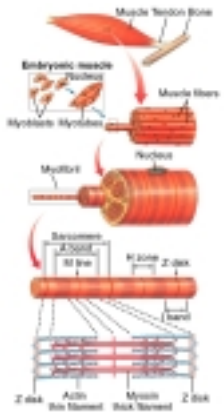
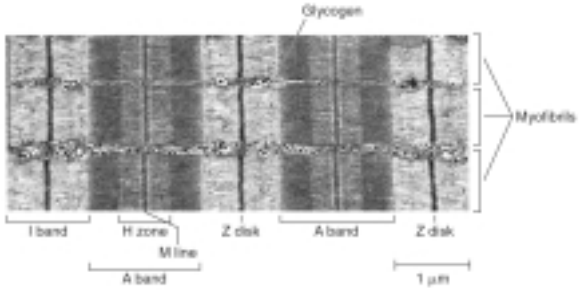
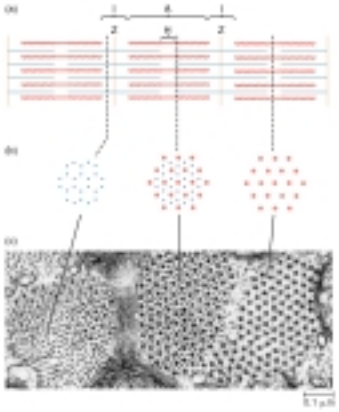
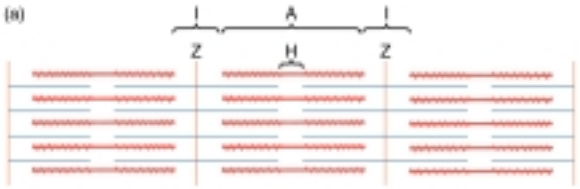
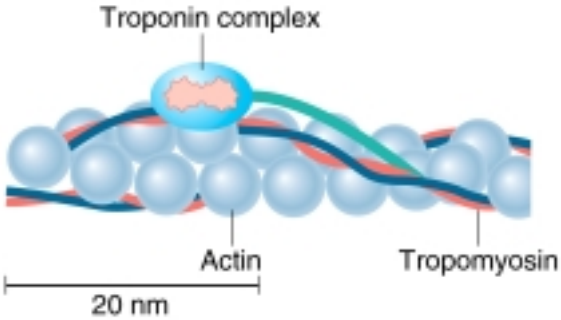

Muscle
Tendon
Bone
Embryonic muscle
Nucleus
Muscle fibers
Myoblasts
Myotubes
Nucleus
Myofibril
Sarcomere
Z disk
M line
H zone
Z disk
I band
Z disk
Actin
thin filament
Myosin
thick filament
Z disk

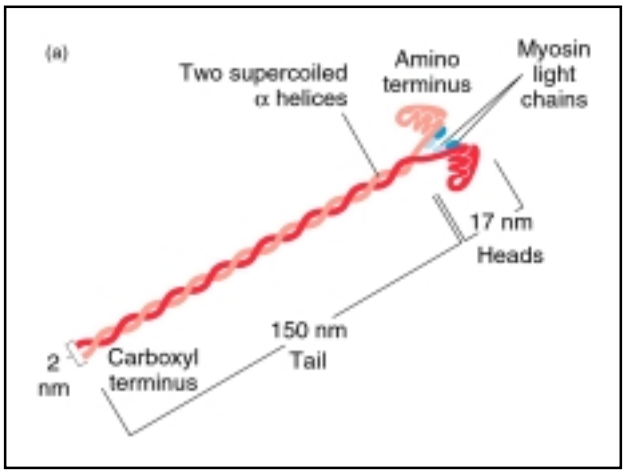

Glycogen
Myofibrils
I band
H zone
Z disk
A band
Z disk
M line
A band
1 μm

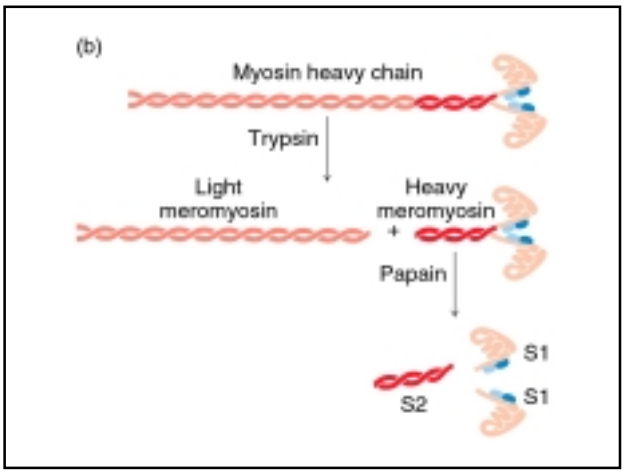

(a)
I
A
I
Z
H
Z
(b)
(c)
0.1 μm

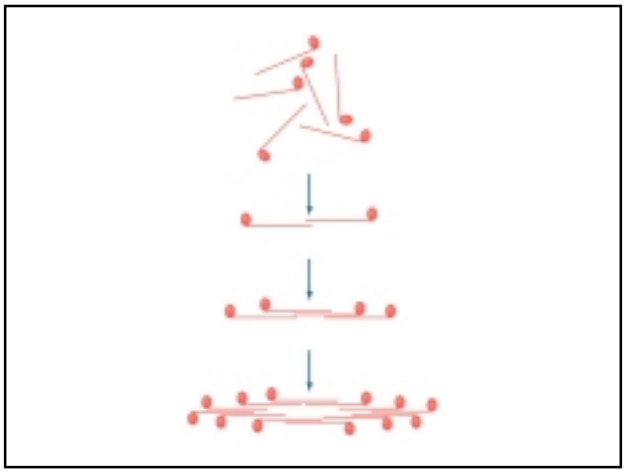

(a)
I
A
I
Z
H
Z

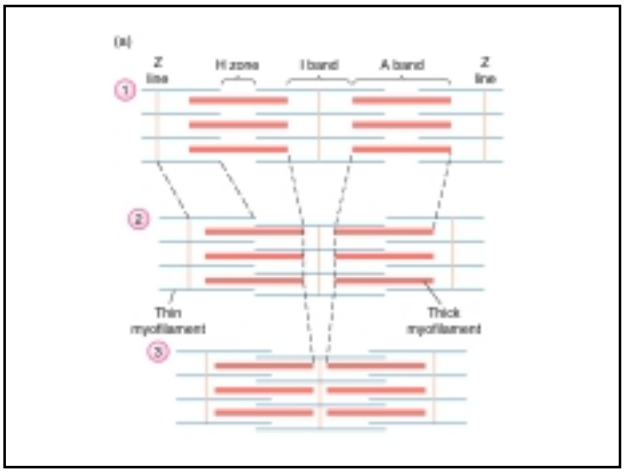
(b)

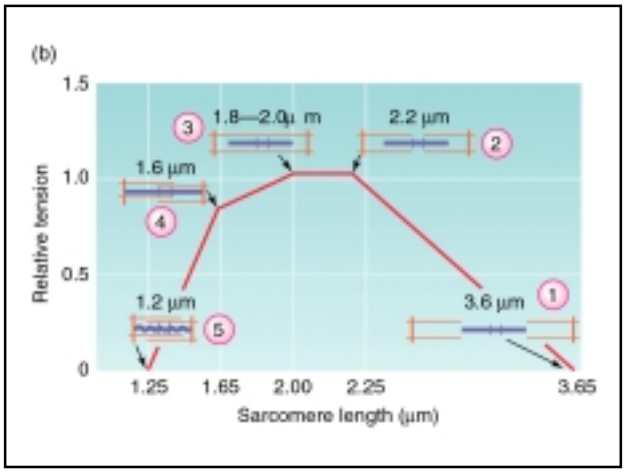

Troponin complex
Actin
Tropomyosin
20 nm

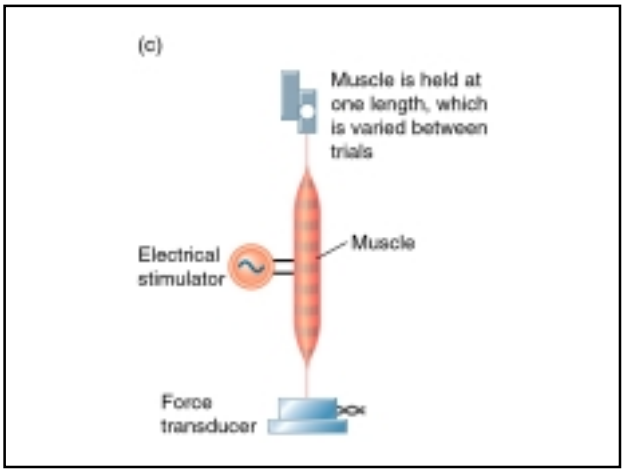

(a)
Two supercoiled α helices
Amino terminus
Myosin light chains
17 nm
Heads
150 nm
Tail
2 nm
Carboxyl terminus

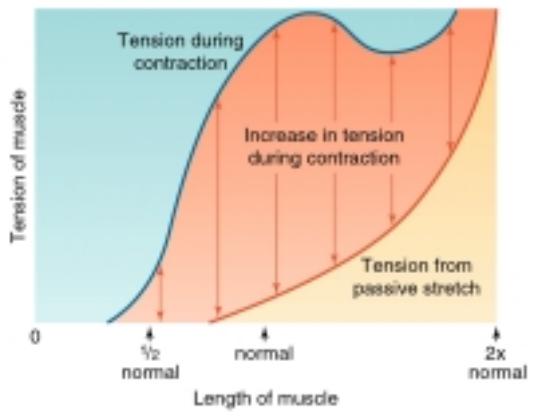

(b)
Myosin heavy chain
Trypsin
Light meromyosin
Heavy meromyosin
+
Papain
S1
S1
S2

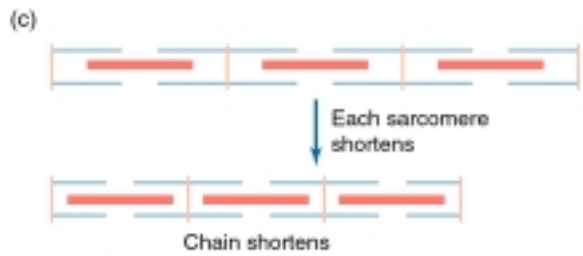


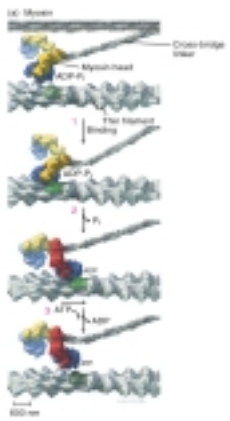

(a)
Z line
H zone
I band
A band
Z line
1
2
Thin myofilament
Thick myofilament
3

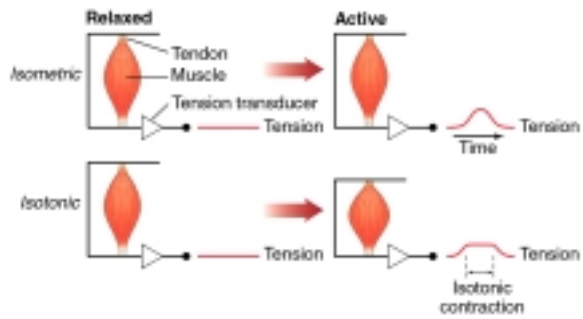

(b)
1.5
1.0
0.5
0
Relative tension
1.8—2.0μ m
2.2 μm
1.6 μm
1.2 μm
3.6 μm
3
2
4
5
1
1.25
1.65
2.00
2.25
3.65
Sarcomere length (μm)

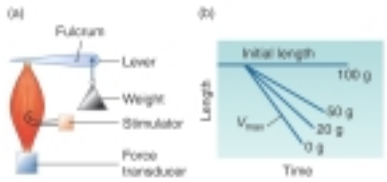

(c)
Muscle is held at one length, which is varied between trials
Electrical stimulator
Muscle
Force transducer

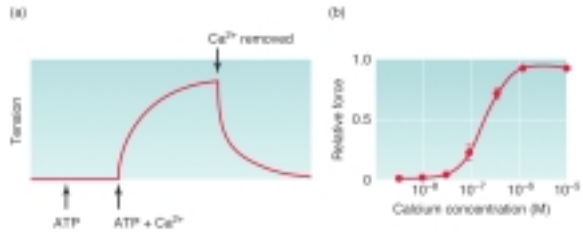

Tension during contraction
Increase in tension during contraction
Tension from passive stretch
Tension of muscle
0
½ normal
normal
2x normal
Length of muscle

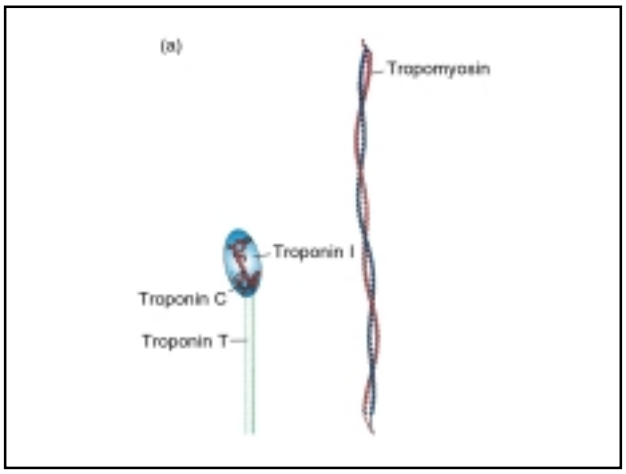

(c)
Each sarcomere shortens
Chain shortens

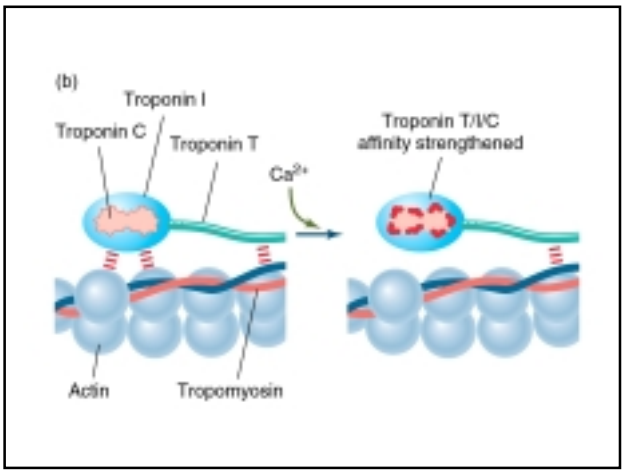


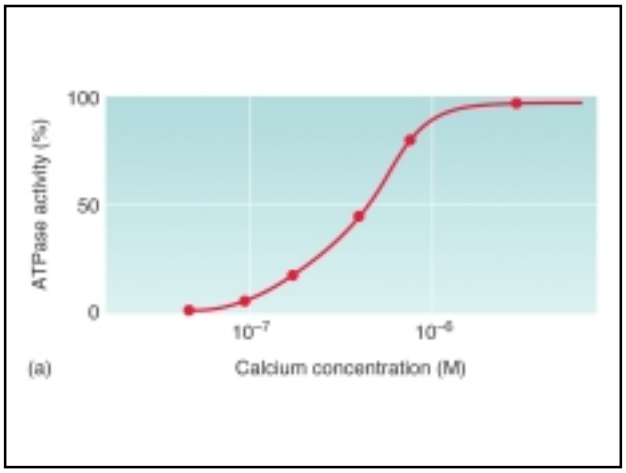

Relaxed
Active
Isometric
Tendon
Muscle
Tension transducer
Tension
Tension
Time
Isotonic
Tension
Tension
Isotonic contraction

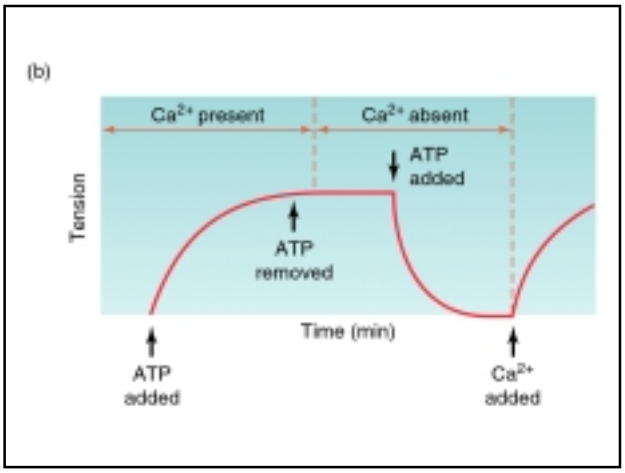

(a)
Fulcrum
Lever
Weight
Stimulator
Force transducer
(b)
Initial length
100 g
50 g
20 g
0 g
Length
Time

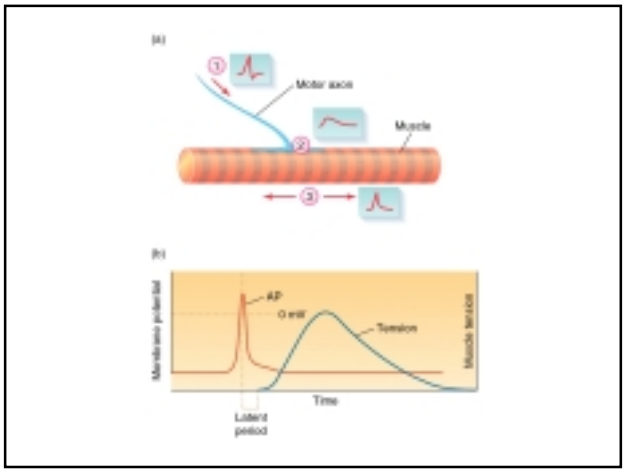

(a)
Ca2+ removed
Tension
ATP
ATP + Ca2+
(b)
1.0
0.5
0
Relative force
Calcium concentration (M)

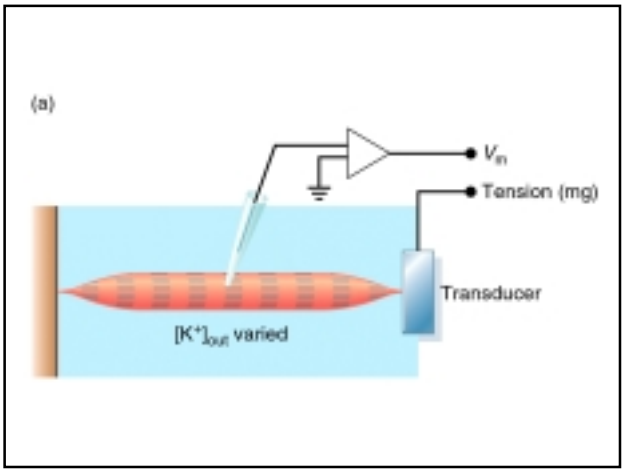

(a)
Tropomyosin
Troponin I
Troponin C
Troponin T

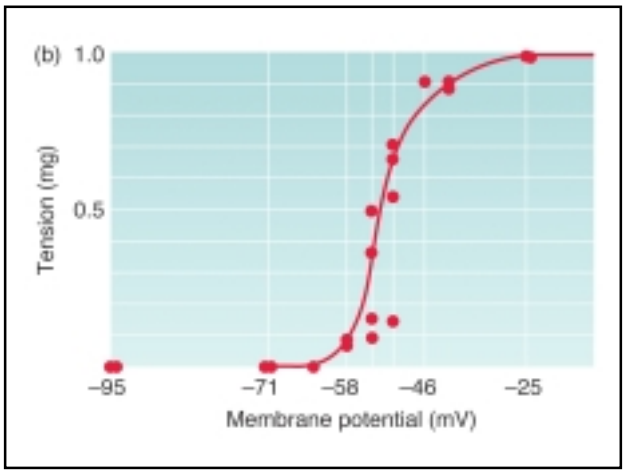

(b)
Troponin I
Troponin C
Troponin T
Troponin T/I/C
affinity strengthened
Ca2+
Actin
Tropomyosin

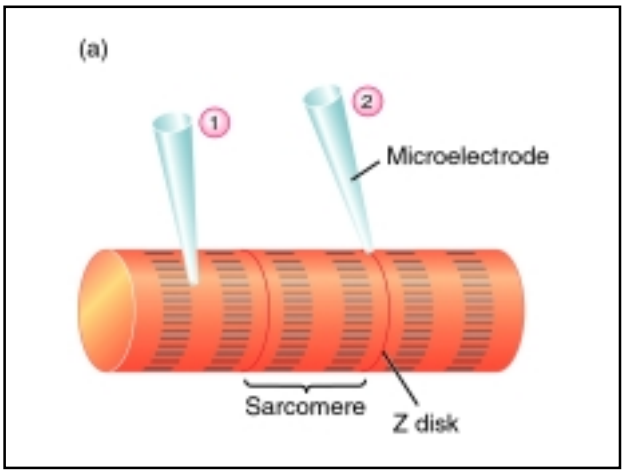

100
50
0
ATPase activity (%)
10−7
10−6
(a)
Calcium concentration (M)

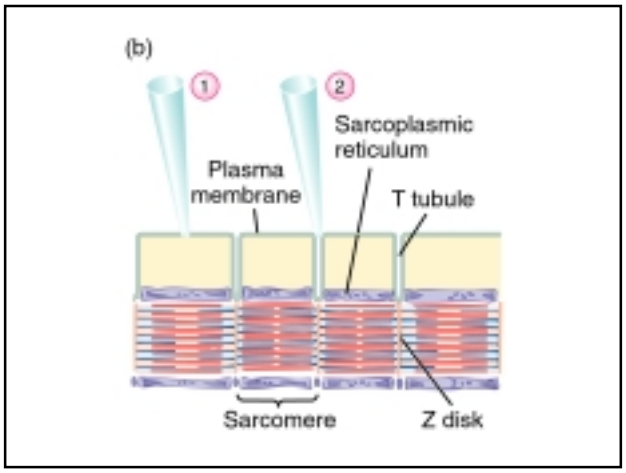

(b)
Ca2+ present
Ca2+ absent
ATP
added
Tension
ATP
removed
Time (min)
ATP
added
Ca2+
added

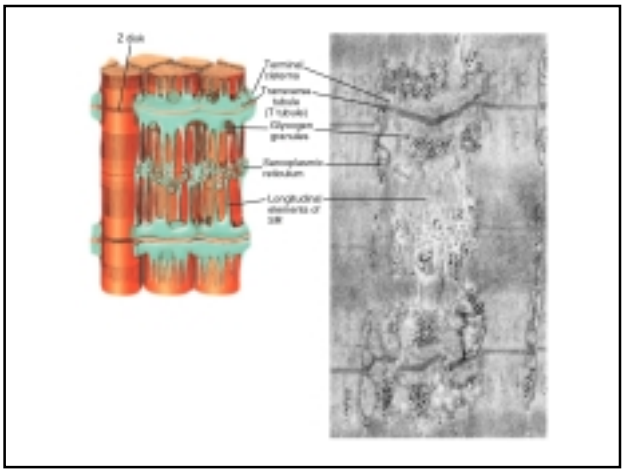

Motor axon
Muscle
Tension
Time

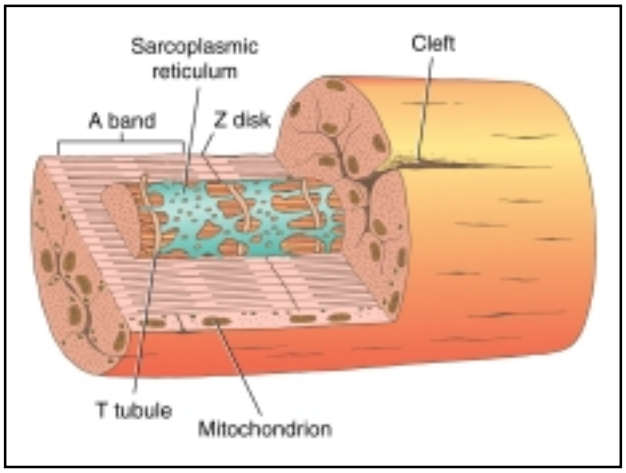

(a)
Vin
Tension (mg)
Transducer
[K+]out varied

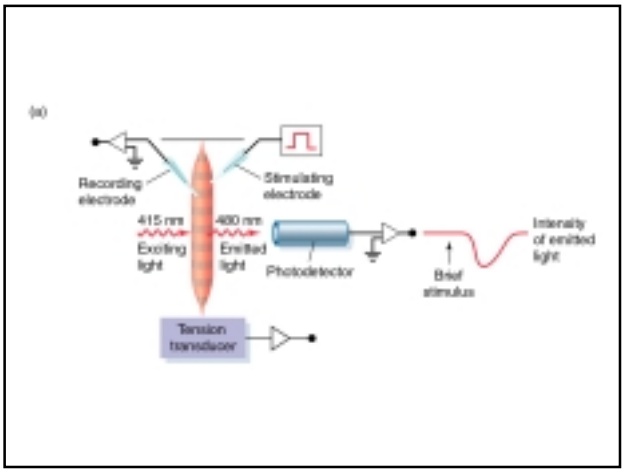

(b)
1.0
0.5
Tension (mg)
–95
–71
–58
–46
–25
Membrane potential (mV)

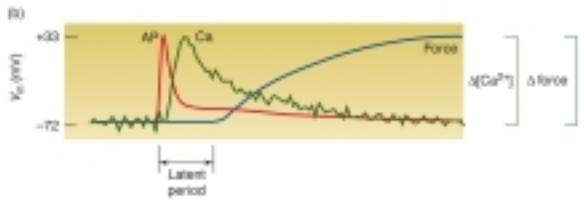

(a)
1
2
Microelectrode
Sarcomere
Z disk


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




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
AP
Ca
Force
Δ[Ca2+]
Δ force
Latent
period