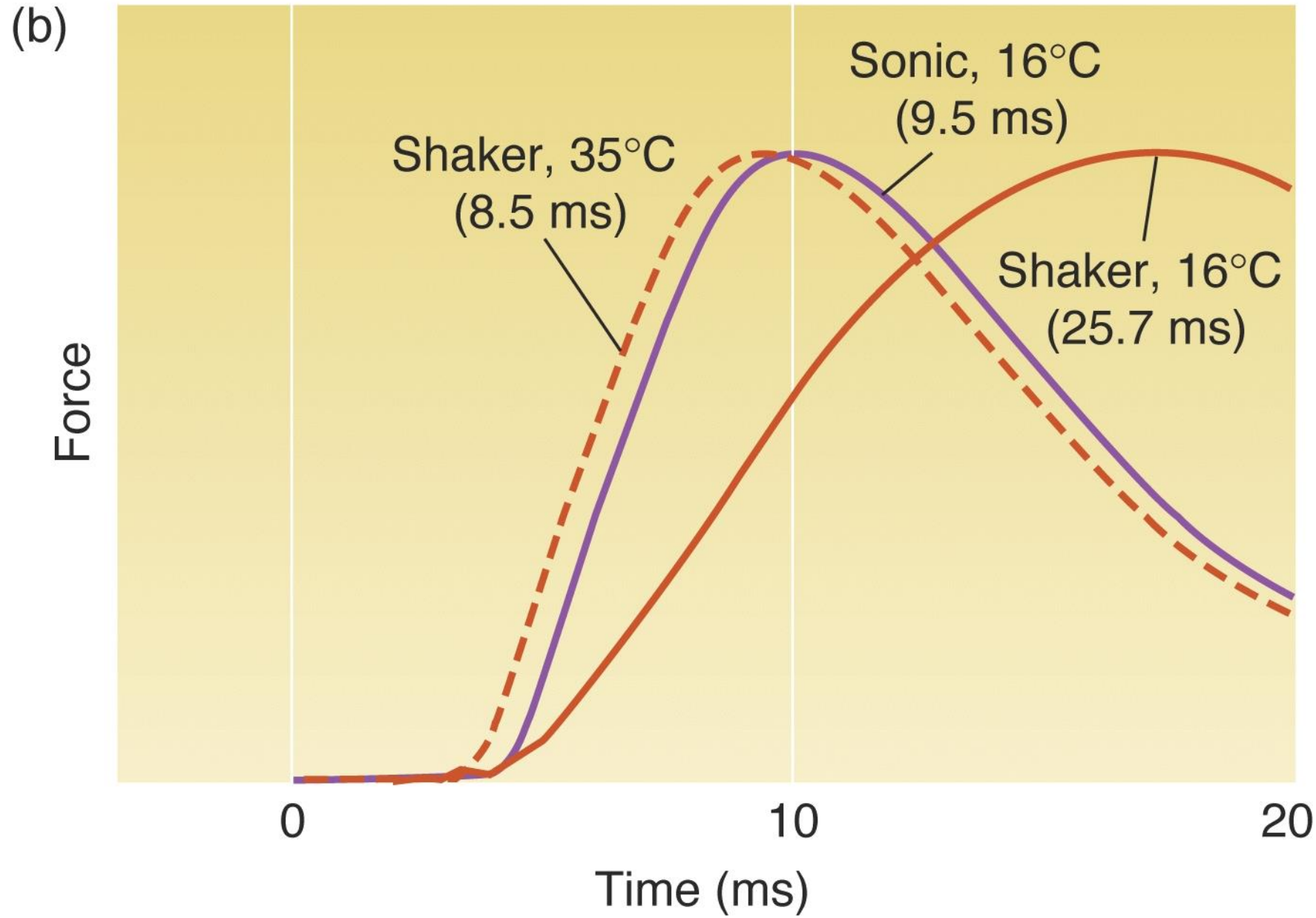
(b) Twitch tension over time




(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)

Heart

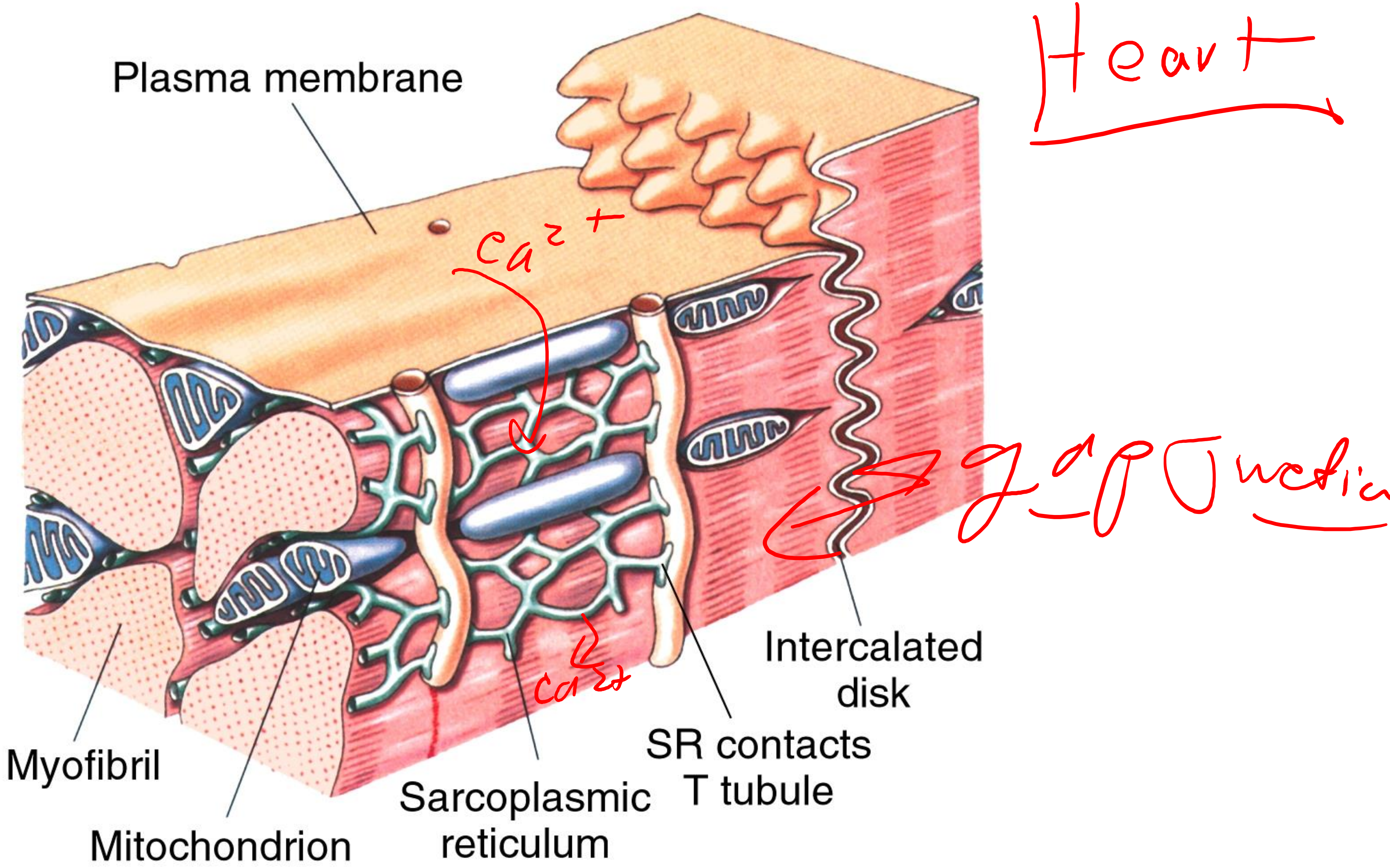

Plasma membrane
Intercalated disk
SR contacts T tubule
Sarcoplasmic reticulum
Mitochondrion
Myofibril

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

Property/component	Striated muscle: Skeletal	Striated muscle: 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 filam past each othe
Innervation	Somatic nerves	Autonomic nerve
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.

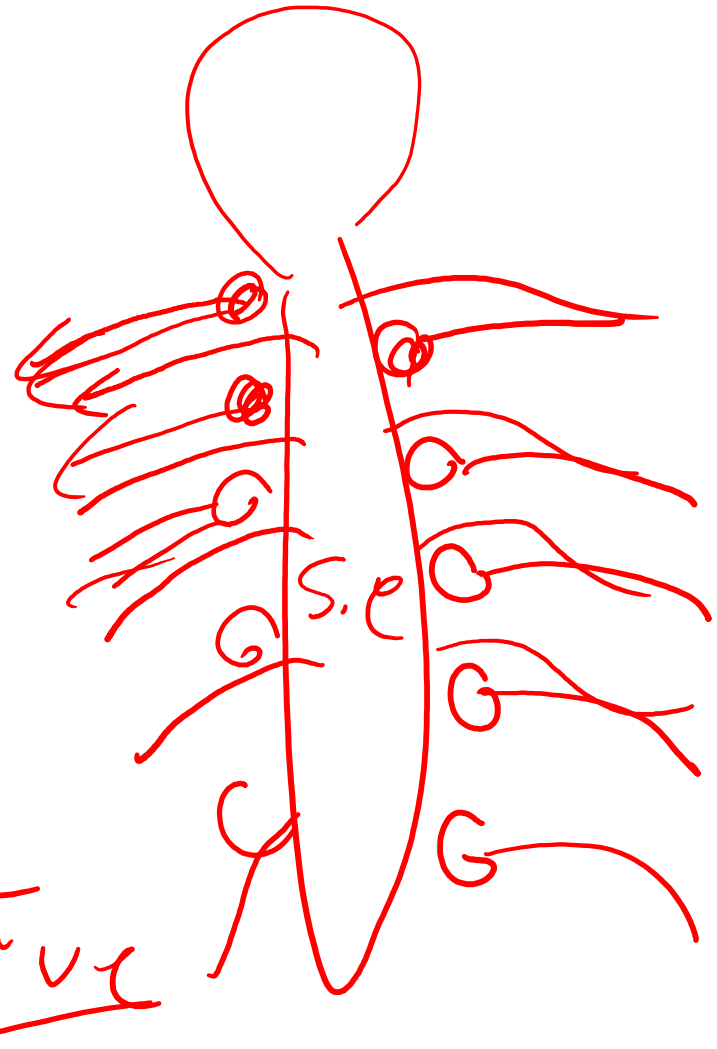
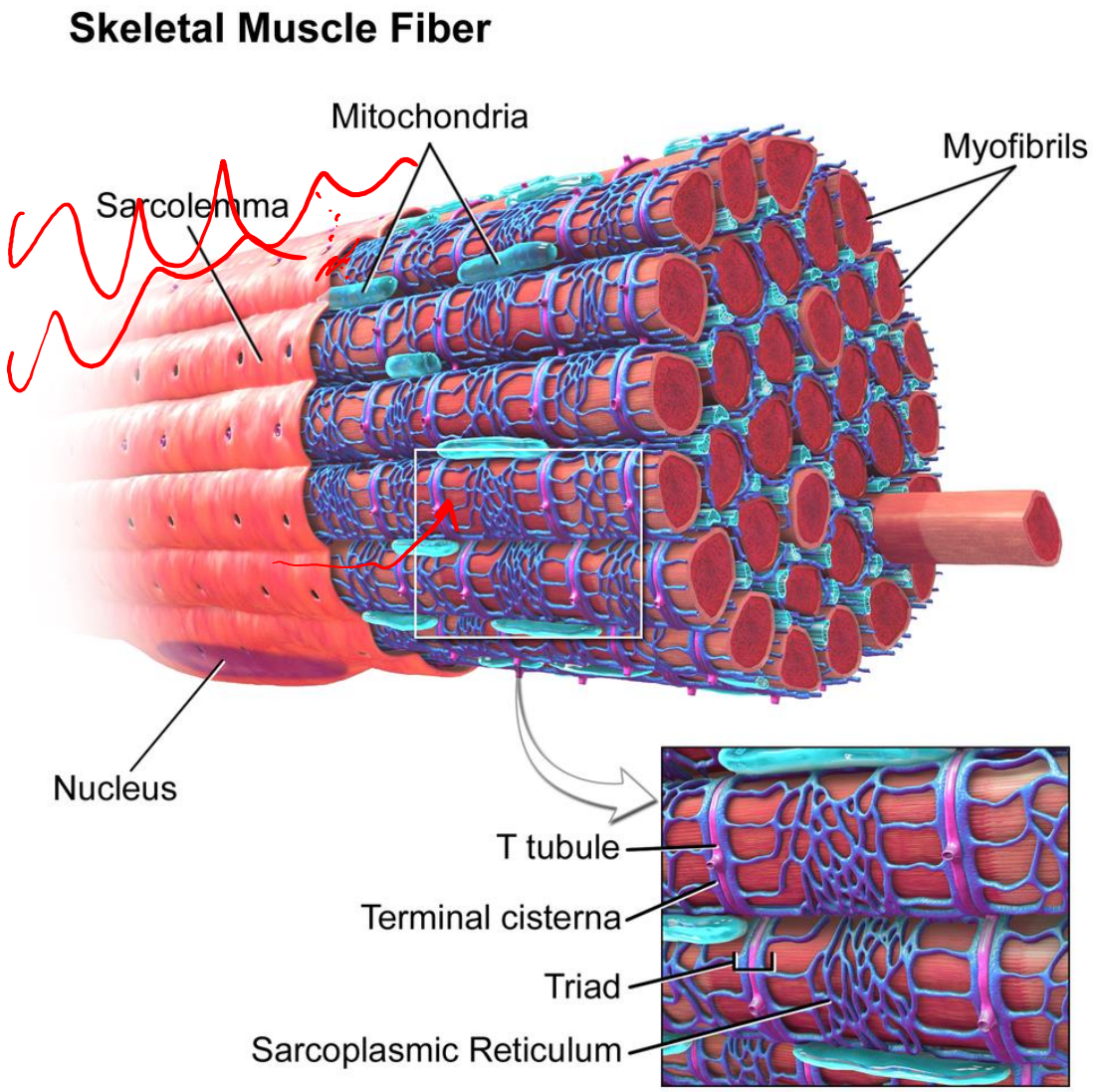


Table 10-2 Characteristics of the major types of muscle fibers in vertebrates

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

*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.

The **sarcolemma** (*sarco (from sarx)* from Greek; flesh, and *lemma* from Greek; sheath.) also called the **myolemma**, is the cell membrane of a striated muscle fiber cell. (wikipedia)



https://en.wikipedia.org/wiki/Sarcolemma