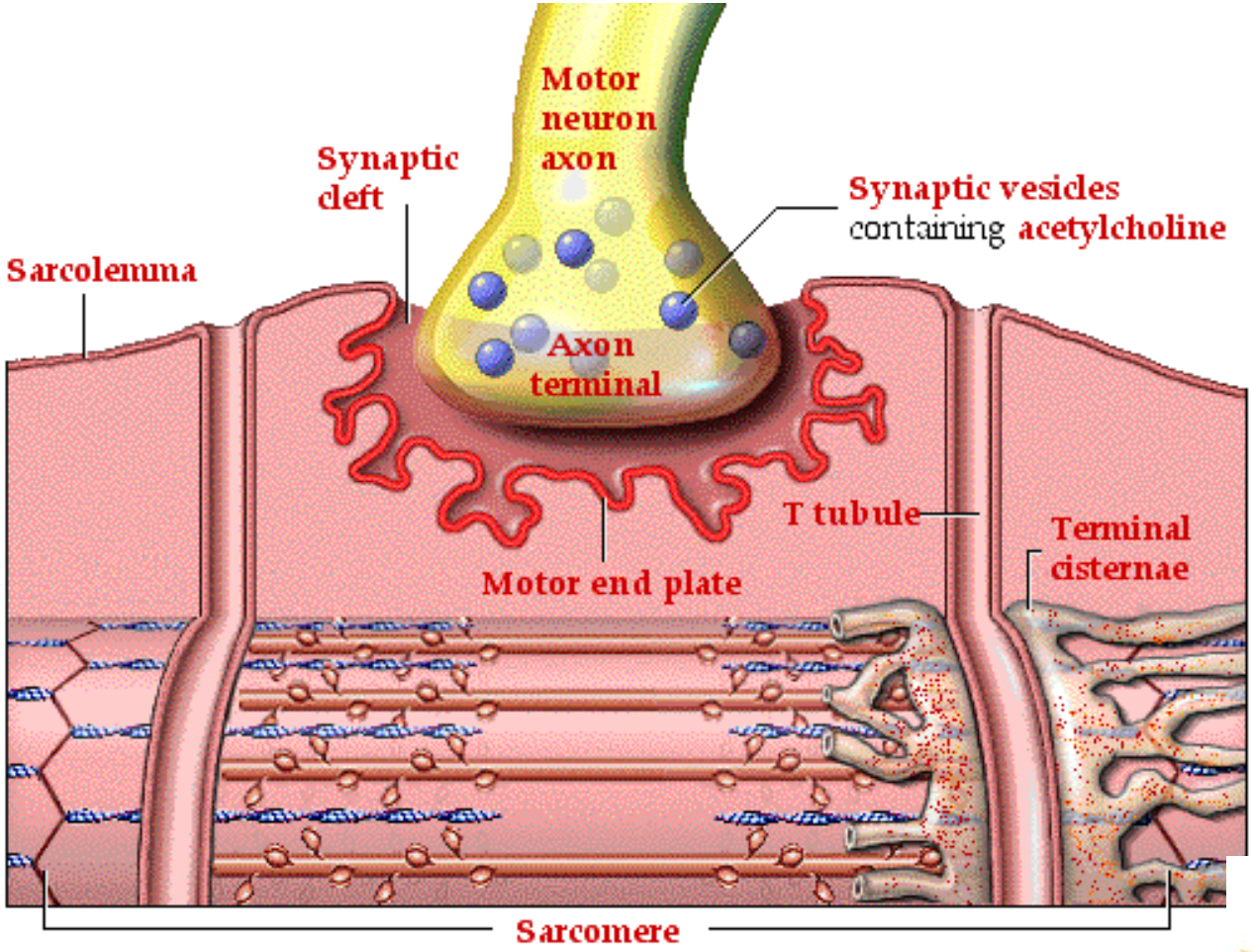
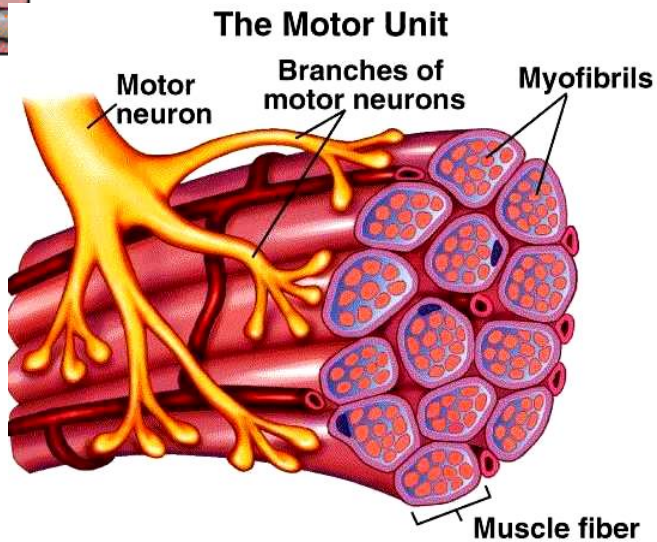
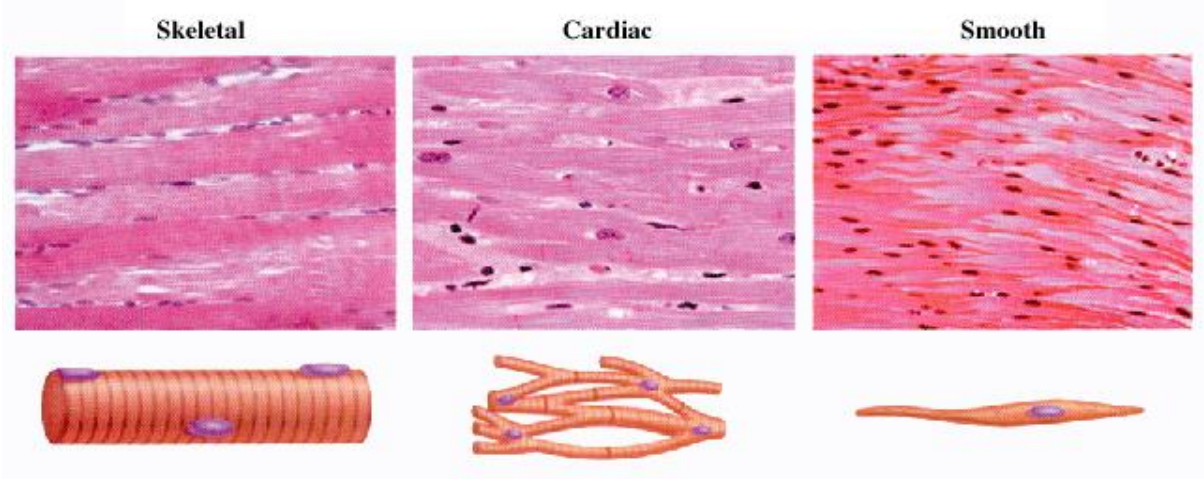
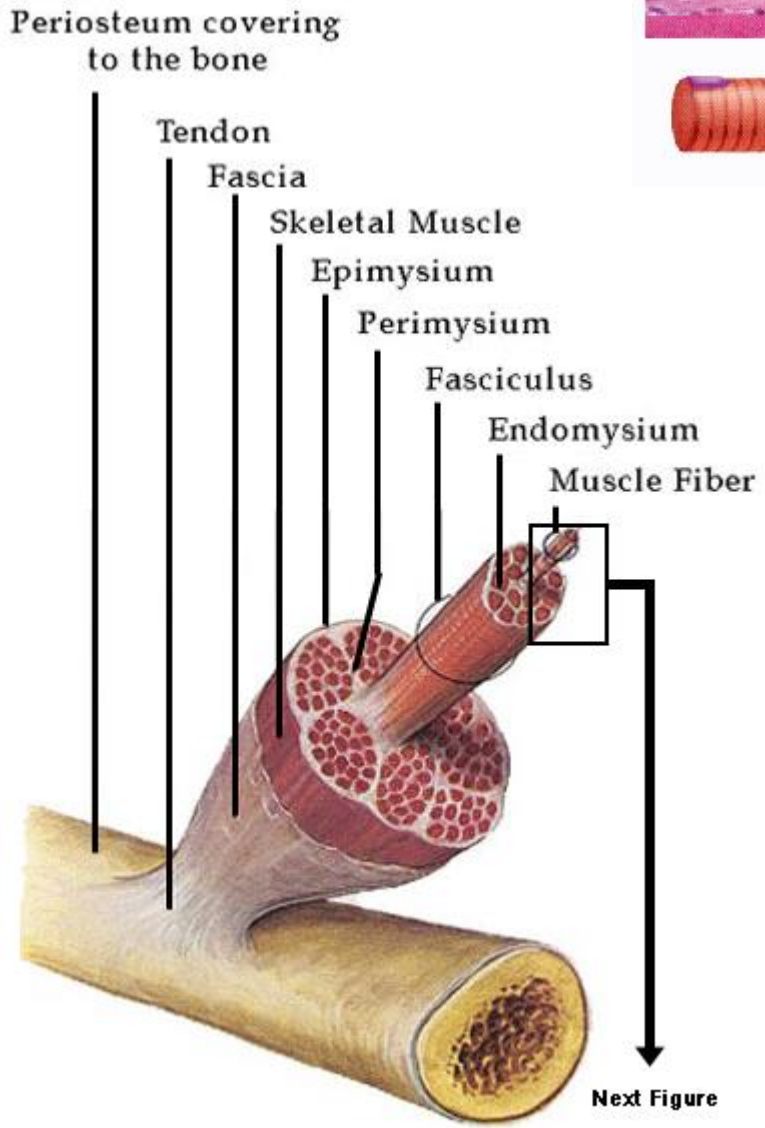
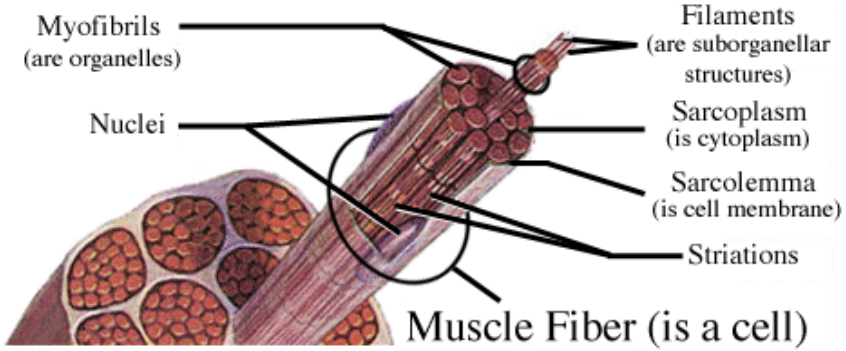
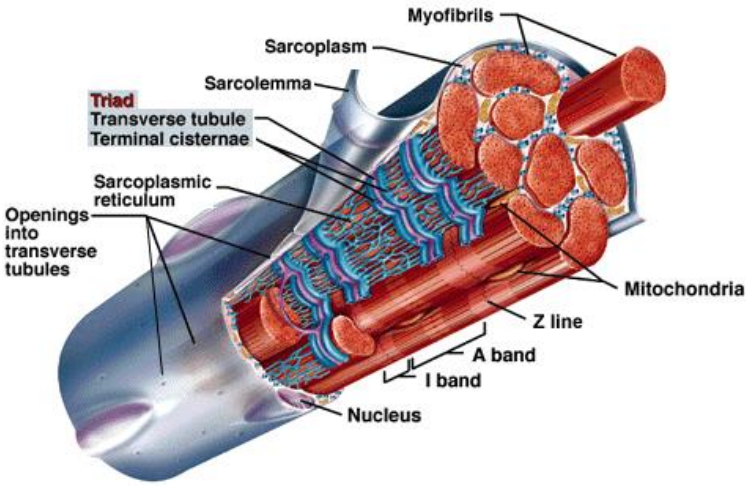

Motor neuron axon
Synaptic cleft
Synaptic vesicles containing acetylcholine
Sarcolemma
Axon terminal
T tubule
Terminal cisternae
Motor end plate
Sarcomere


The Motor Unit
Motor neuron
Branches of motor neurons
Myofibrils
Muscle fiber

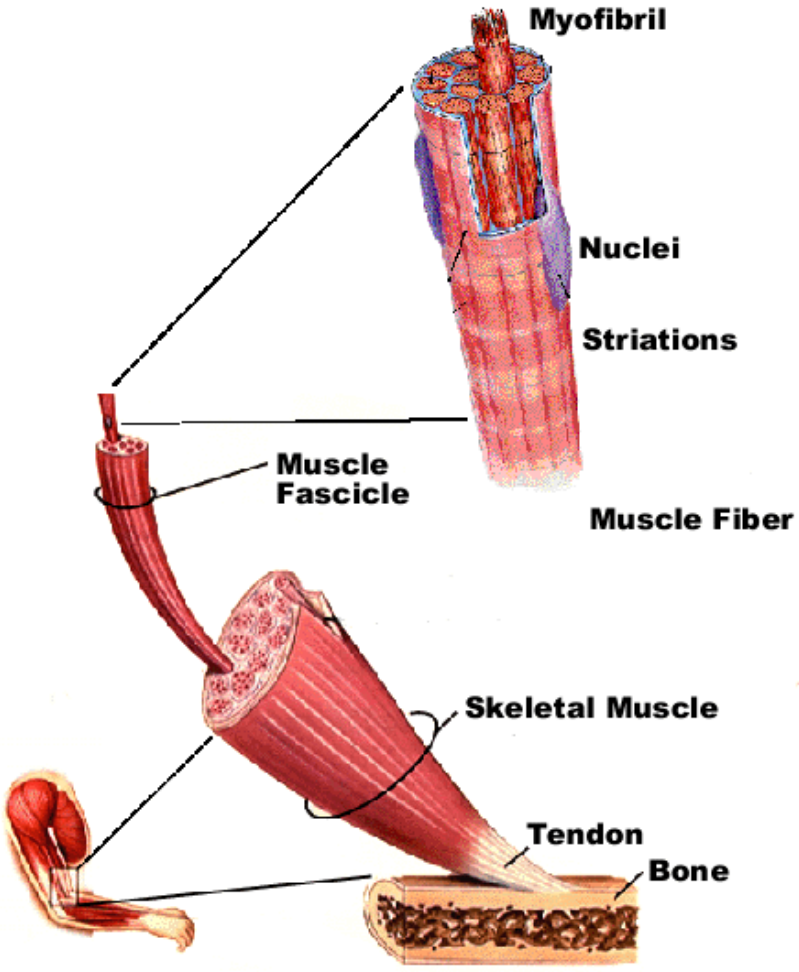

Skeletal
Cardiac
Smooth

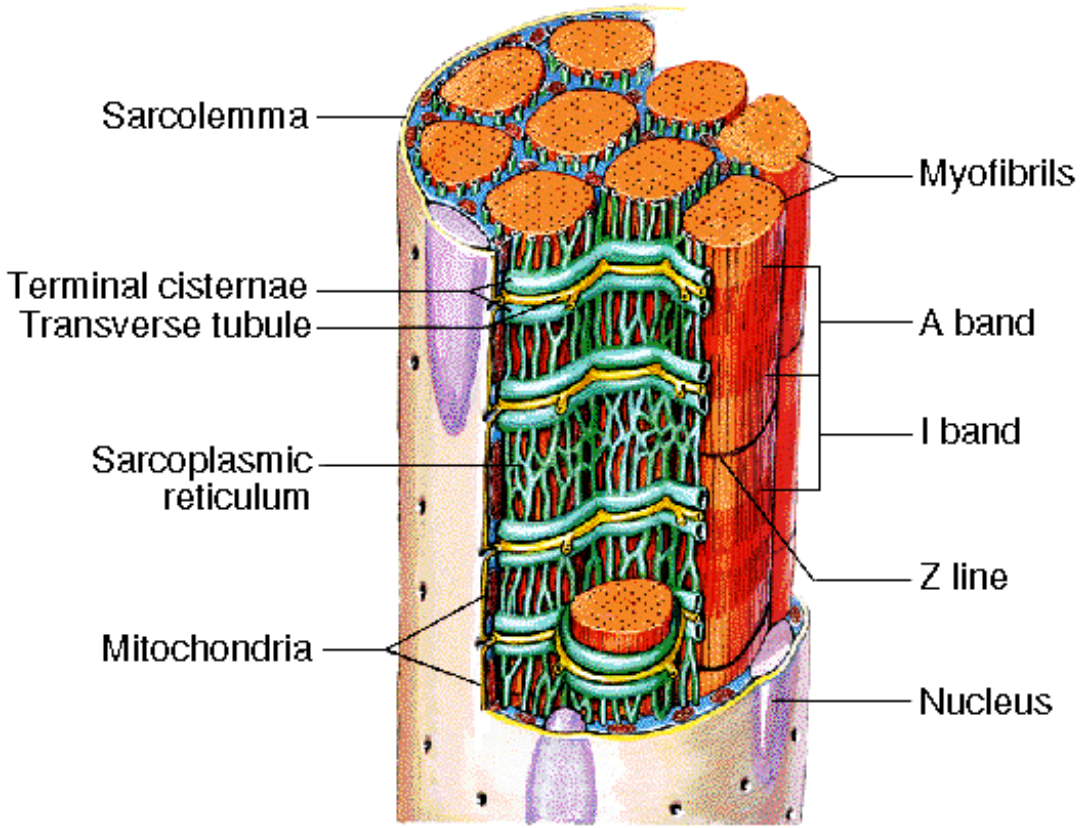

Periosteum covering to the bone
Tendon
Fascia
Skeletal Muscle
Epimysium
Perimysium
Fasciculus
Endomysium
Muscle Fiber
Next Figure


Myofibrils
(are organelles)
Nuclei
Filaments
(are suborganellar structures)
Sarcoplasm
(is cytoplasm)
Sarcolemma
(is cell membrane)
Striations
Muscle Fiber (is a cell)

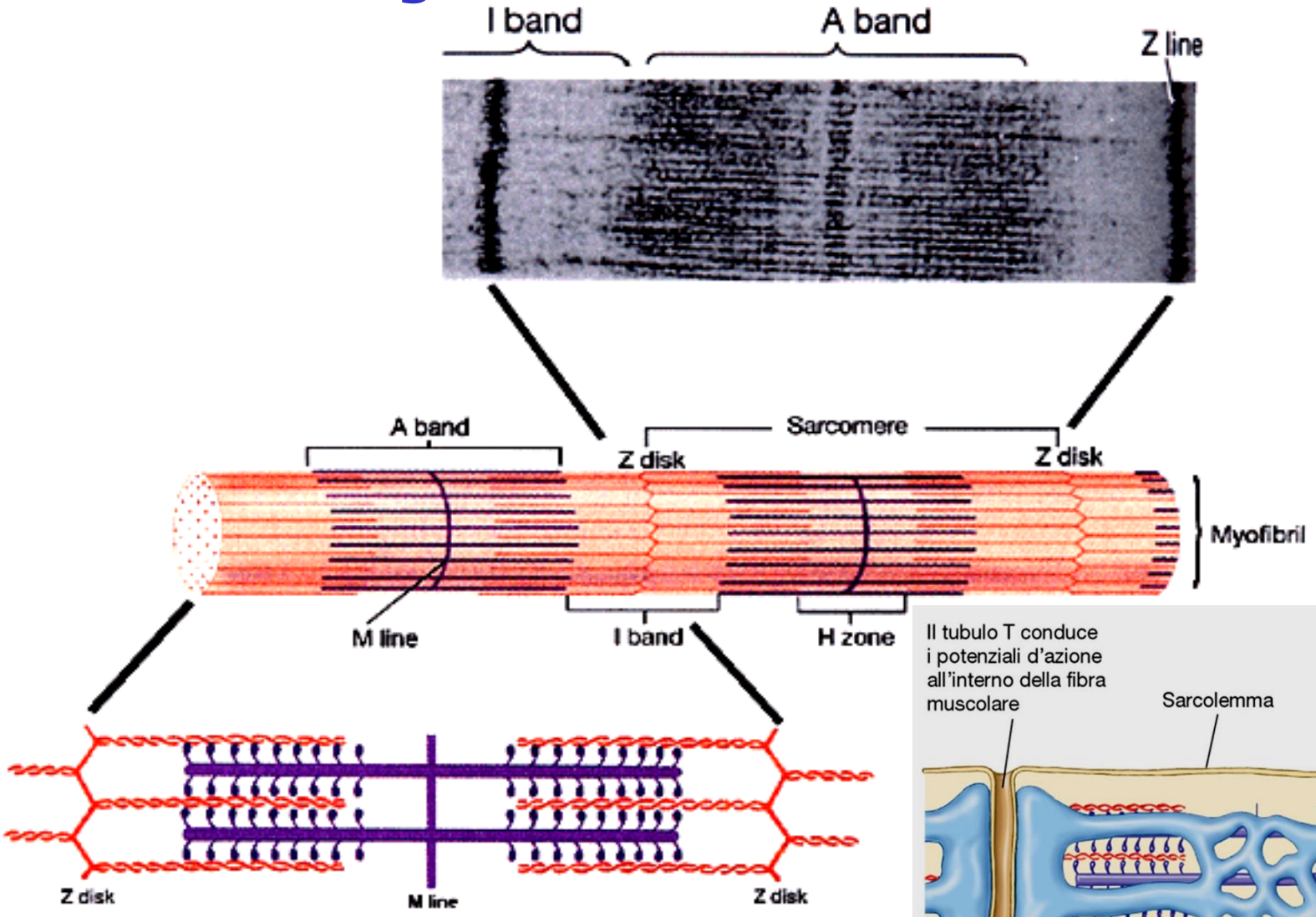

Myofibrils
Sarcoplasm
Sarcolemma
Triad
Transverse tubule
Terminal cisternae
Sarcoplasmic reticulum
Openings into transverse tubules
Mitochondria
Z line
A band
I band
Nucleus

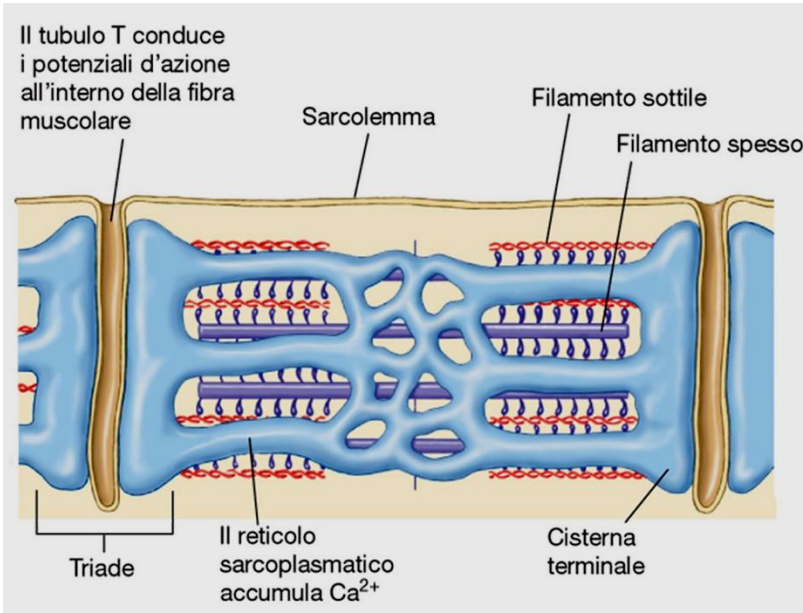
Muscolo scheletrico



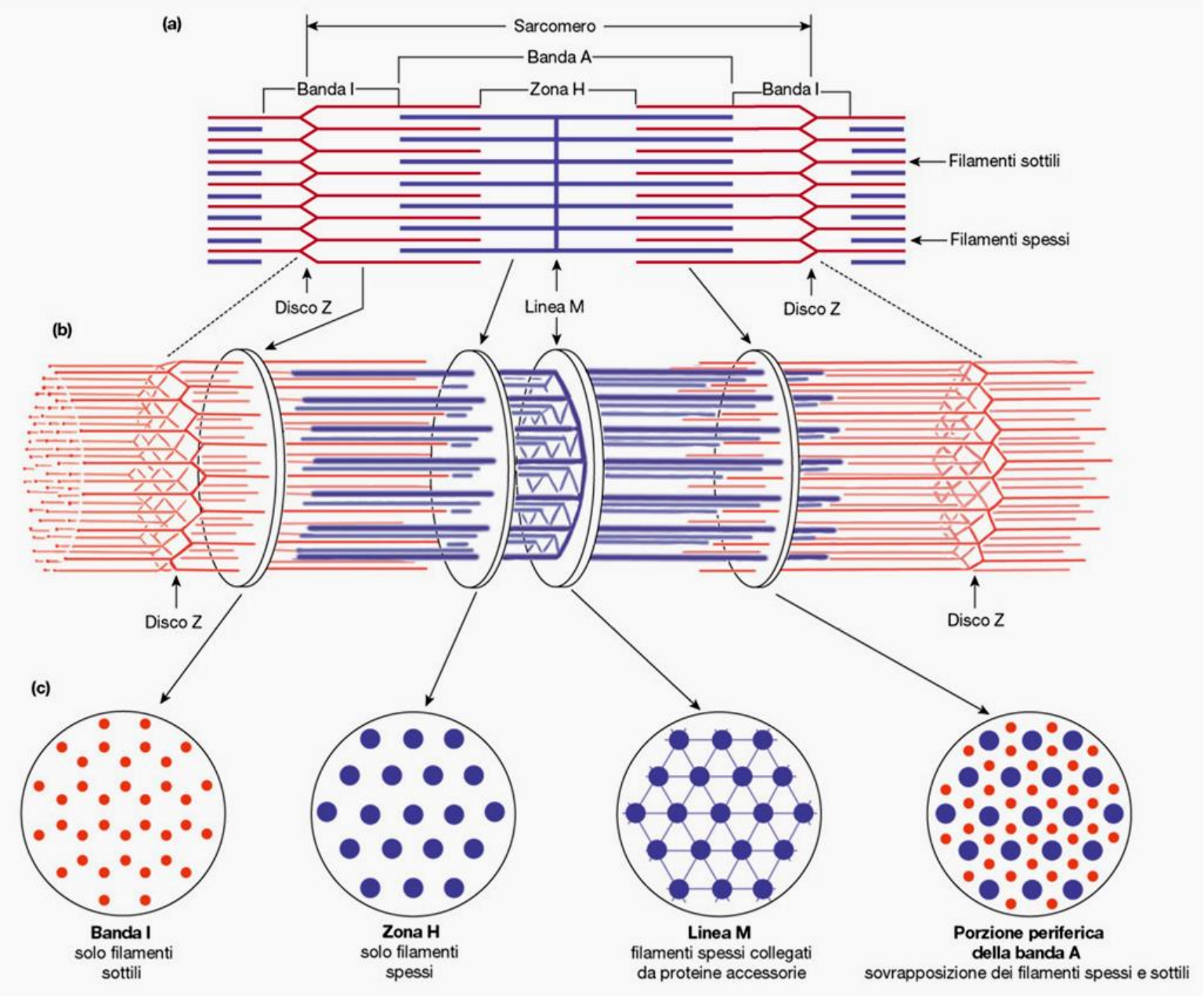


Organizzazione del sarcomero



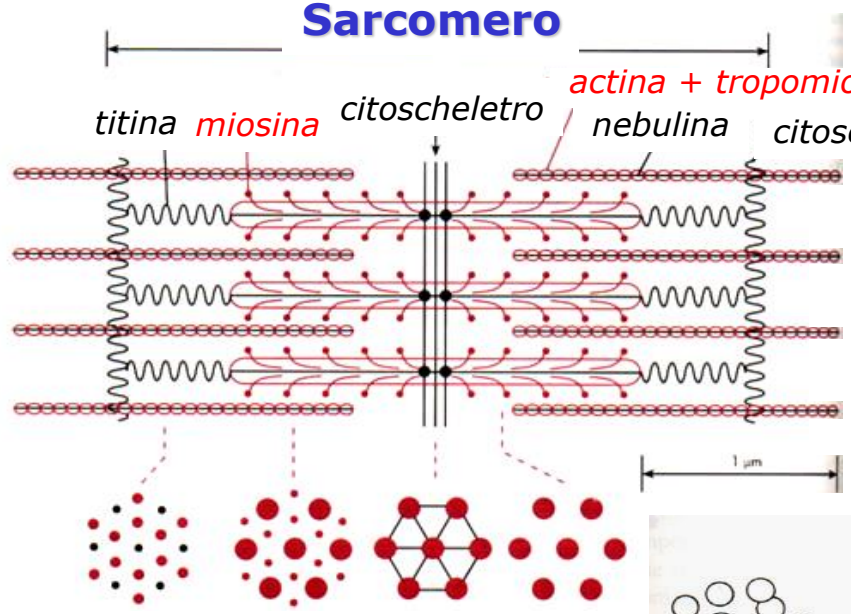


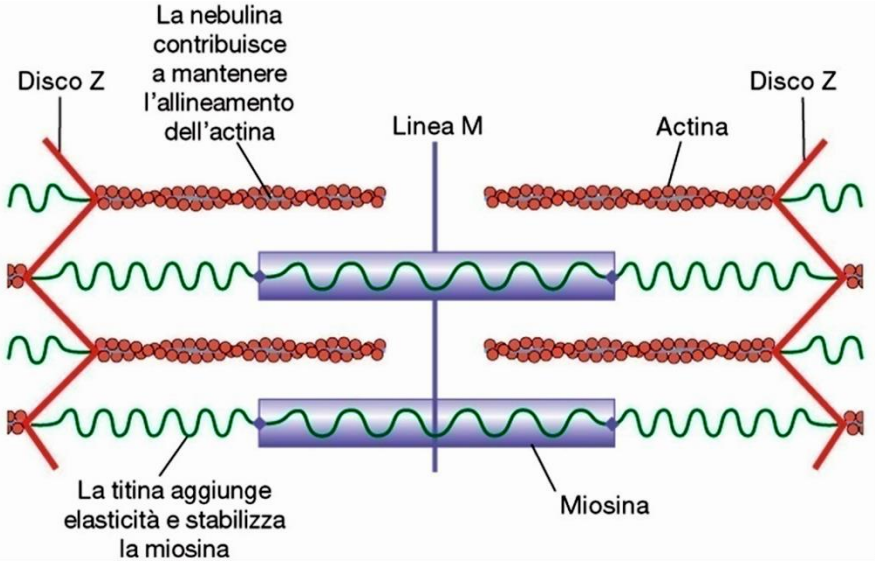
Organizzazione del sarcomero



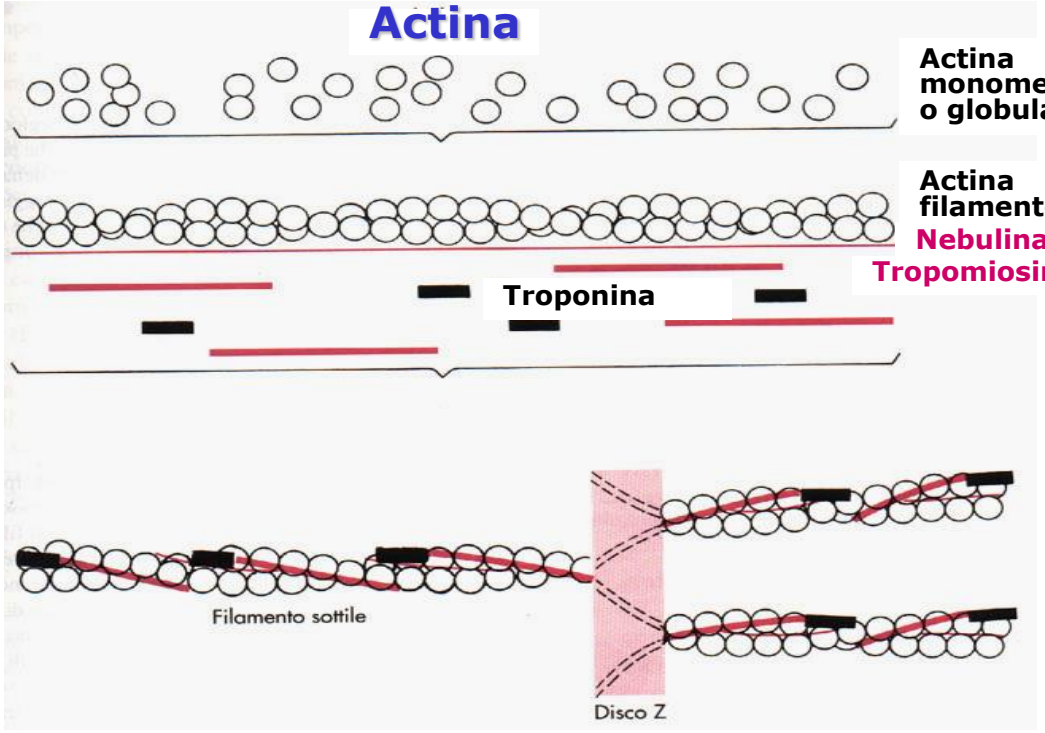
Organizzazione delle proteine contrattili

Sarcomero

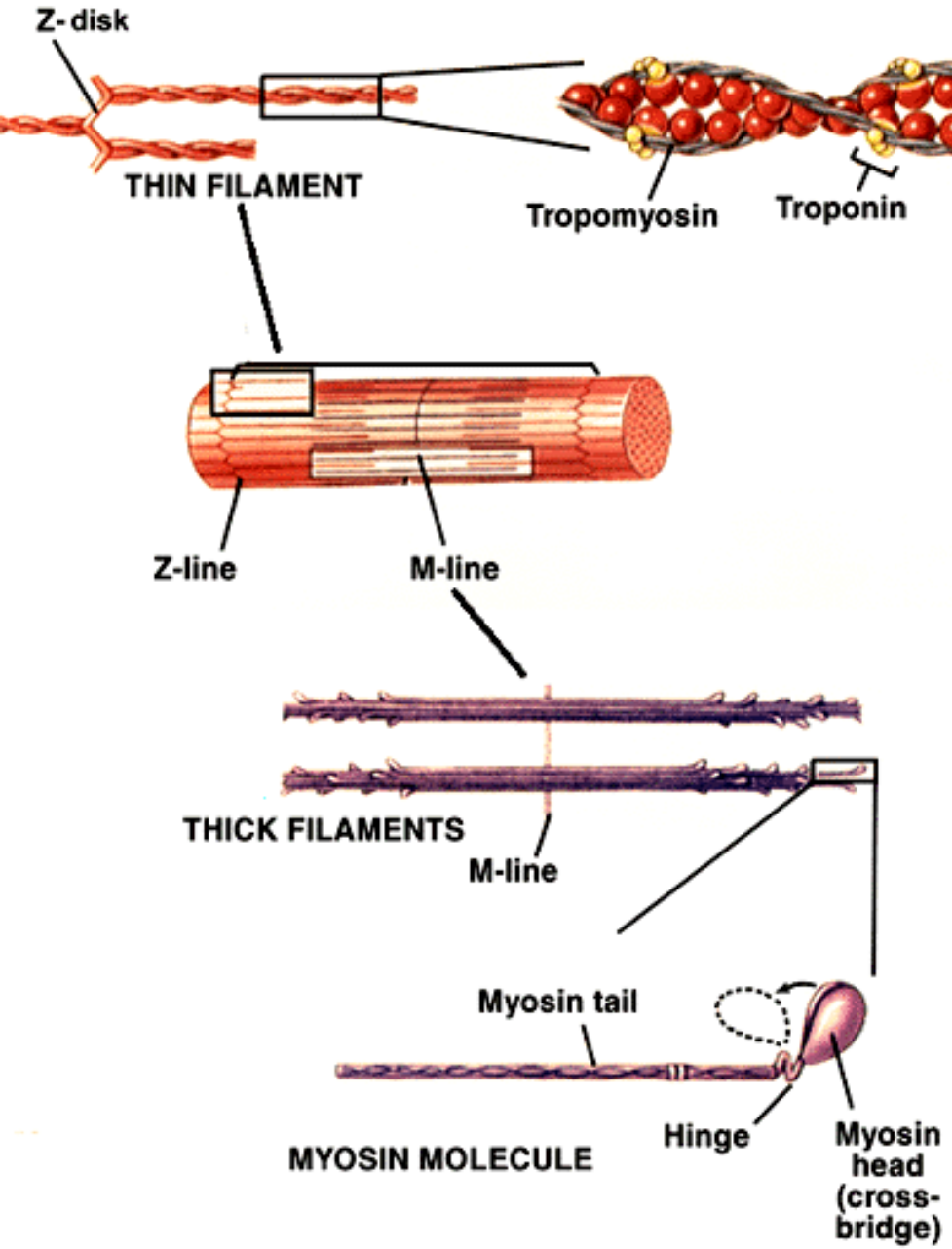




Actina



Organizzazione delle proteine contrattili

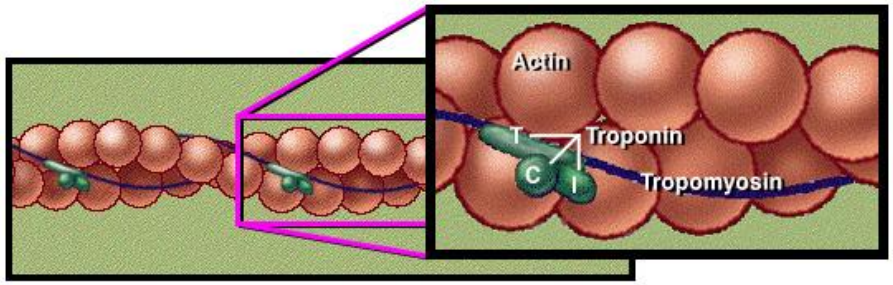


Tropomiosina: proteina filamentosa alloggiata nella doccia del del filamento di actina F.

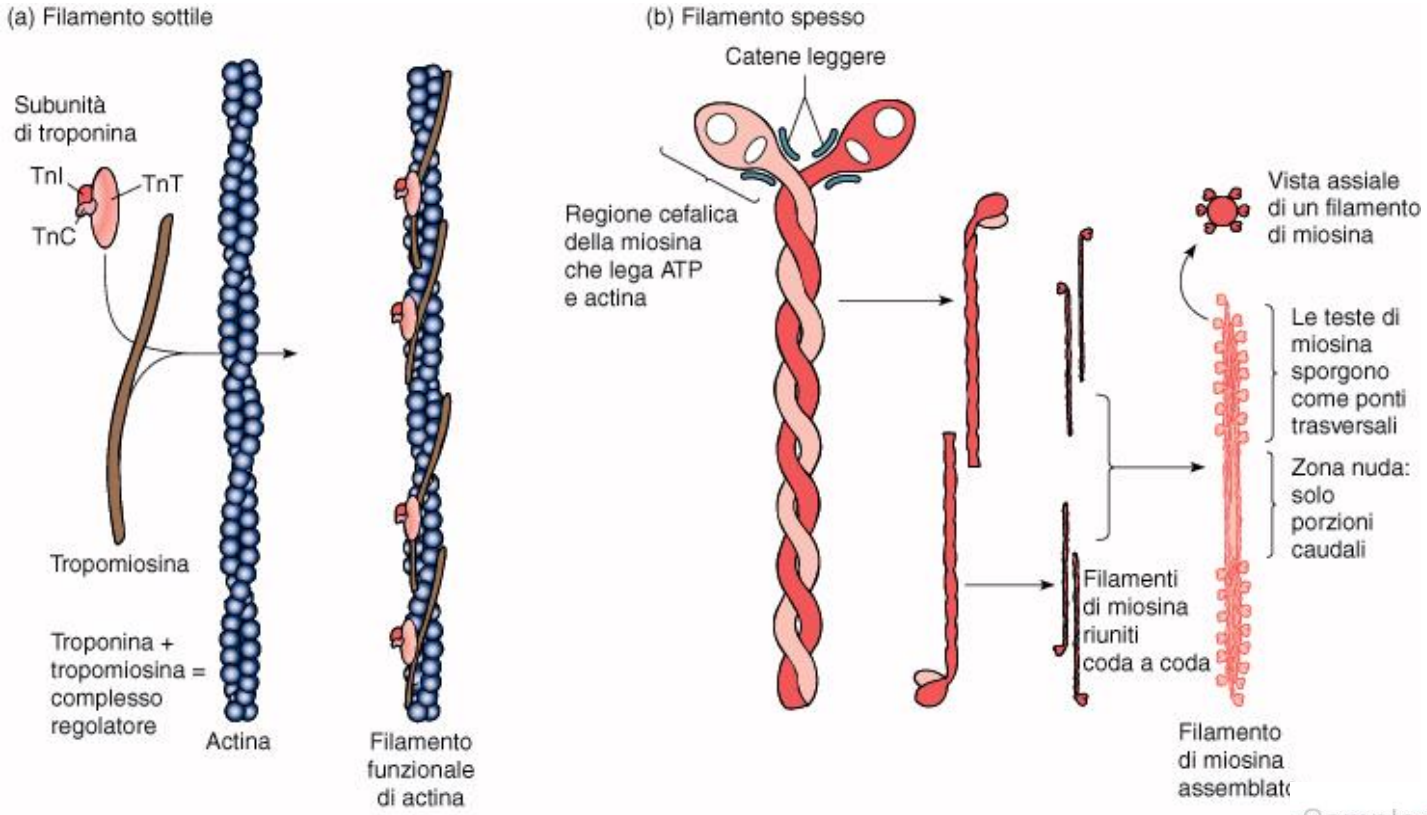
Ogni 7 molecole di actina G:

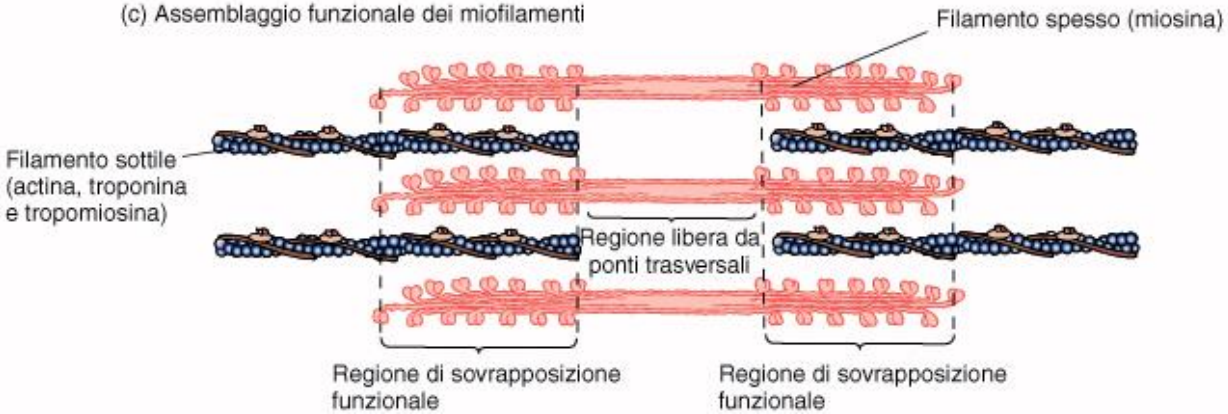
Troponina C = alta affinità per il Ca^{++} (4 ioni)

- **Troponina I** = blocco del sito miosinico dell'actina
- **Troponina T** = collocazione sulla tropomiosina



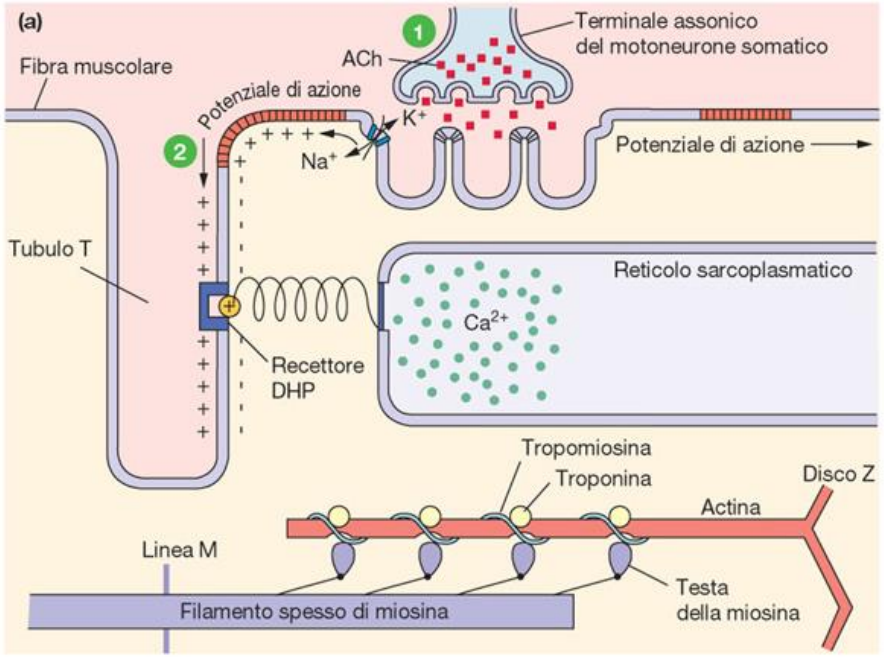
Actina e miosina

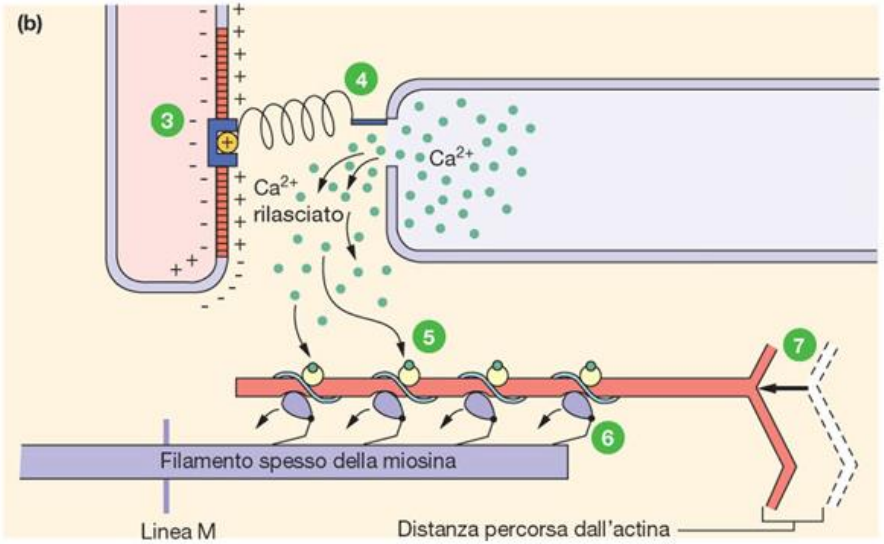




Actin and Myosin

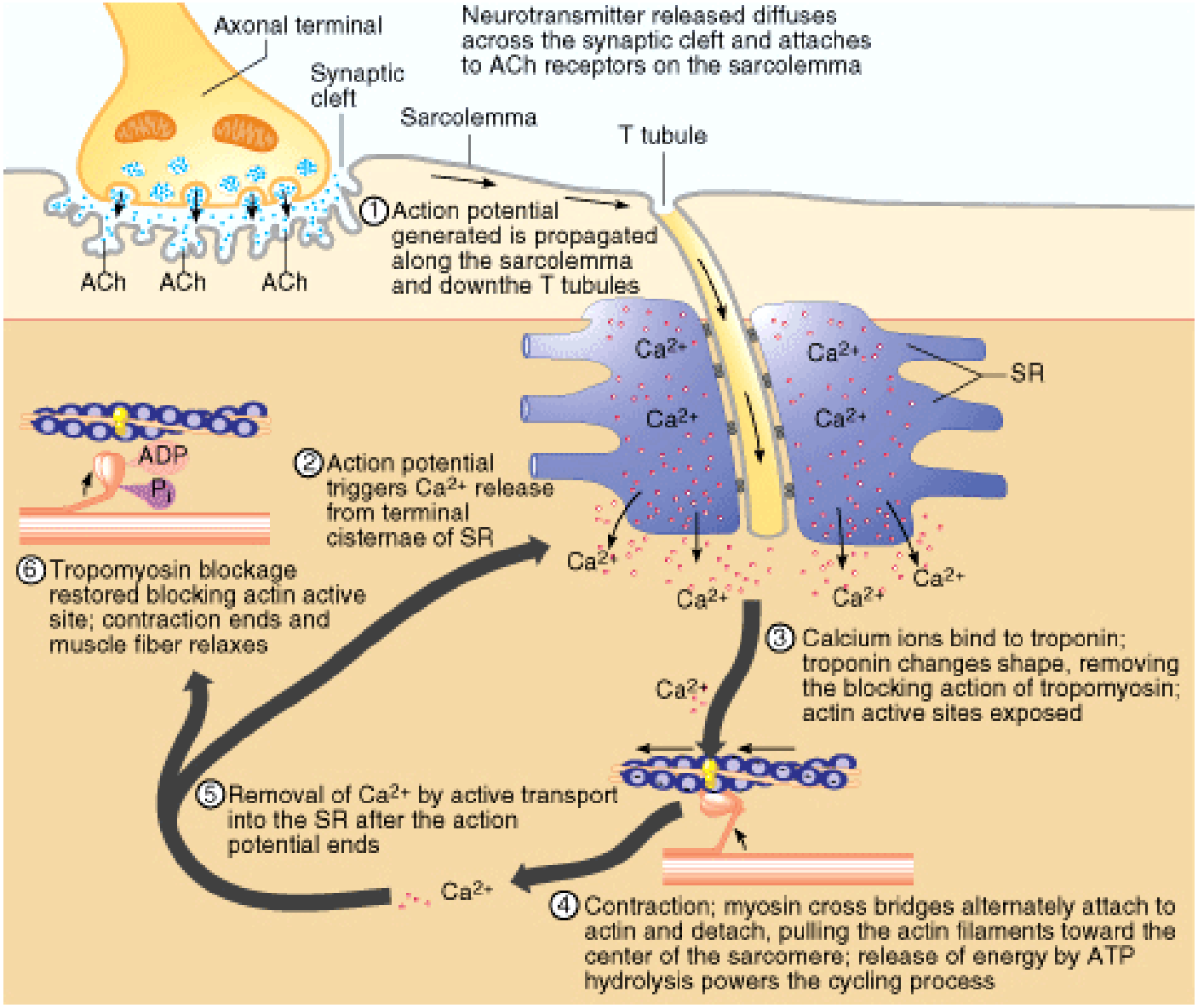
Accoppiamento eccitazione-contrazione



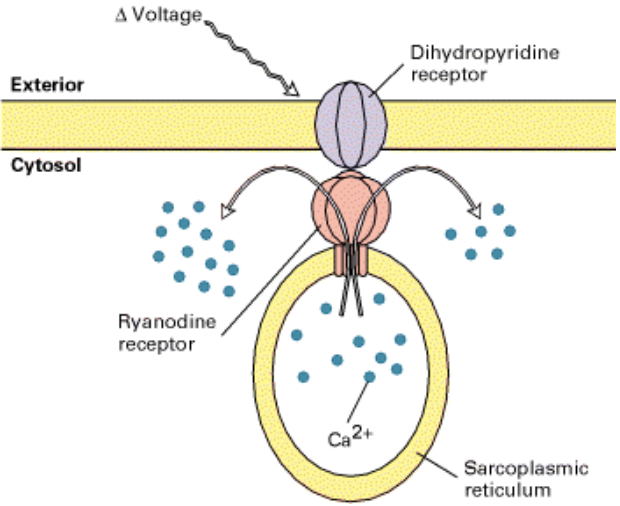


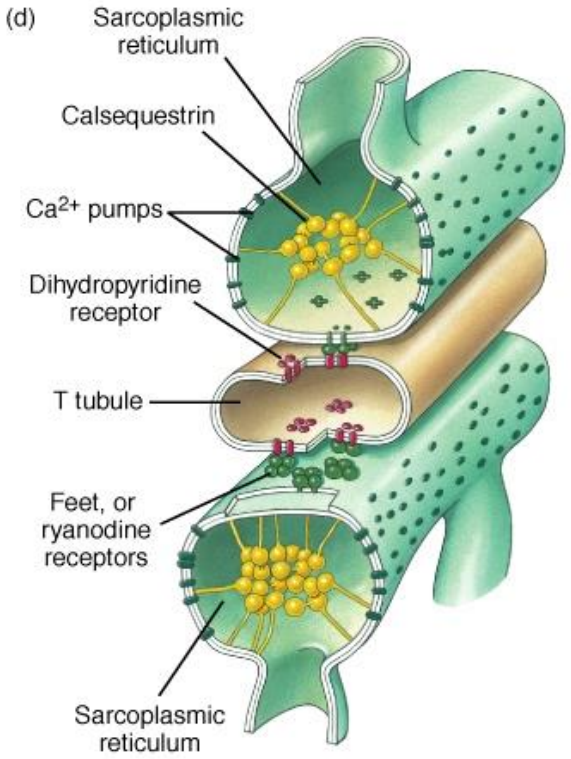
1. Il motoneurone somatico rilascia ACh a livello della giunzione neuromuscolare.
2. L'ingresso netto di Na^+ tramite i canali controllati dai recettori per l'ACh induce un potenziale d'azione.
3. Il potenziale d'azione nei tubuli T altera la conformazione del recettore DHP.
4. Il recettore DHP apre canali per il rilascio del Ca^{2+} nel reticolo sarcoplasmatico e il Ca^{2+} entra nel citoplasma.
5. Il Ca^{2+} si lega alla troponina, consentendo il legame forte fra actina e miosina.
6. Le teste della miosina generano il colpo di forza.
7. I filamenti di actina scorrono verso il centro del sarcomero.

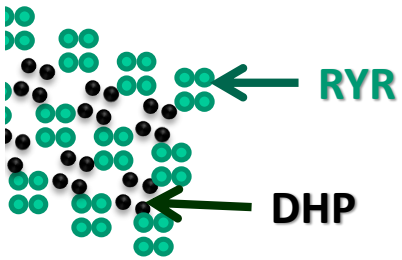
L'insieme degli eventi

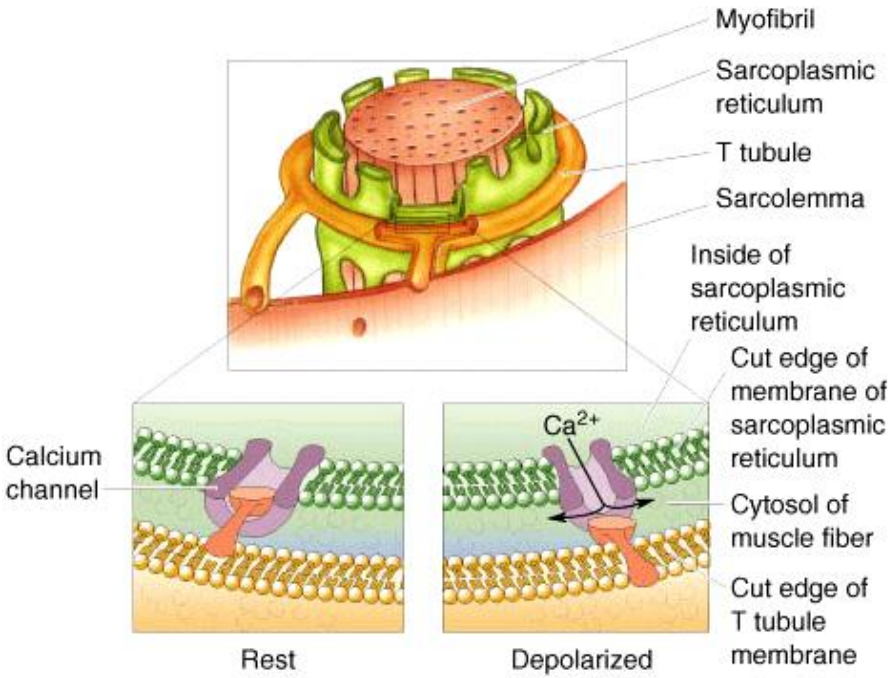


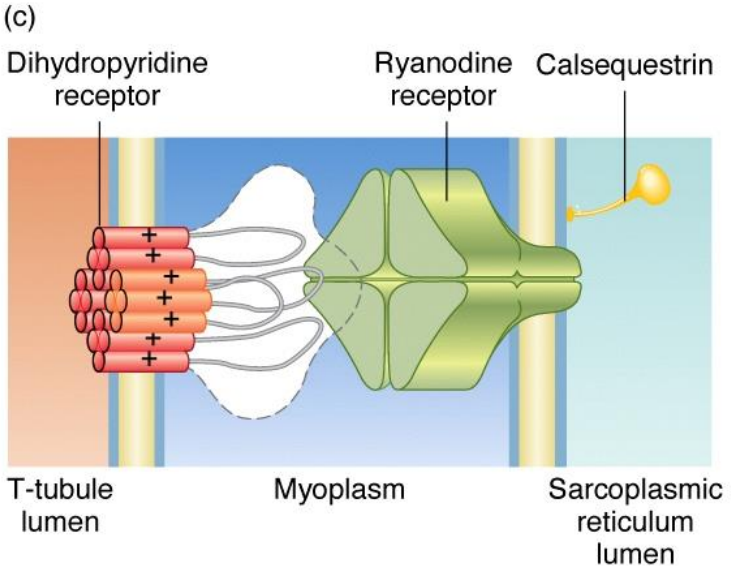
L'ingresso del calcio

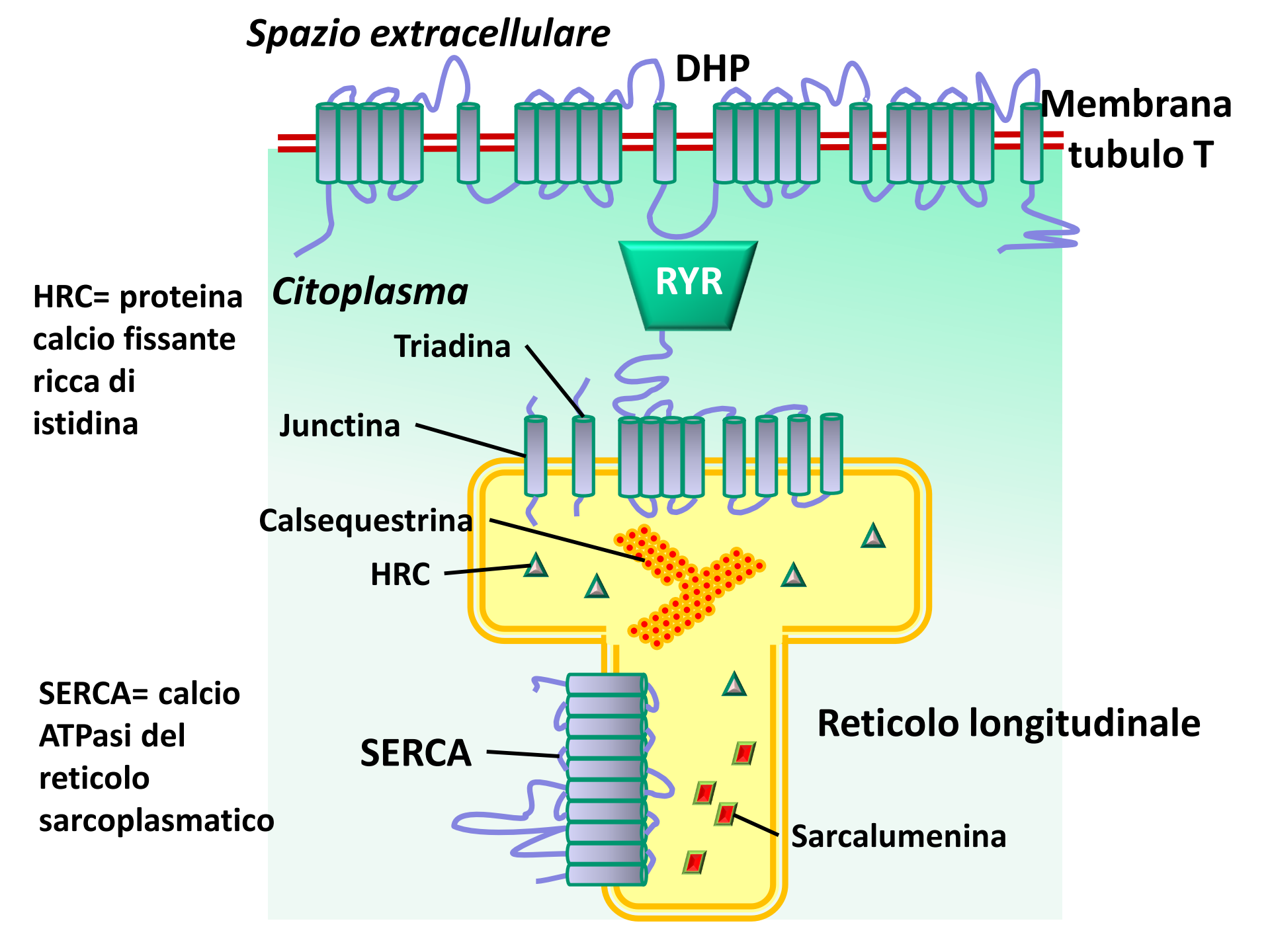








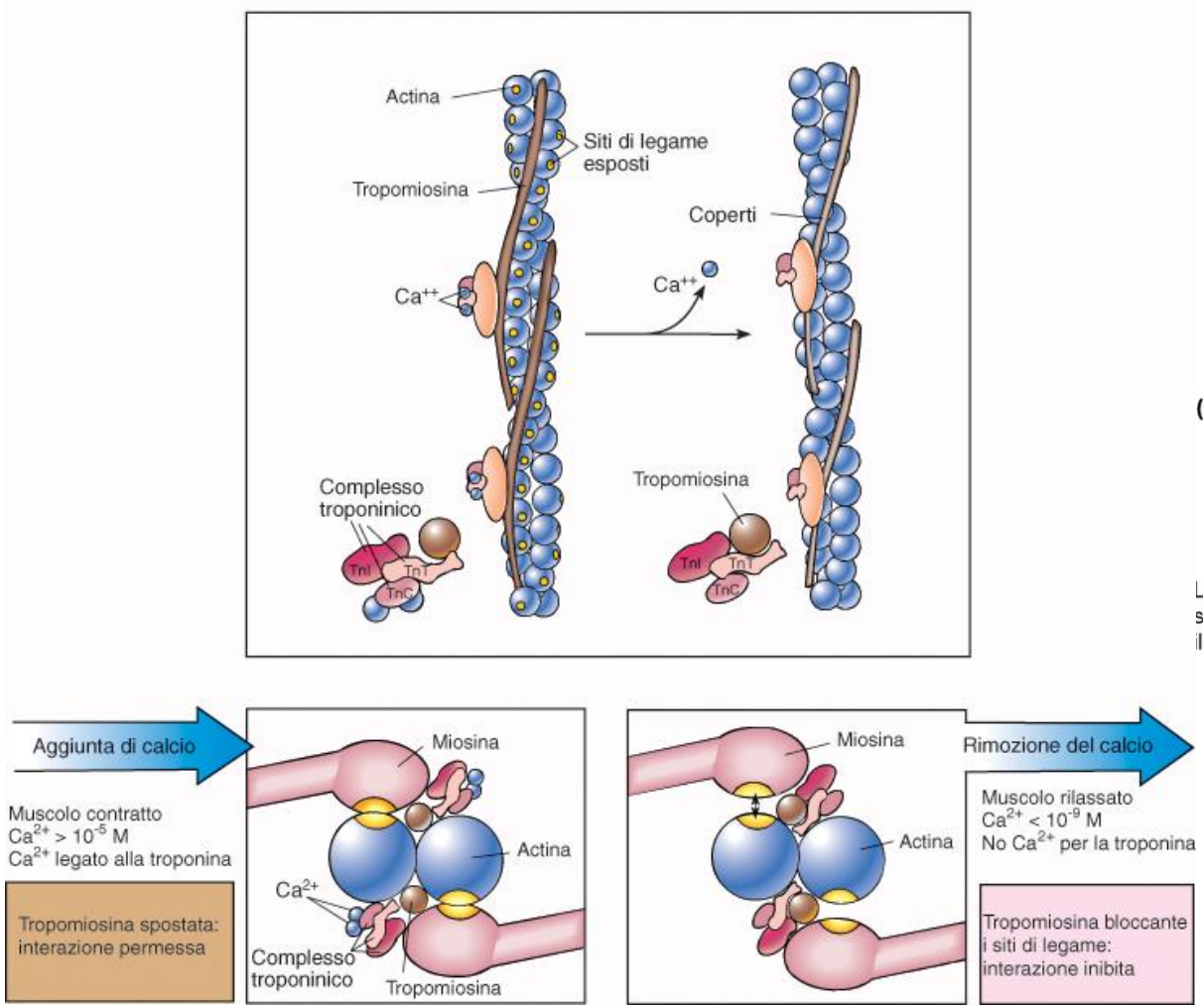


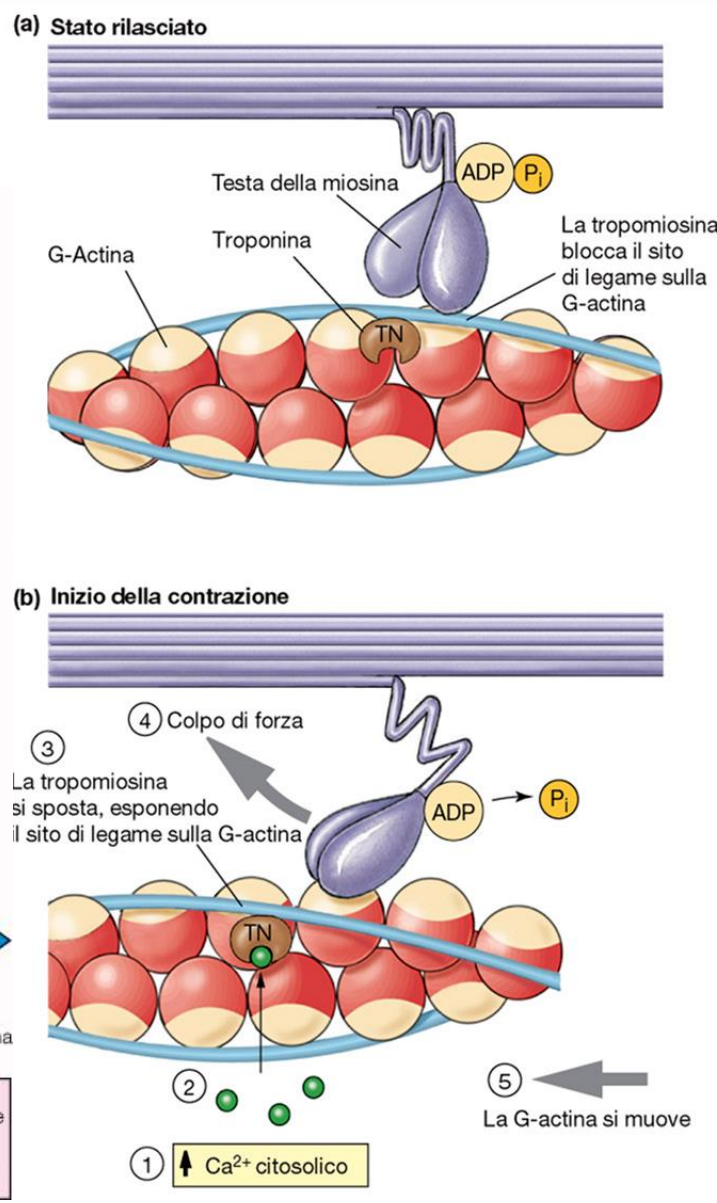


HRC= proteina calcio fissante ricca di istidina

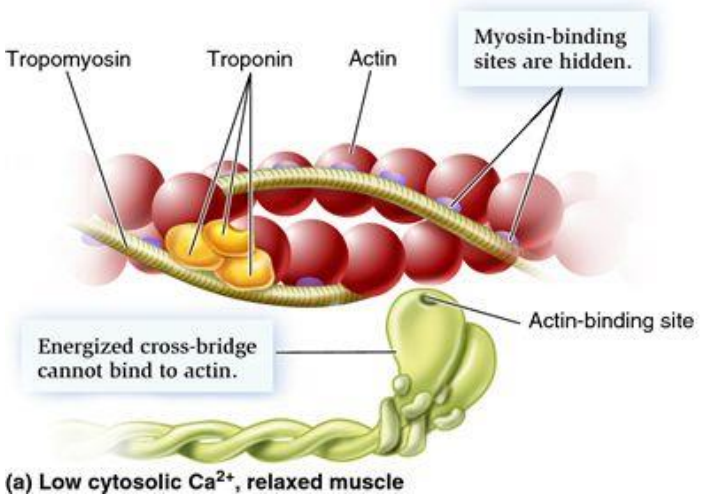
SERCA= calcio ATPasi del reticolo sarcoplasmatico

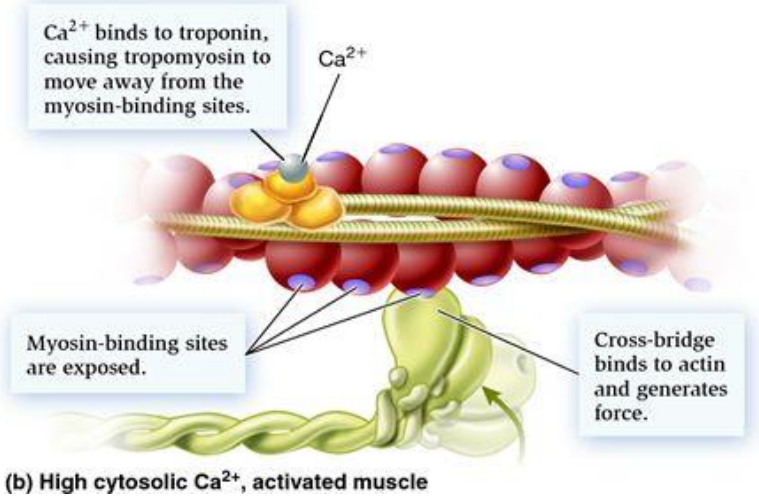
Troponina-tropomiosina

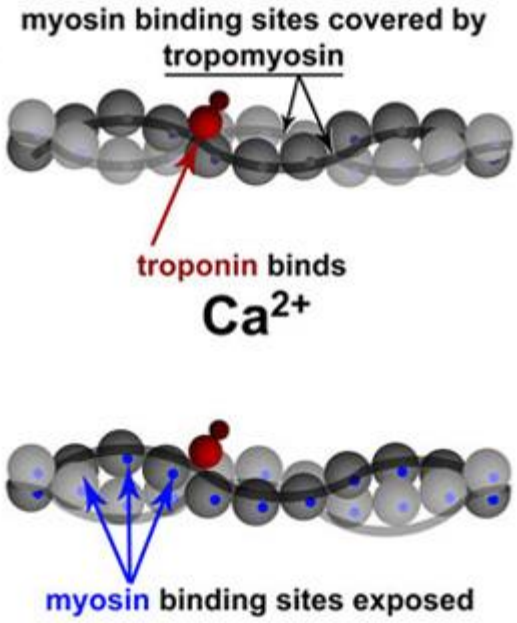


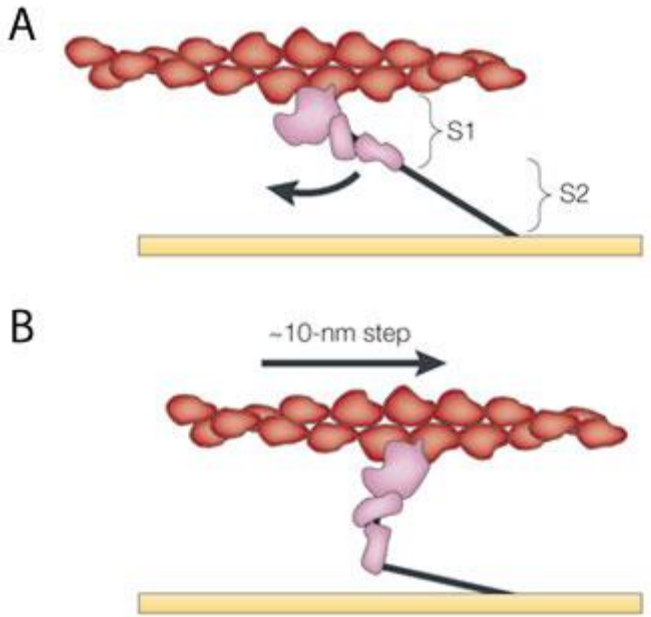


Interazione actina-miosina





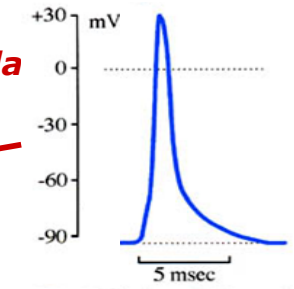




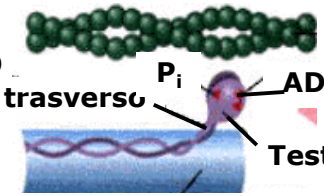
Nature Reviews | Molecular Cell Biology

Ciclo dei ponti trasversi

•*Ingresso di Ca^{++}*
•*Liberazione dell'inibizione da troponina-tropomiosina*



Arresto nel muscolo rilasciato



A+(M•ADP•P_i)
Alta affinità per l'actina

Aggancio al filamento di actina

A-M•ADP•P_i

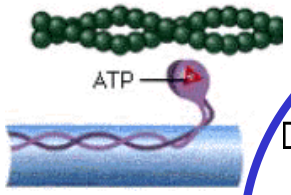
ADP **P_i**

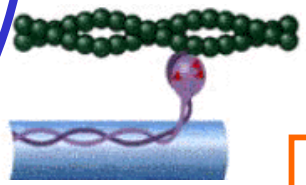
A-M
Alta affinità per ATP

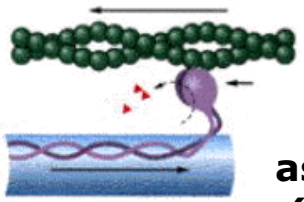
ATP

A-M•ATP
Bassa affinità per l'actina

Dissociazione ed idrolisi parziale dell'ATP

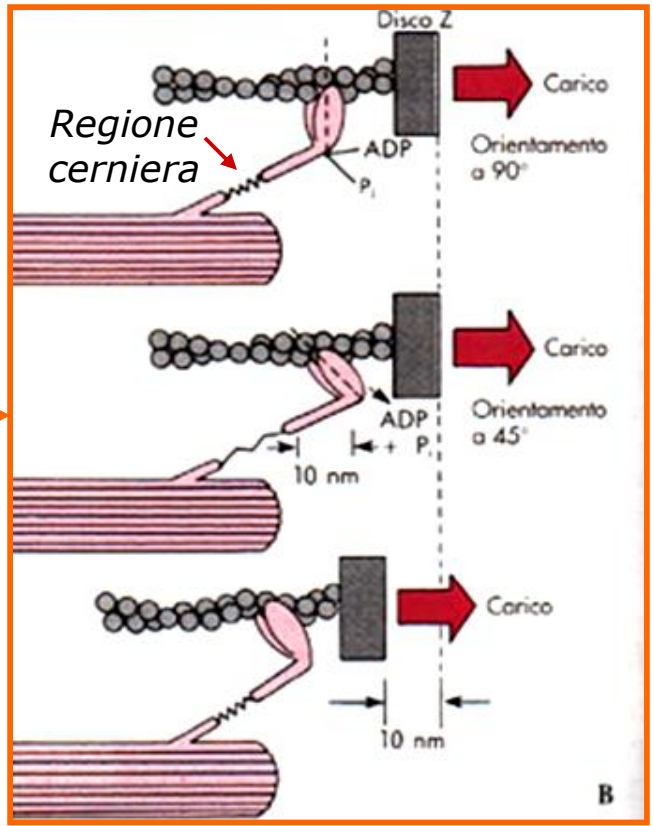




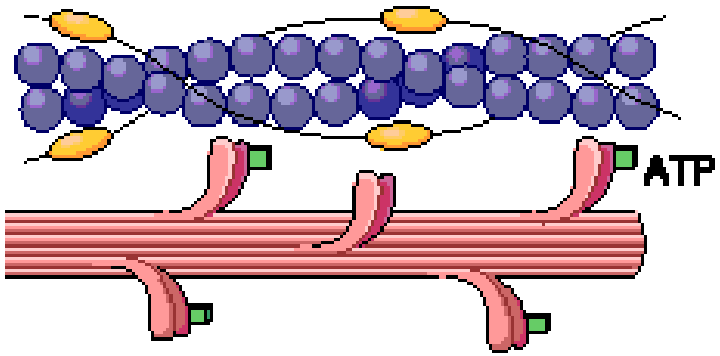


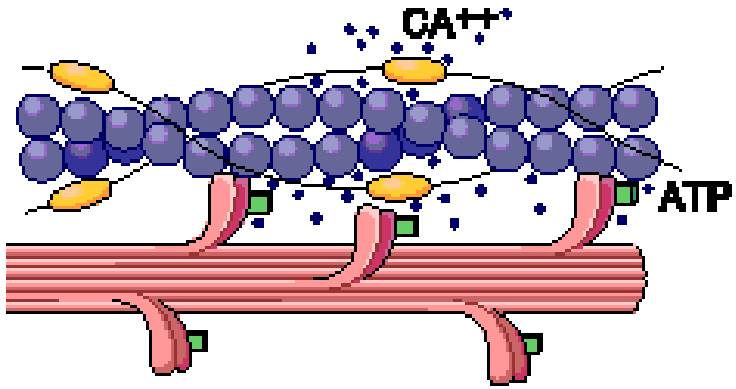
Arresto in assenza di ATP (*rigor mortis*)

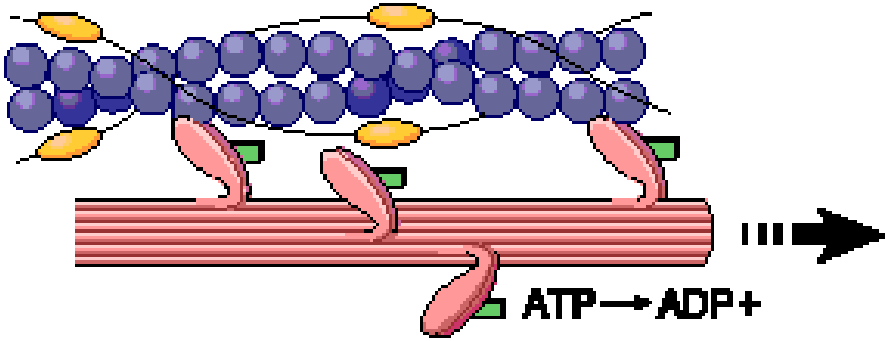
Modificazione conformazionale

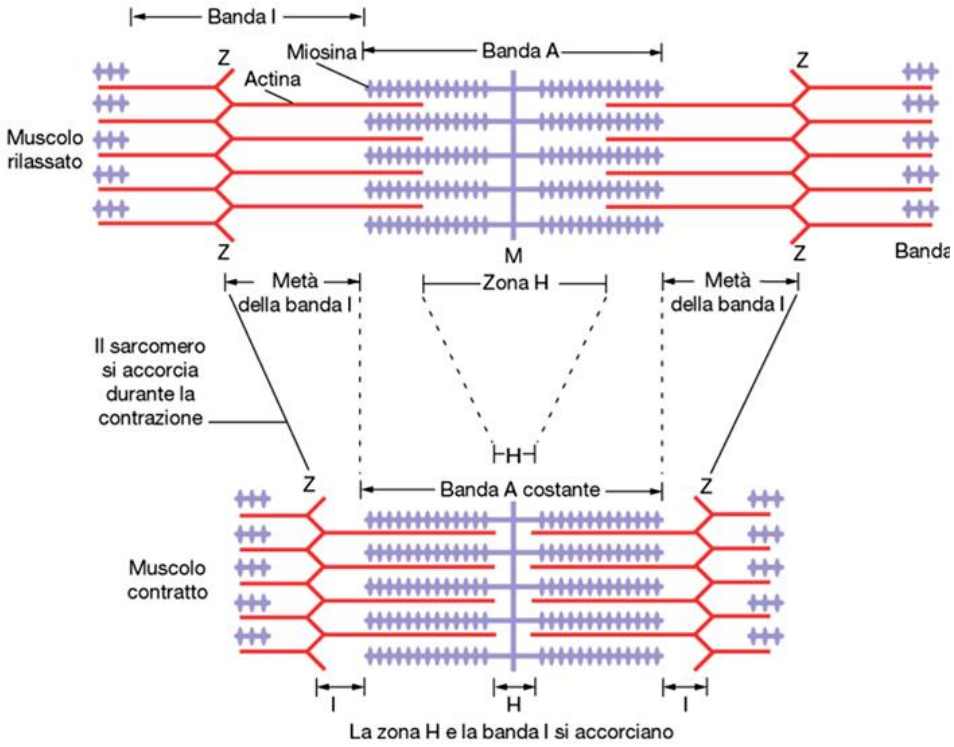


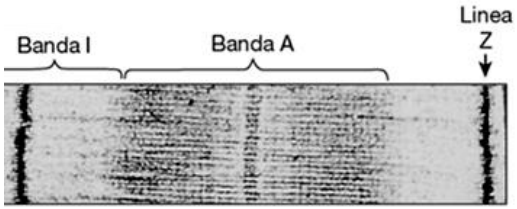
Scorrimento dei miofilamenti

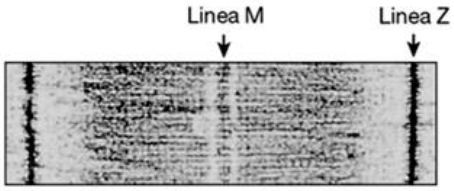




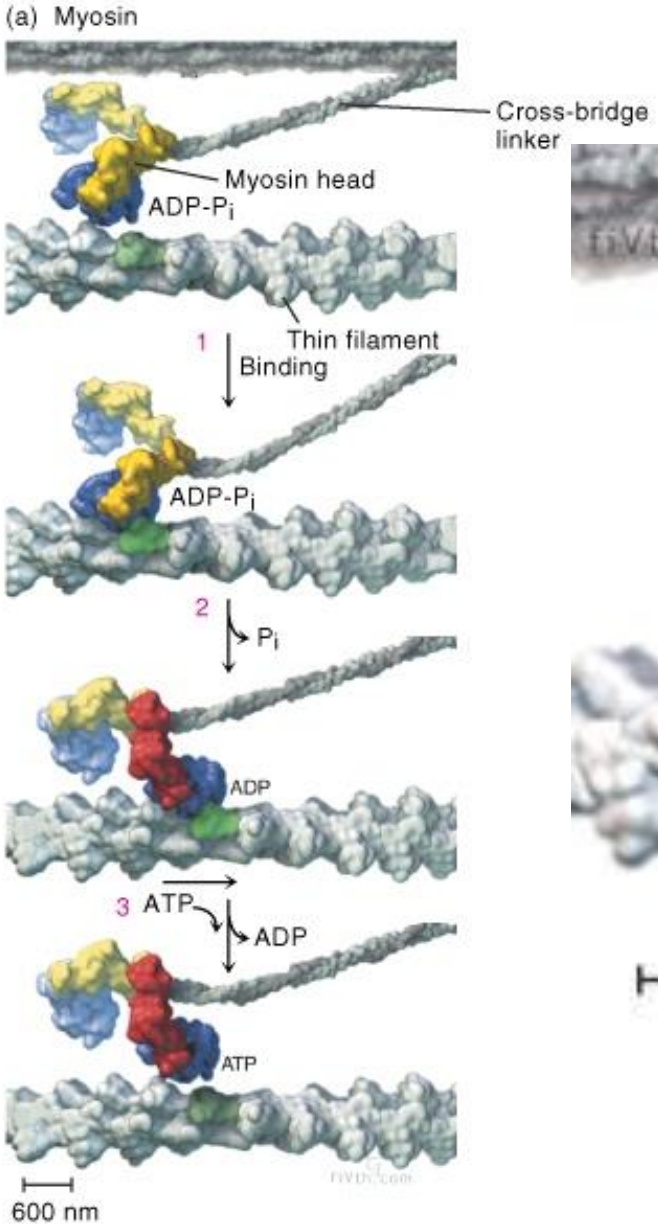


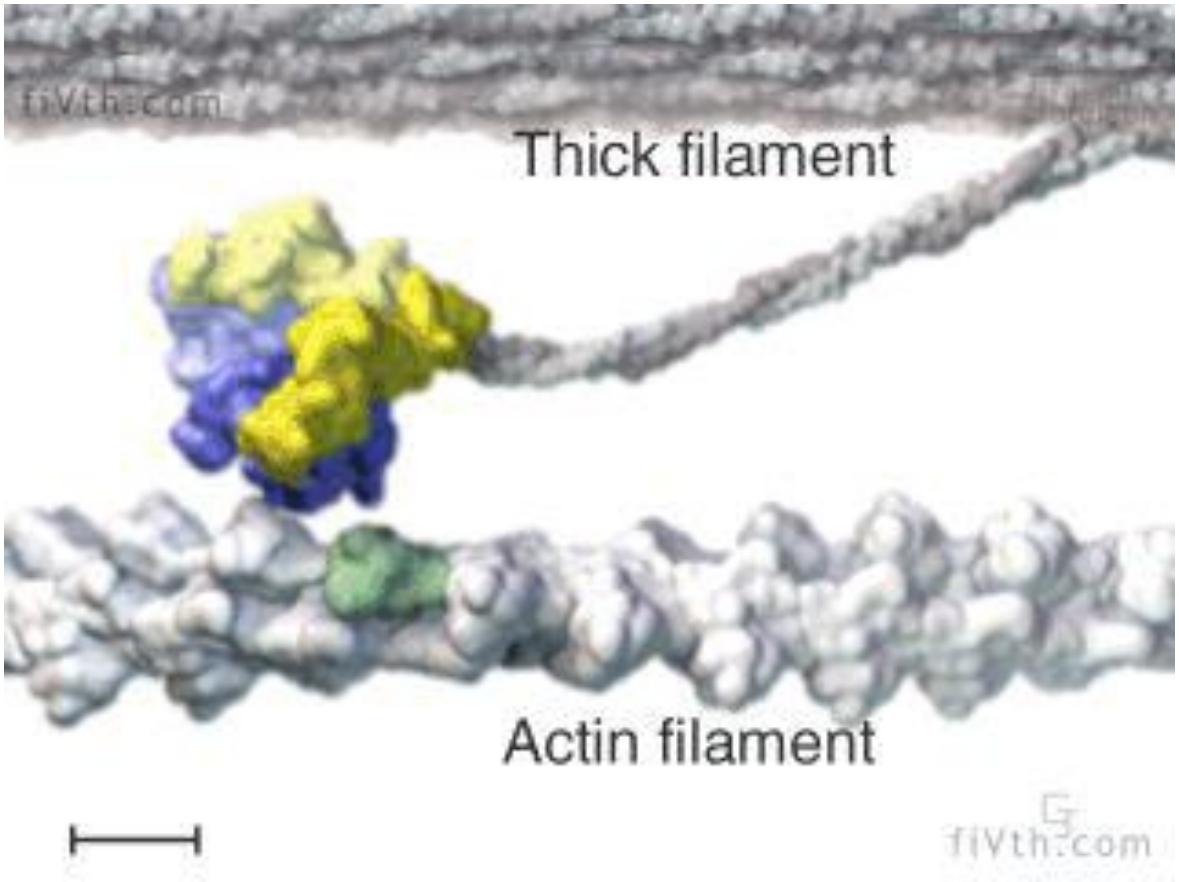




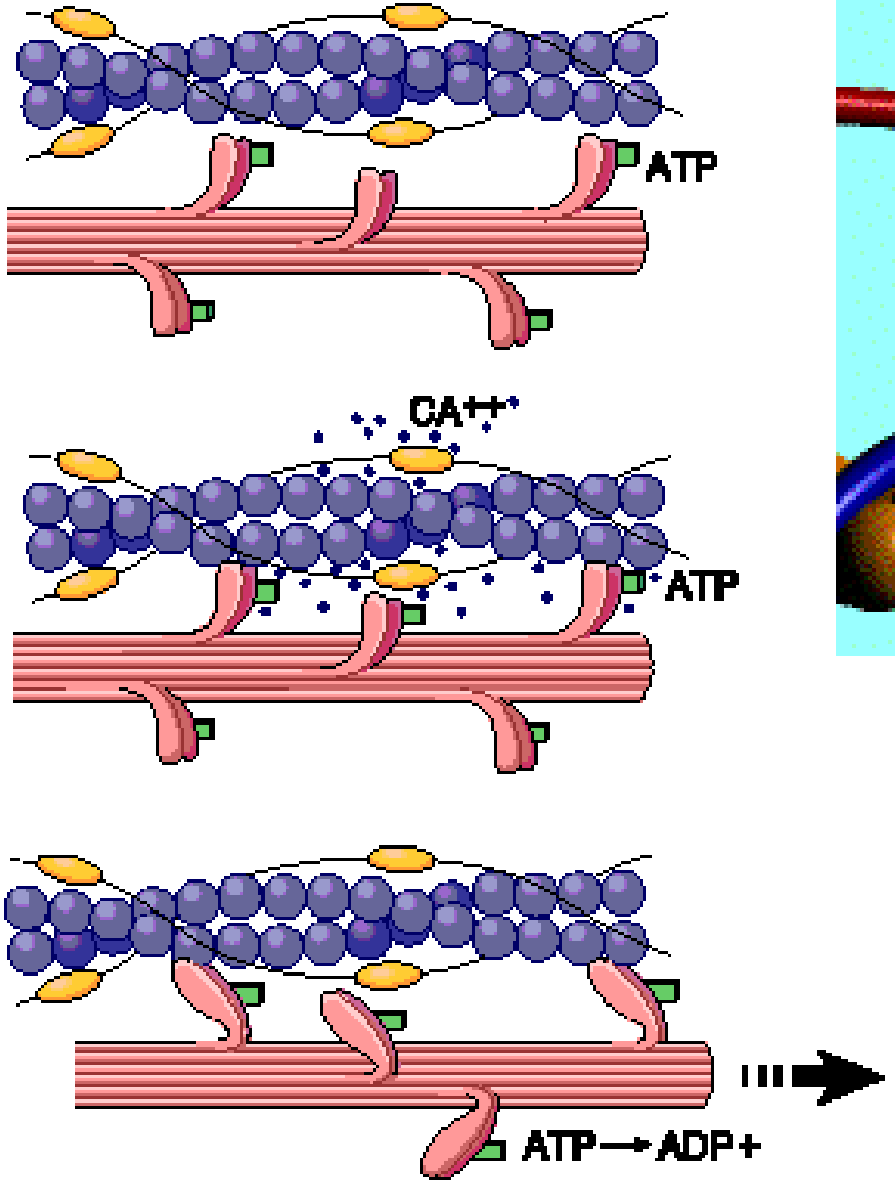


Il ciclo dei ponti trasversi

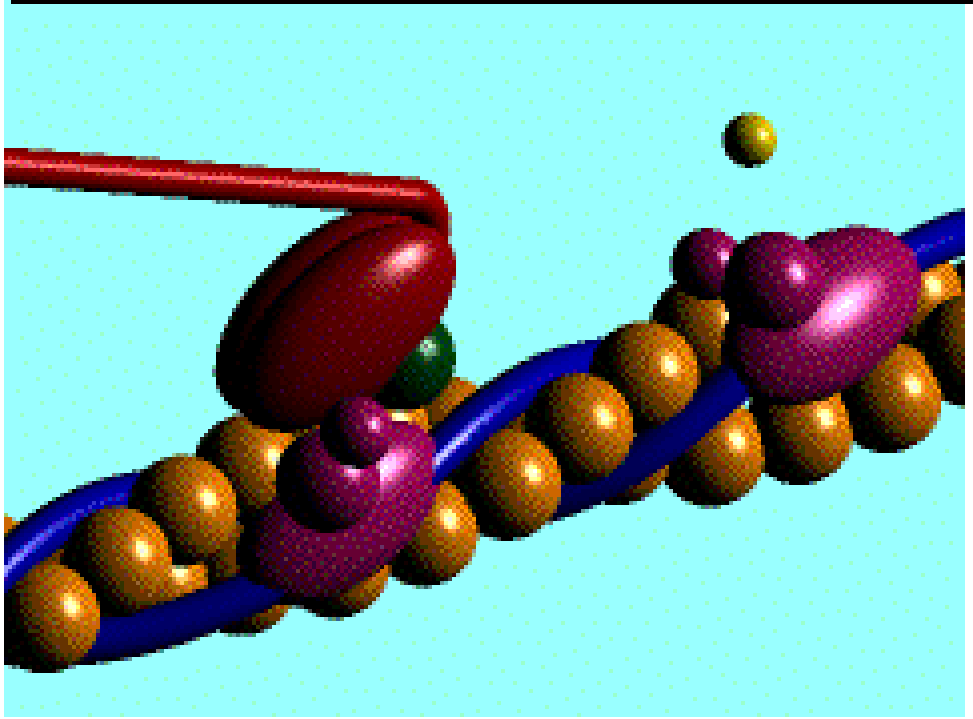


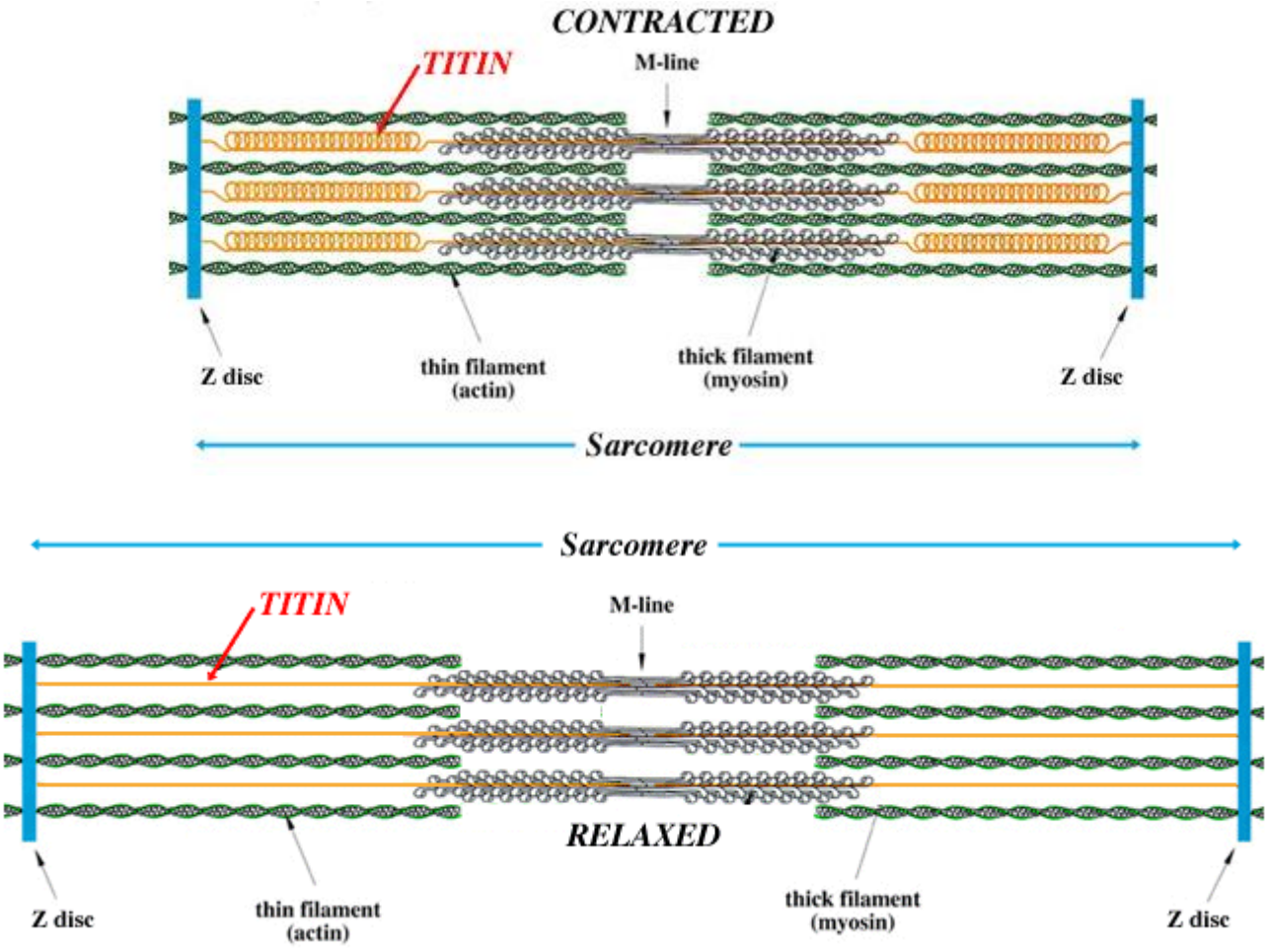


"Walk-along" Mechanism for contraction of the muscle

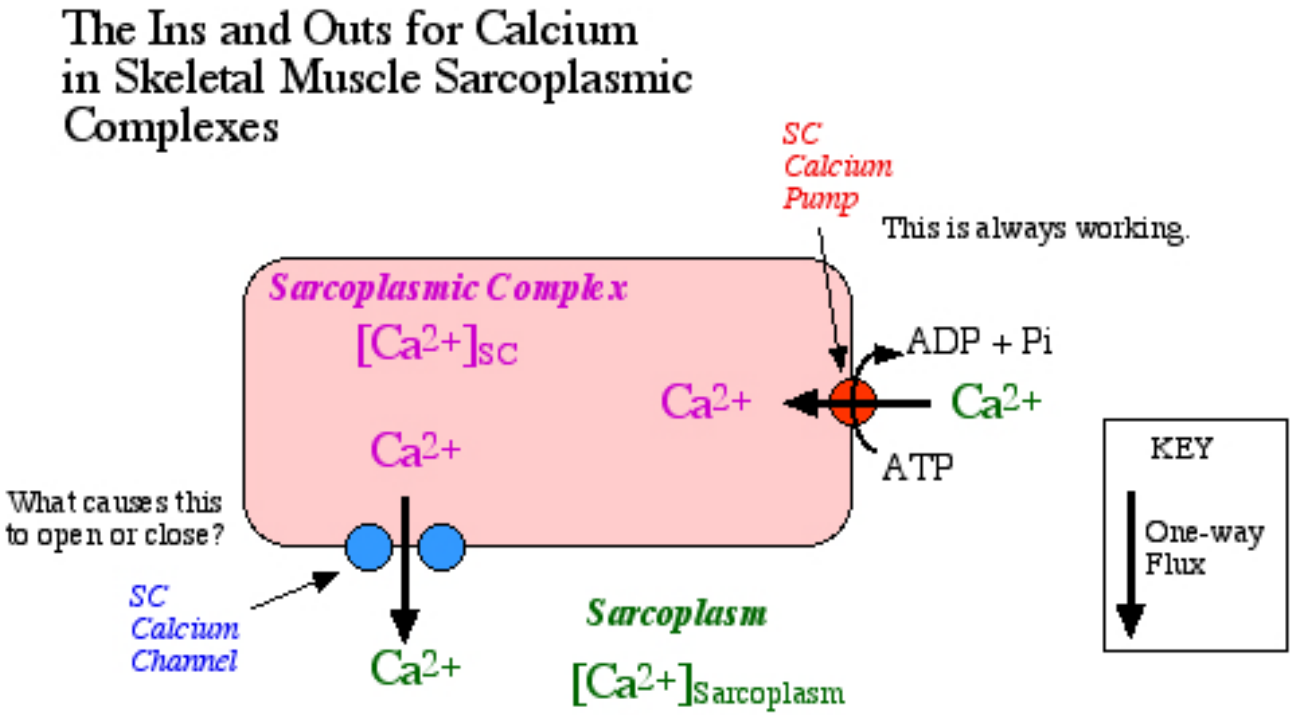


www.colorado.edu/.../IPHY3430-200/08muscle.html




CONTRACTED
TITIN
M-line
Z disc
thin filament
(actin)
thick filament
(myosin)
Z disc
Sarcomere
Sarcomere
TITIN
M-line
RELAXED
Z disc
thin filament
(actin)
thick filament
(myosin)
Z disc

Come si blocca la contrazione?

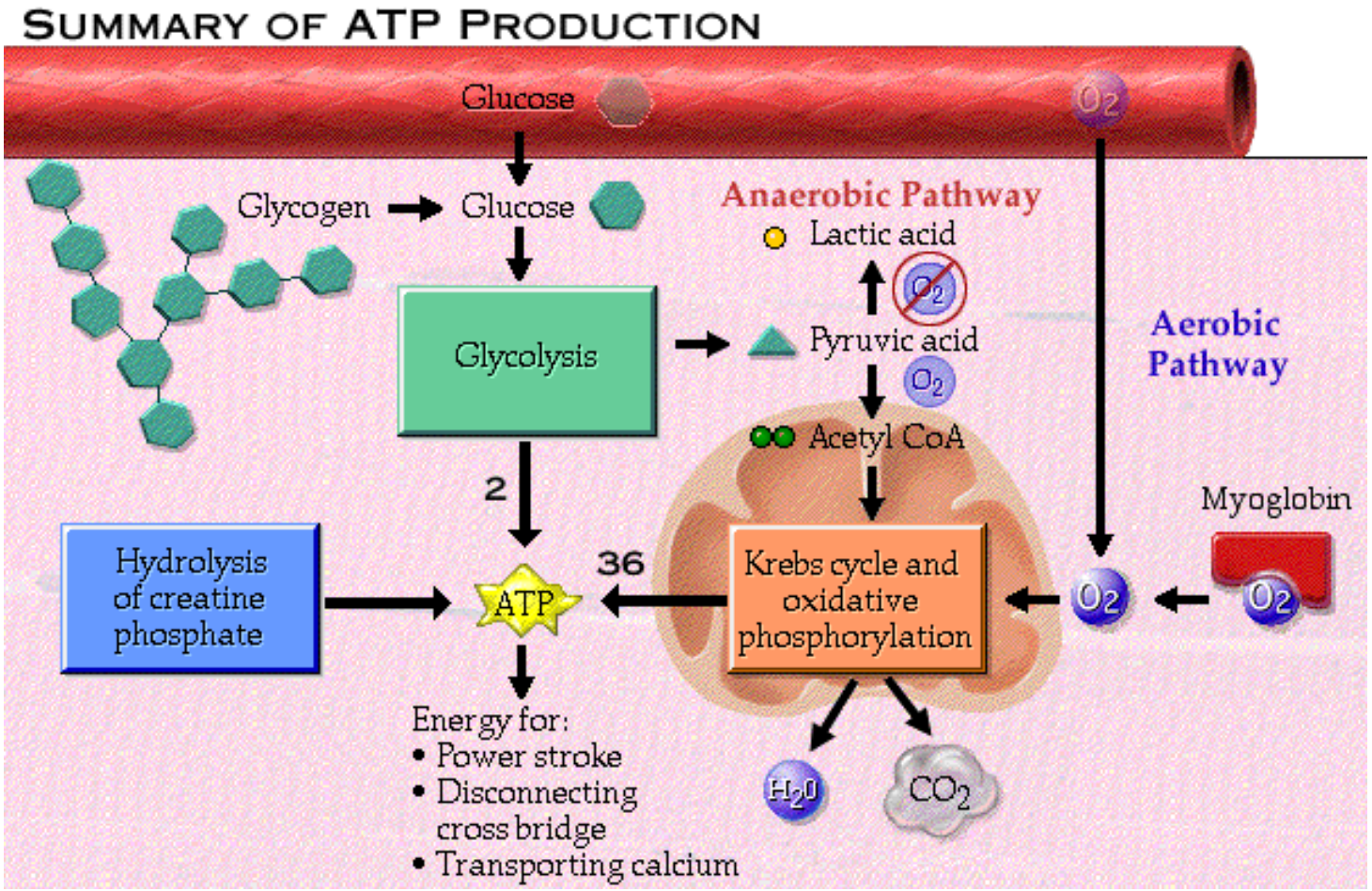


$[Ca^{2+}]_{Sarcoplasm}$ is determined by the values of the calcium movement (flux) outward versus inward.

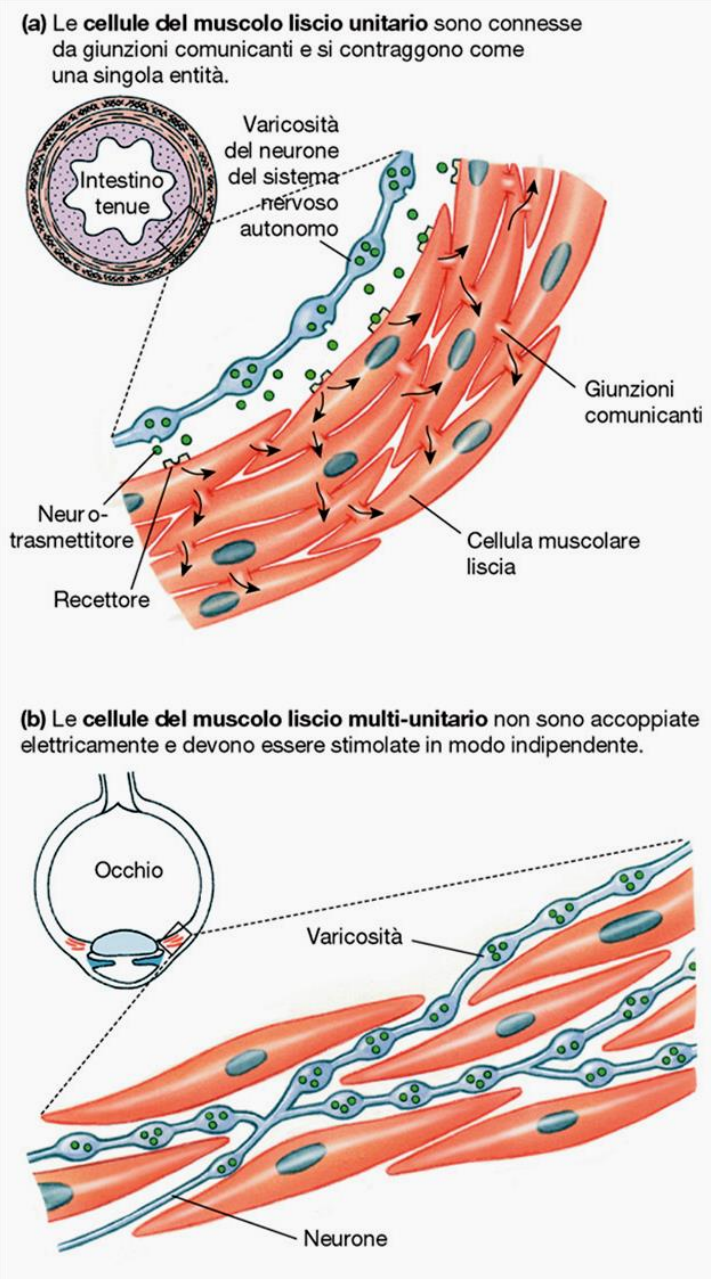
If $[Ca^{2+}]_{Sarcoplasm} > 10^{-6}$ M, then contraction occurs.

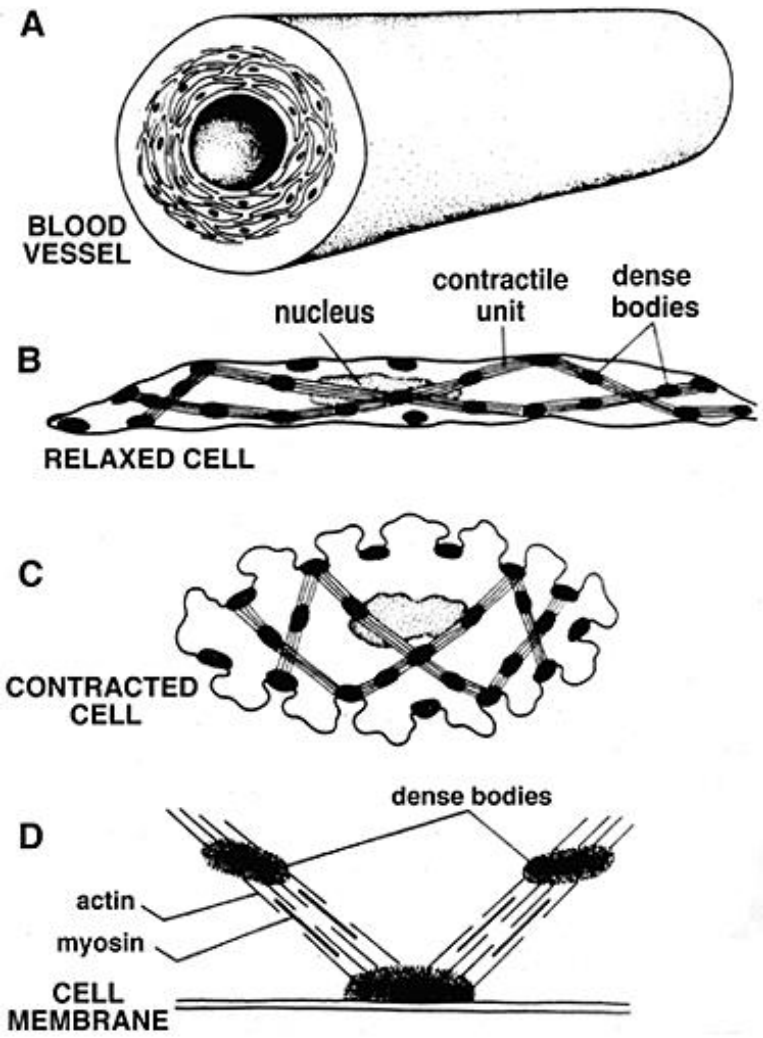
If $[Ca^{2+}]_{Sarcoplasm} < 10^{-7}$ M, then contraction stops.

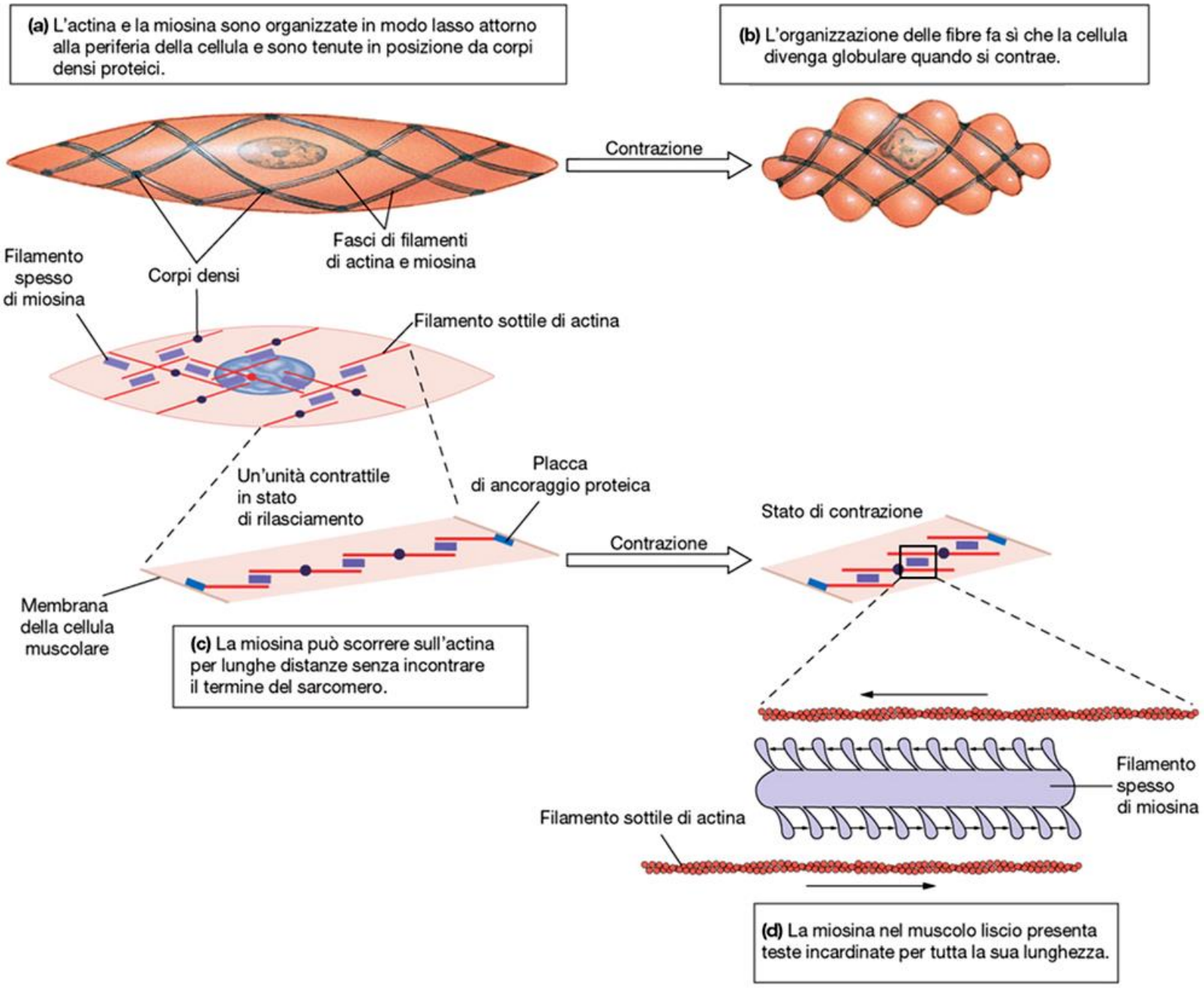
Energetica della contrazione



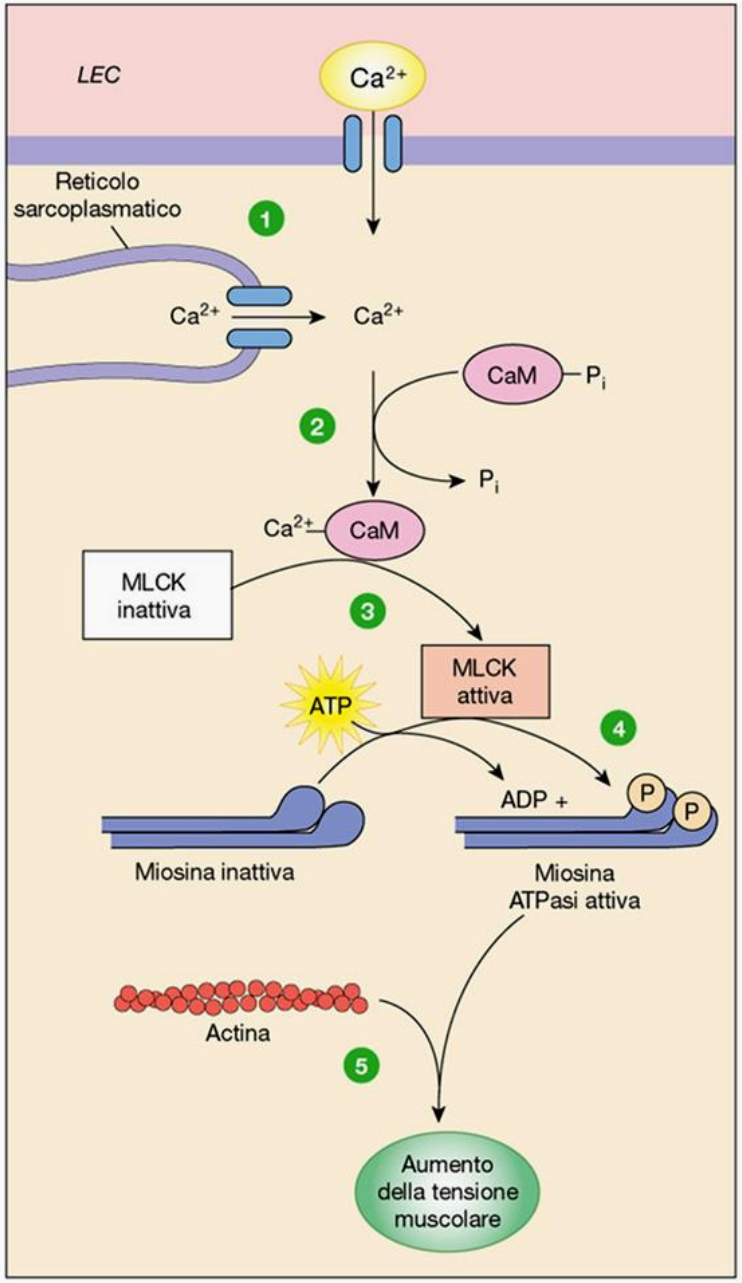
Muscolo liscio





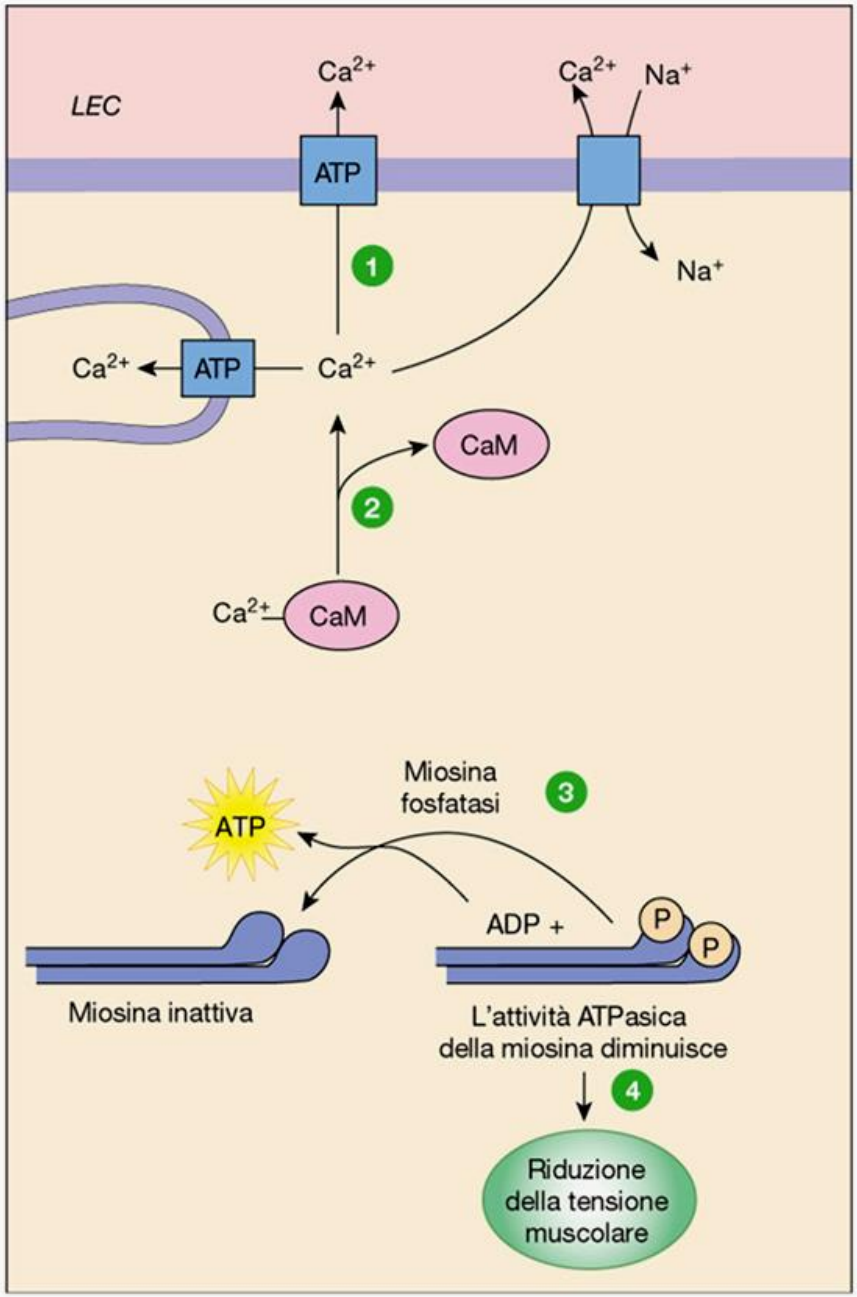

(a) L'actina e la miosina sono organizzate in modo lasso attorno alla periferia della cellula e sono tenute in posizione da corpi densi proteici.
(b) L'organizzazione delle fibre fa sì che la cellula divenga globulare quando si contrae.
Contrazione
Fasci di filamenti di actina e miosina
Filamento spesso di miosina
Corpi densi
Filamento sottile di actina
Un'unità contrattile in stato di rilasciamento
Placca di ancoraggio proteica
Membrana della cellula muscolare
Contrazione
Stato di contrazione
(c) La miosina può scorrere sull'actina per lunghe distanze senza incontrare il termine del sarcomero.
Filamento spesso di miosina
Filamento sottile di actina
(d) La miosina nel muscolo liscio presenta teste incardinate per tutta la sua lunghezza.

Contrazione del muscolo liscio



1. La concentrazione intracellulare di Ca^{2+} aumenta quando il Ca^{2+} entra nella cellula o viene rilasciato dal reticolo sarcoplasmatico.
2. Il Ca^{2+} si lega alla calmodulina (CaM).
3. Il complesso Ca^{2+}-calmodulina attiva la chinasi della catena leggera della miosina (MLCK).
4. La MLCK fosforila le catene leggere della miosina, aumentando l'attività ATPasica della miosina.
5. I ponti trasversali attivati della miosina scorrono sull'actina e generano la tensione muscolare.

Rilassamento del muscolo liscio



1. Il Ca^{2+} libero nel citosol decresce a opera del trasporto attivo dello ione nel liquido extracellulare o nel reticolo sarcoplasmatico.

2. Il Ca^{2+} è rilasciato dalla calmodulina (CaM).

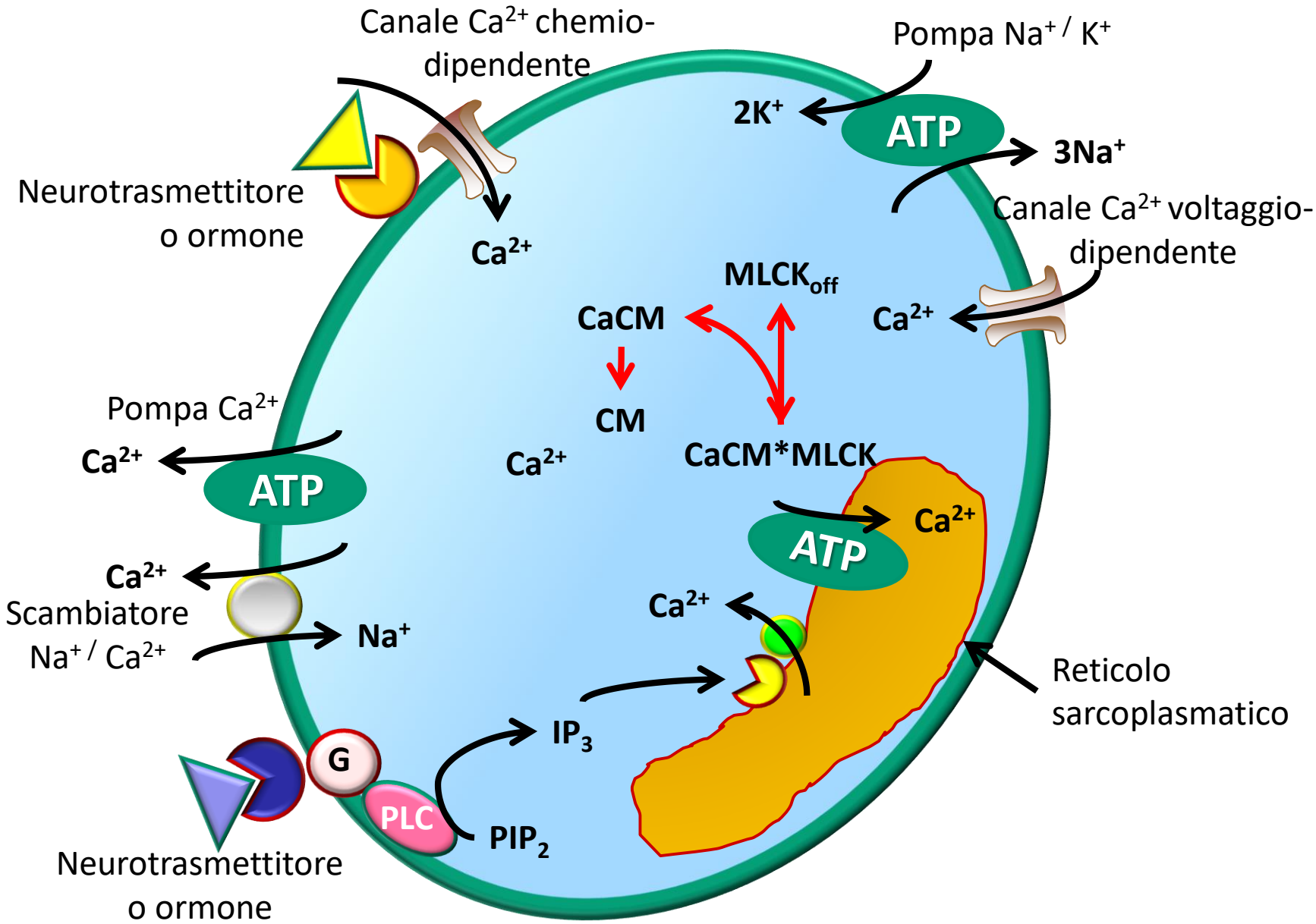
3. La miosina fosfatasi rimuove il fosfato dalla miosina, riducendone l'attività ATPasica.

4. La riduzione dell'attività ATPasica della miosina determina la diminuzione della tensione muscolare.

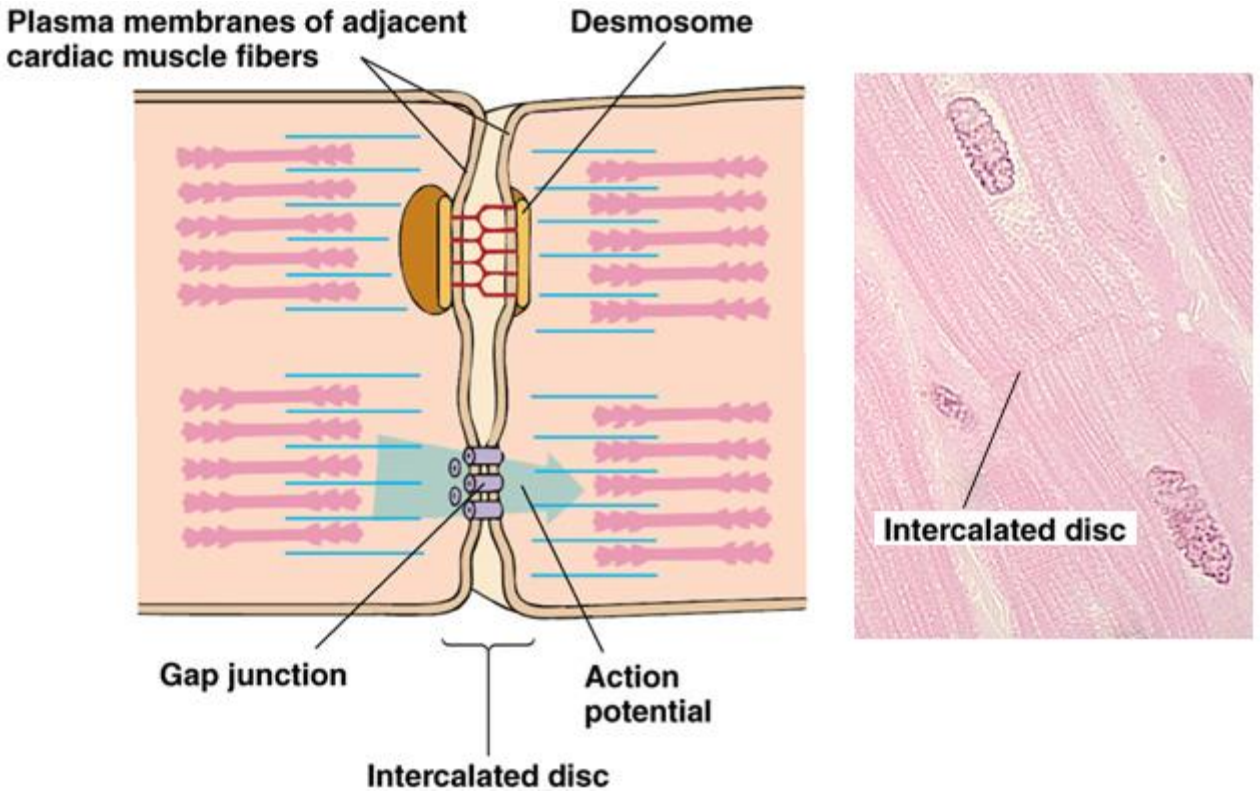
Modulazione dell'attività del muscolo liscio

Agonista	Risposta	Recettore
Noradrenalina e adrenalina da stimolazione simpatica	Contrazione (prevalente) Rilassamento	α1AR β2AR
Acetilcolina da stimolazione parasimpatica	Contrazione (diretta) Rilassamento (indiretto mediato da NO. Es: coronarie)	Recettore muscarinico su SMC Recettore muscarinico su EC
Angiotensina	Contrazione	Recettore Angiotensina
Peptidi Natriuretici	Rilassamento	Recettore Peptidi Natriuretici
Endotelina	Contrazione	Recettore Endotelina
Adenosina	Rilassamento	Recettore Adenosina
Vasopressina	Contrazione	Recettore Vasopressina

Controllo della concentrazione di calcio mioplasmatica

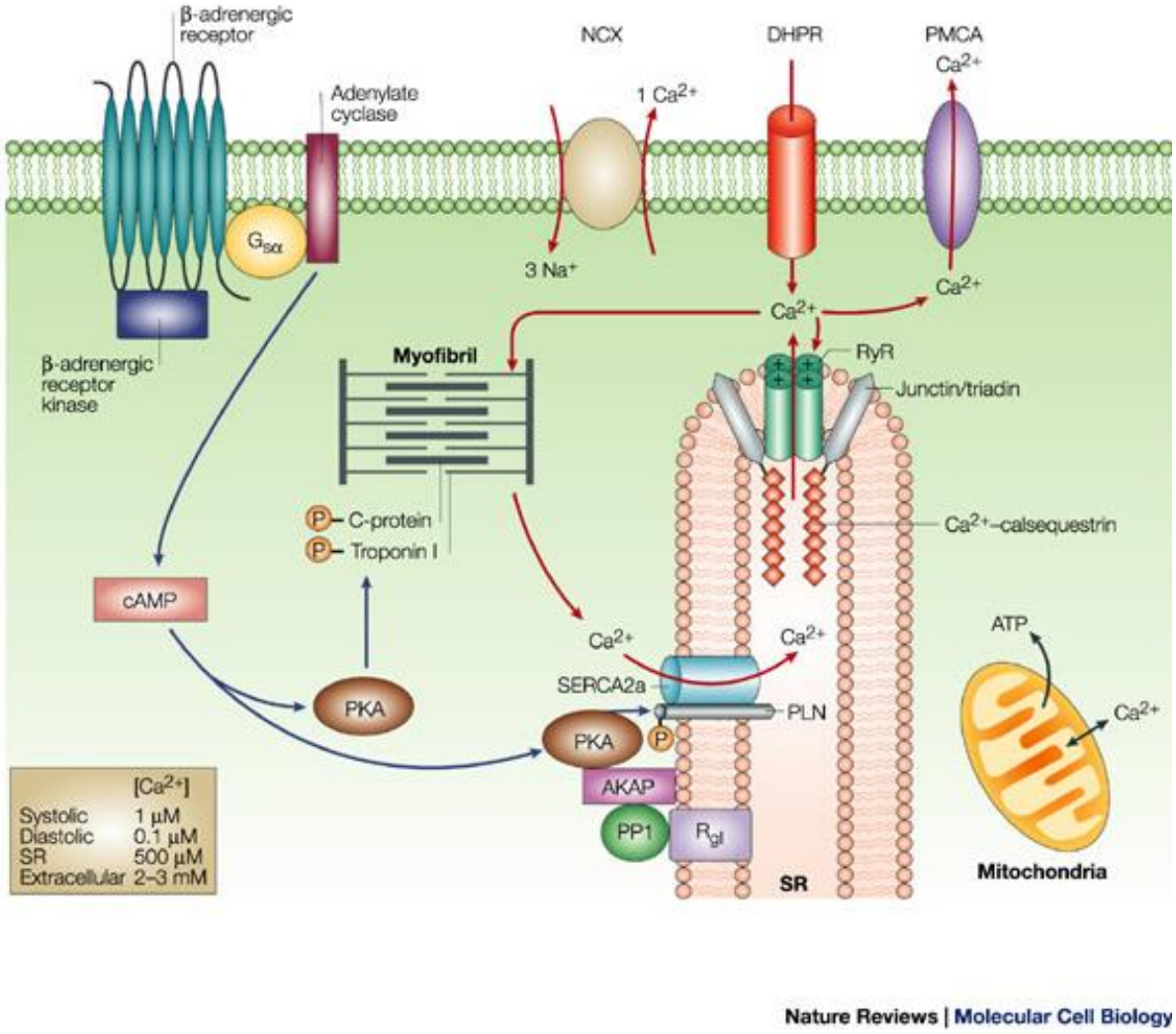


Il muscolo cardiaco

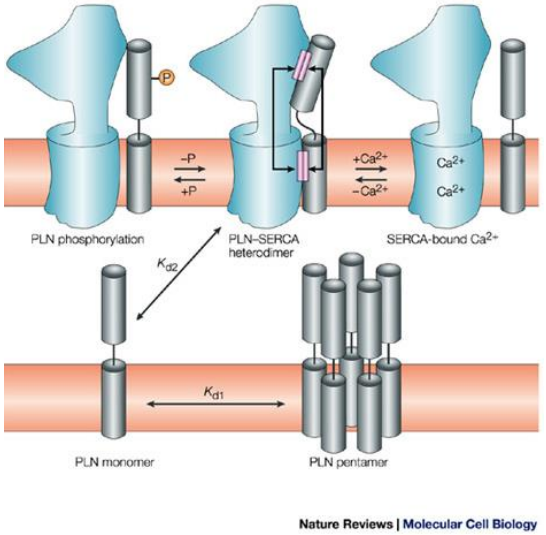


Il ciclo del calcio nel muscolo cardiaco

La concentrazione del calcio extracellulare controlla l'entità della contrazione

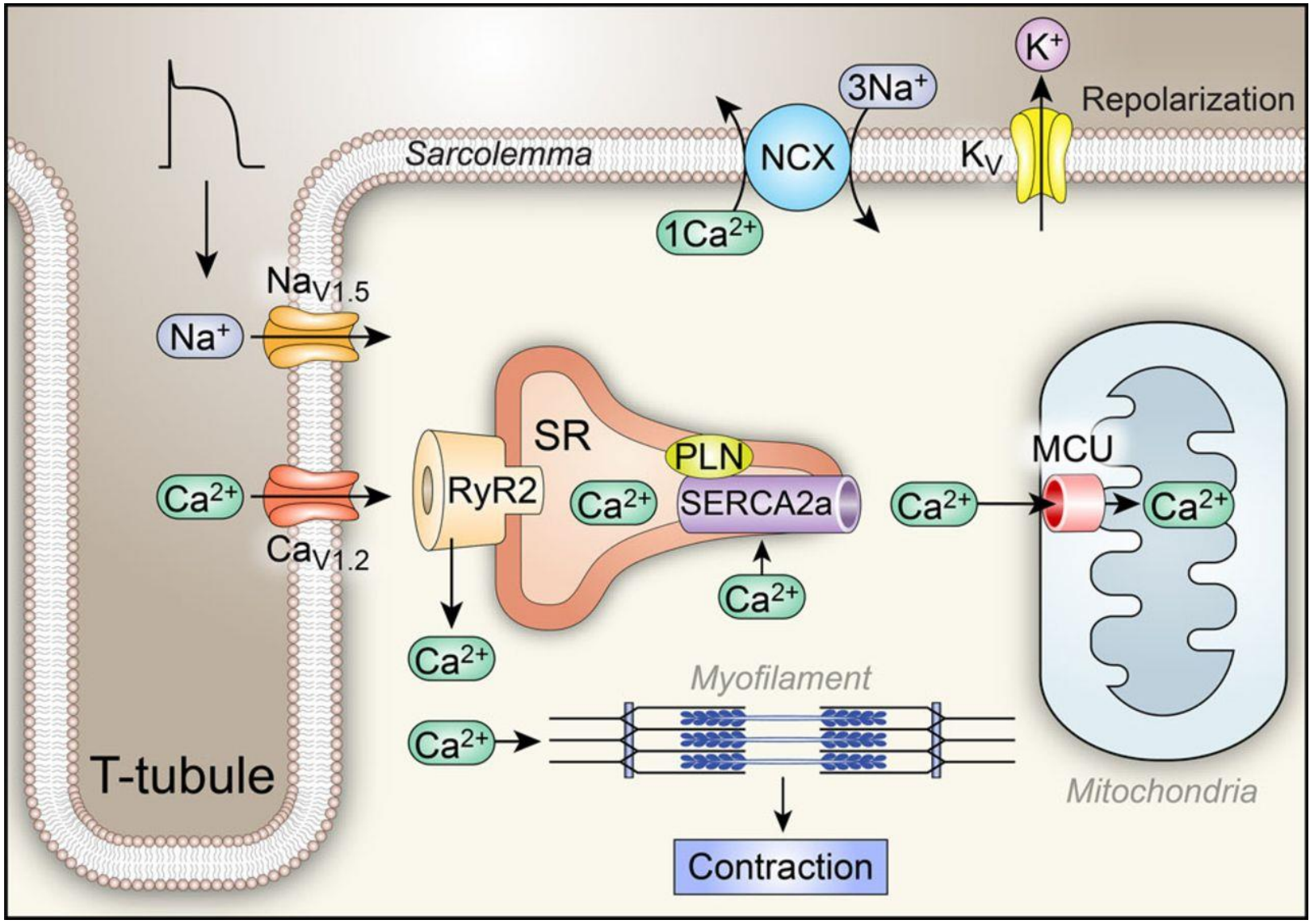


Meccanismo d'azione del fosfolambano



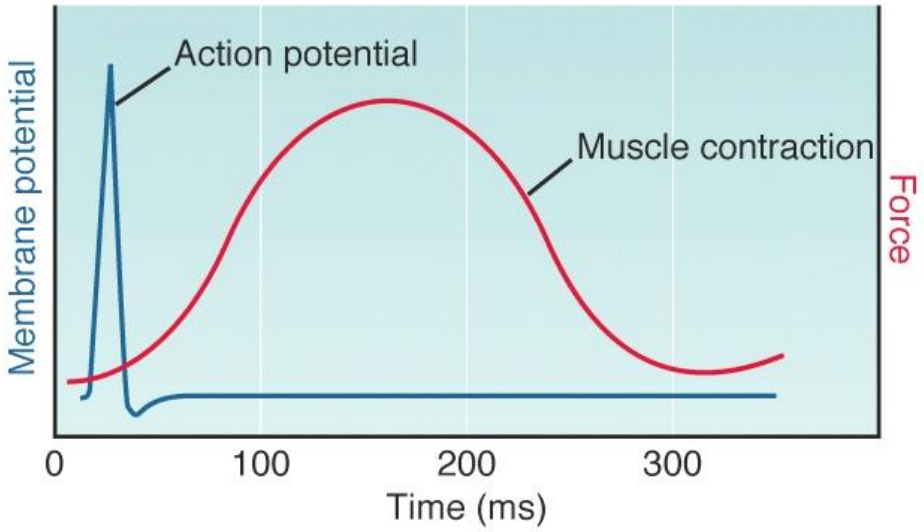
Il fosfolambano defosforilato inibisce le SERCA2a.

Quando è fosforilato dalla PKA o dalla CaMkII il fosfolambano si dissocia dalle SERCA2a e queste pompano calcio nel reticolo.

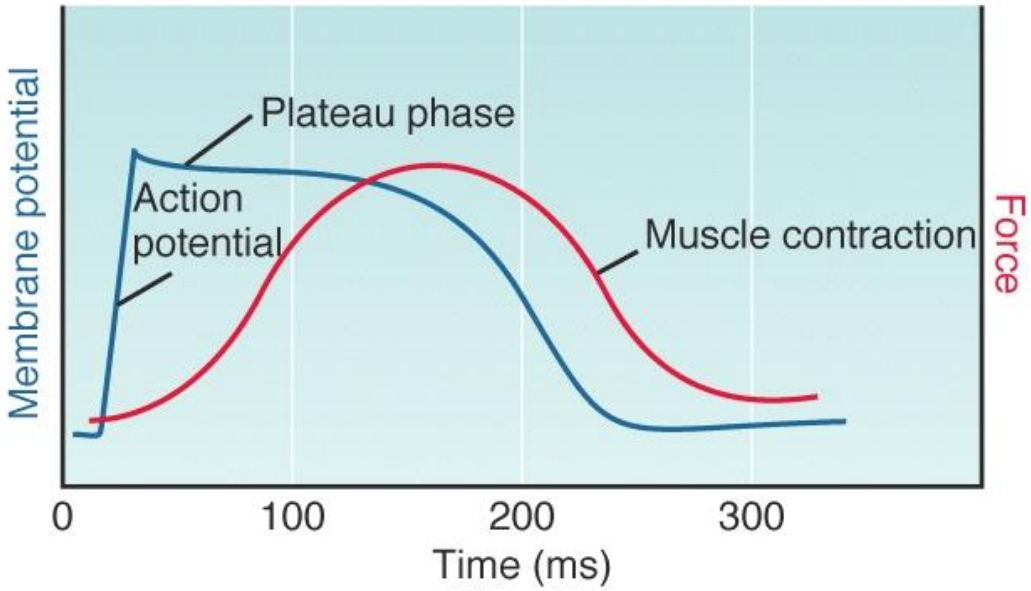

K+
Repolarization
3Na+
NCX
Sarcolemma
KV
1Ca2+
NaV1.5
Na+
SR
PLN
MCU
Ca2+
RyR2
Ca2+
SERCA2a
Ca2+
Ca2+
CaV1.2
Ca2+
Ca2+
Myofilament
T-tubule
Mitochondria
Contraction

Relazione potenziale d'azione-contrazione

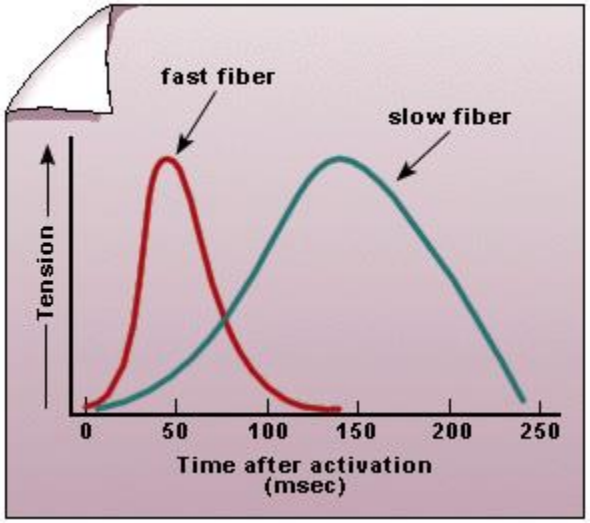
Muscolo scheletrico



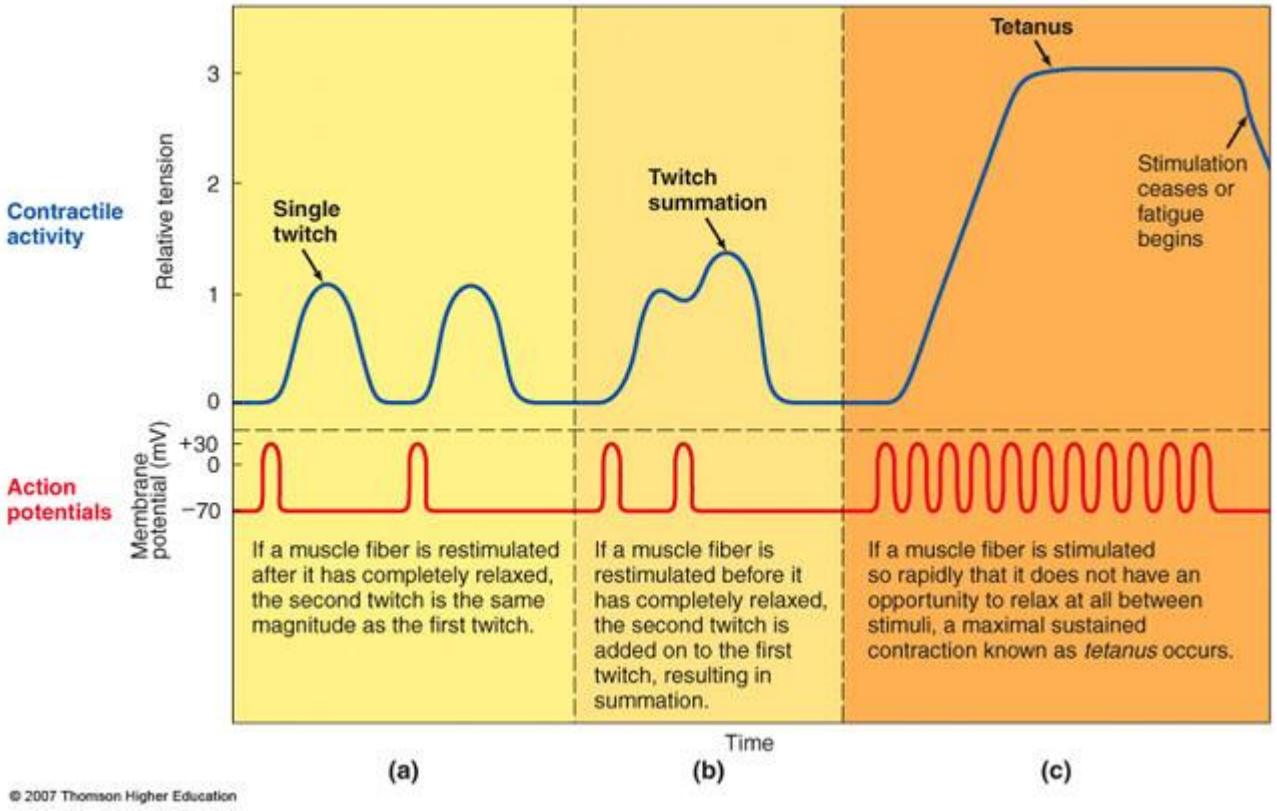
Muscolo cardiaco



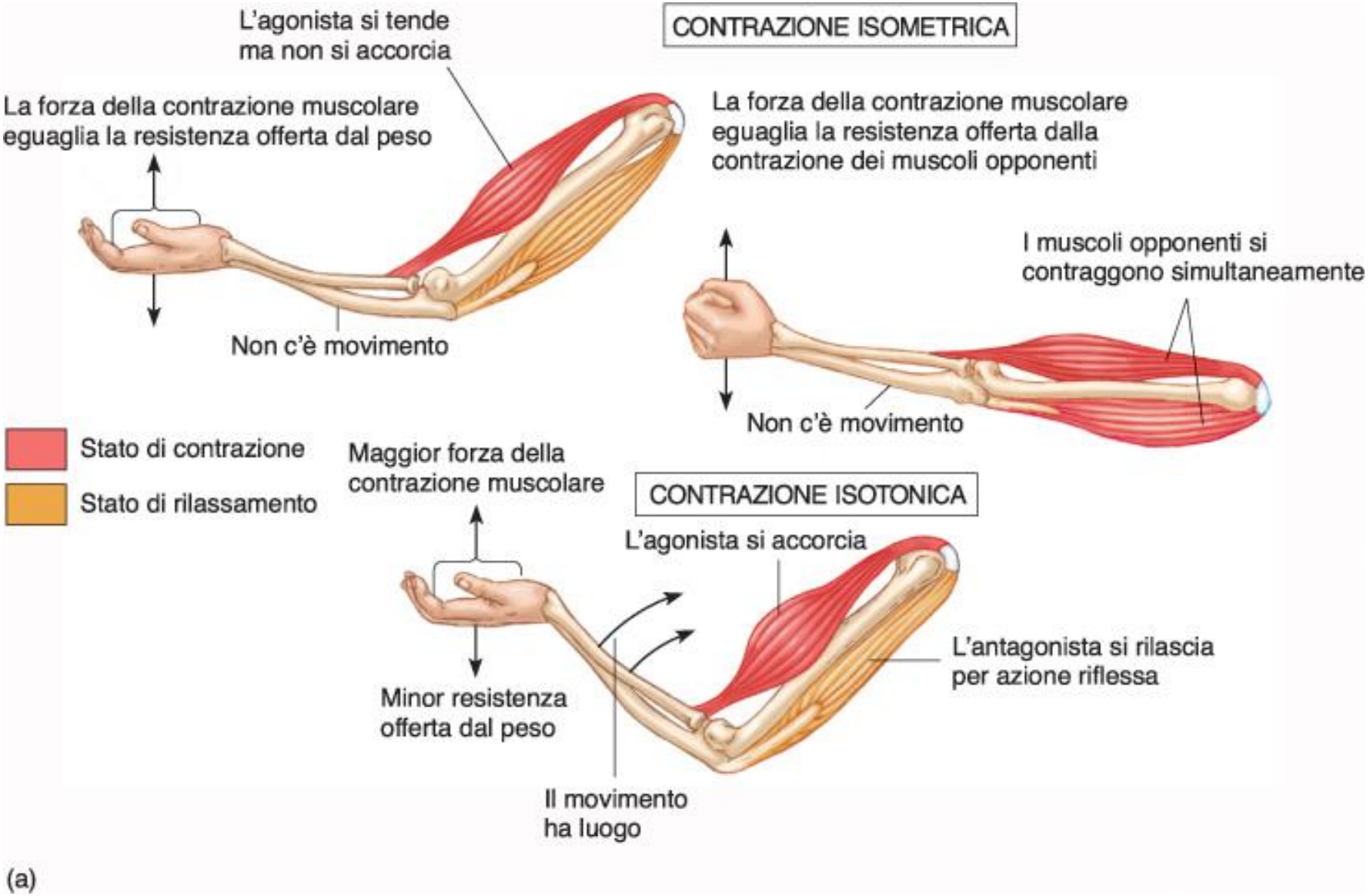
Meccanica della contrazione



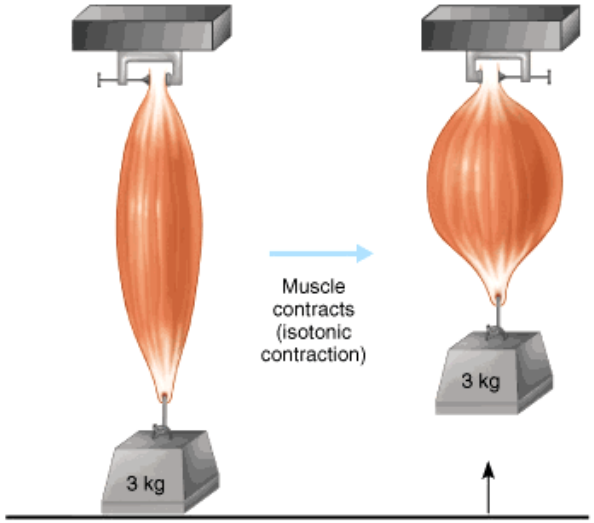
Muscoli lenti= 90 ms (es. muscolo soleus)
Muscoli rapidi= 7.5 ms (es. muscolo extraoculare)

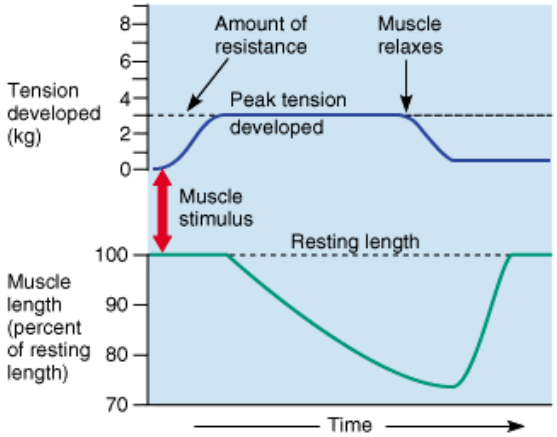


Meccanica della contrazione muscolare



Contrazioni isotoniche e isometriche

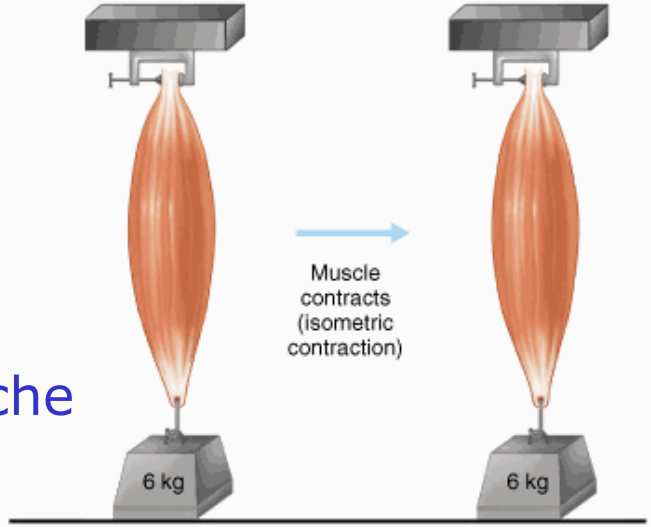


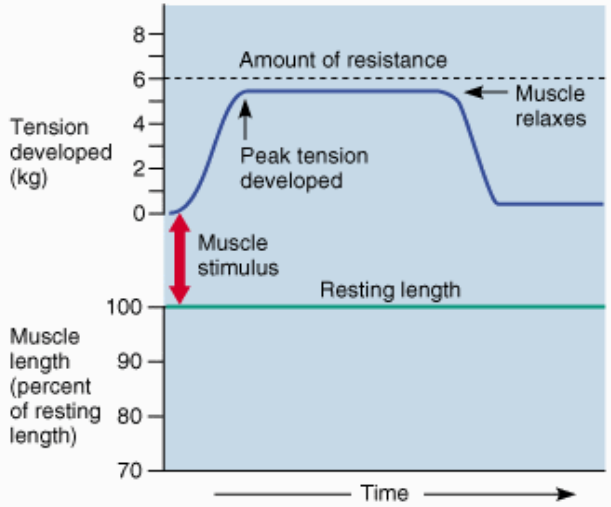


Contrazioni isotoniche

(a) Isotonic (concentric) contraction

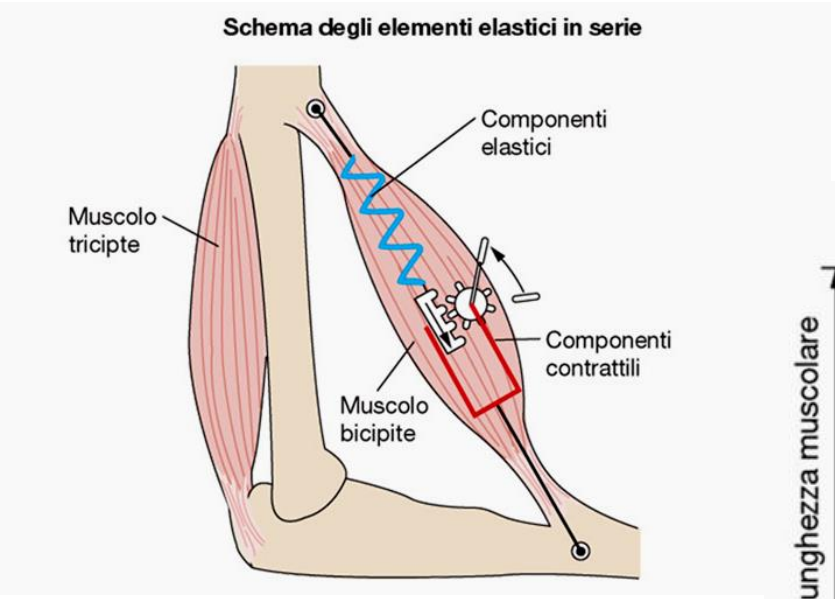
Contrazioni isometriche

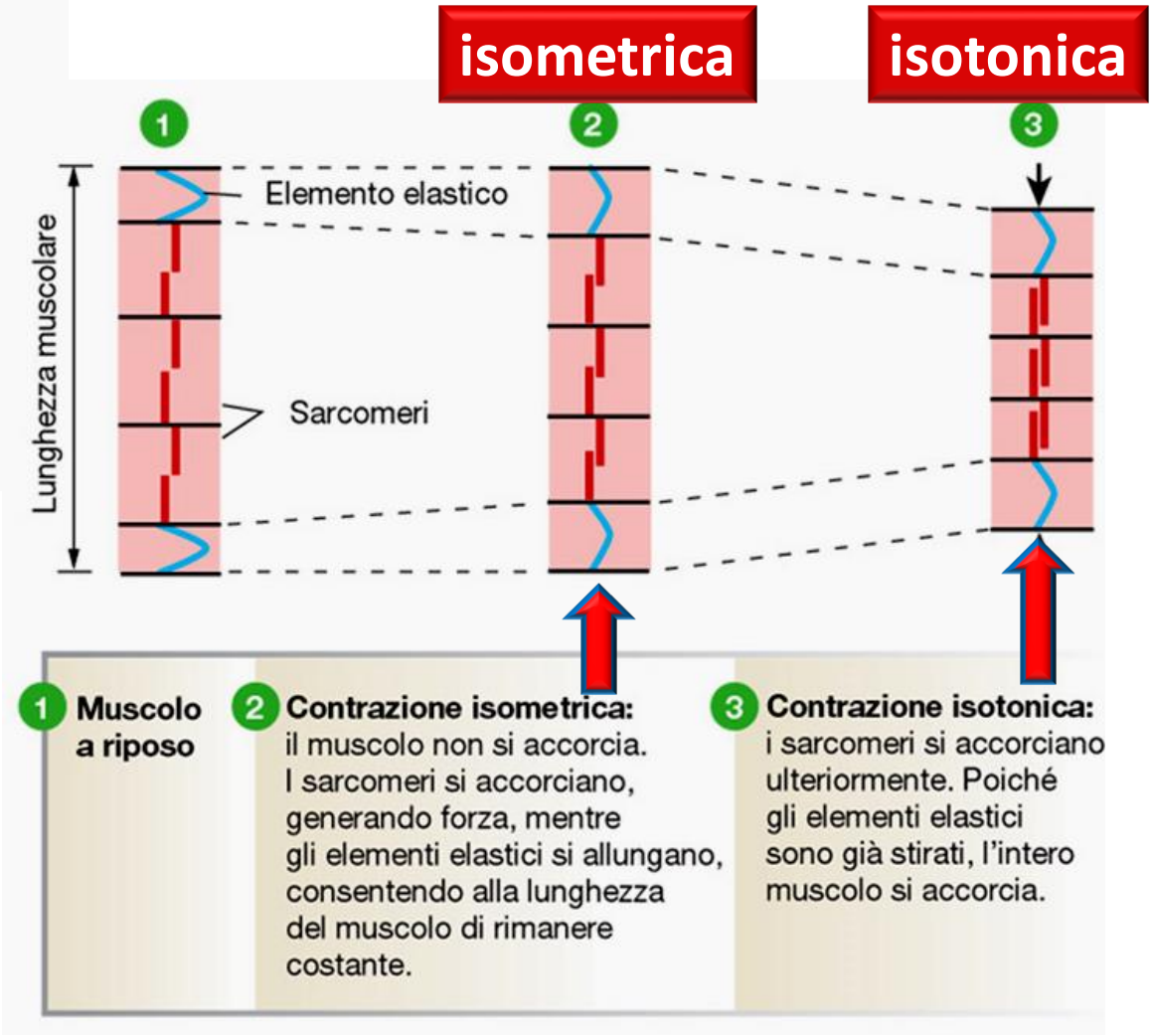




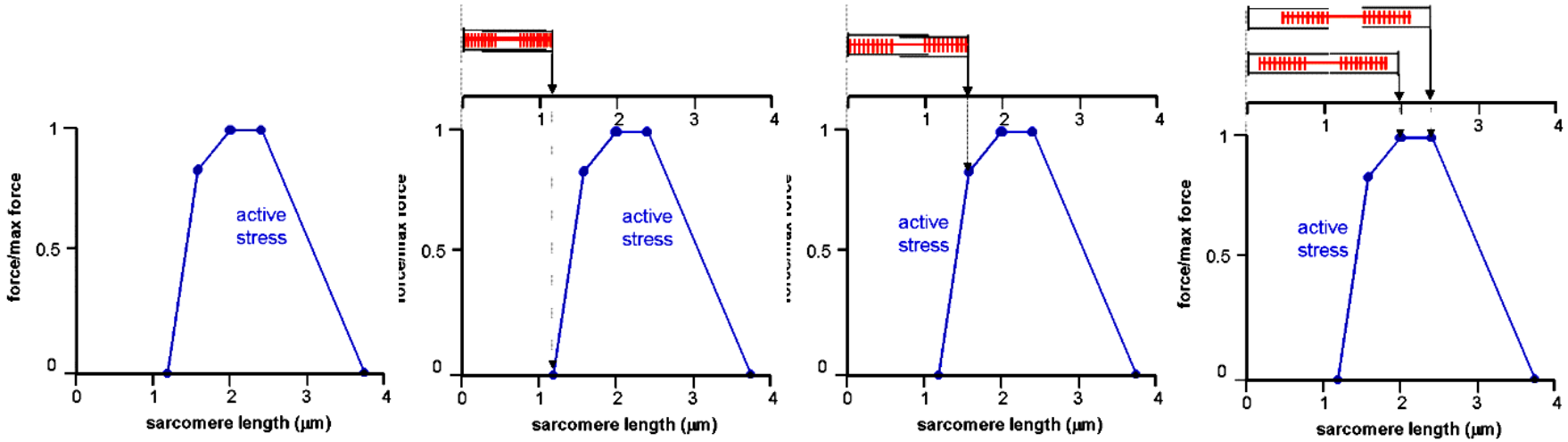
(b) Isometric contraction

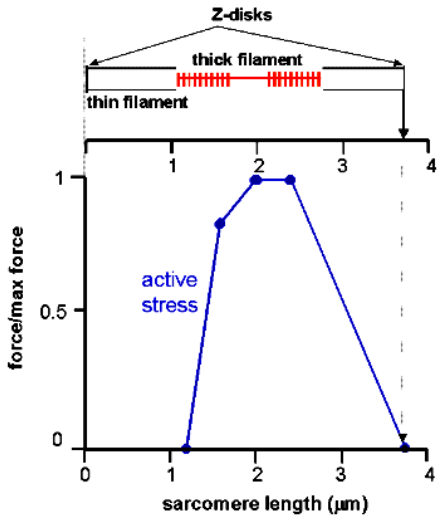
Contrazione isotonica

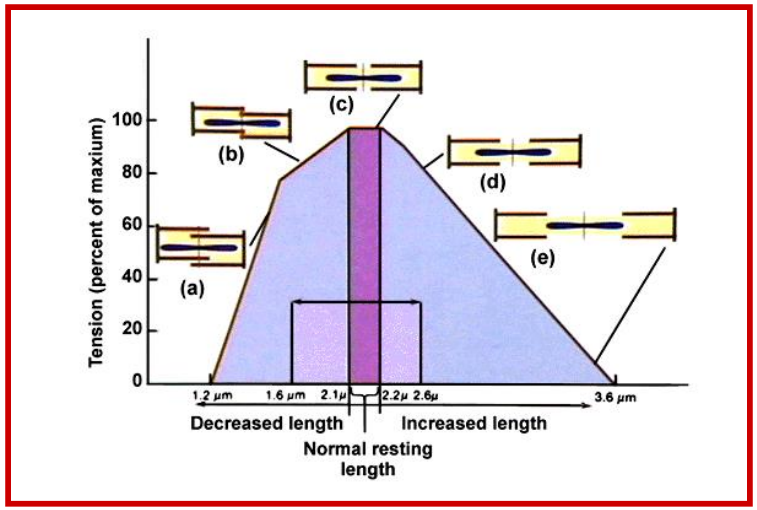


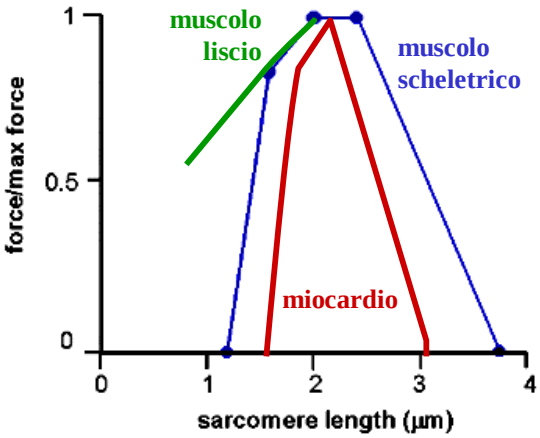


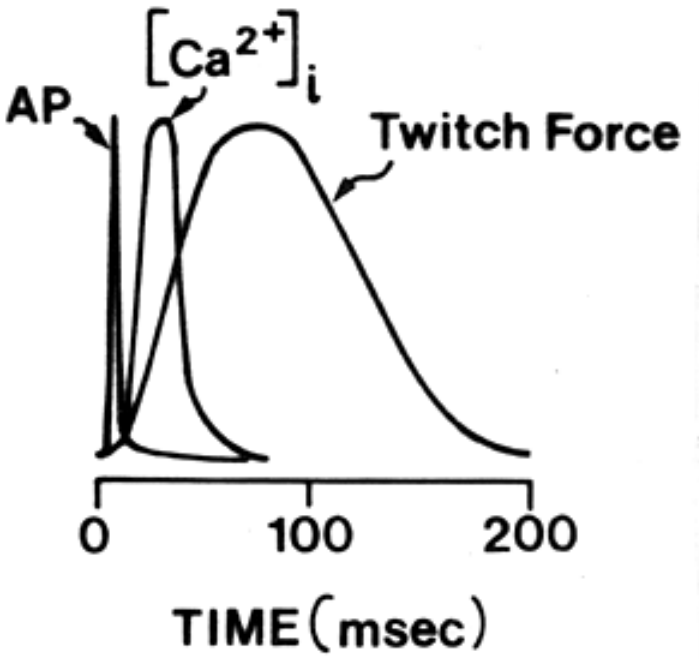
Rapporto stiramento-forza muscolare

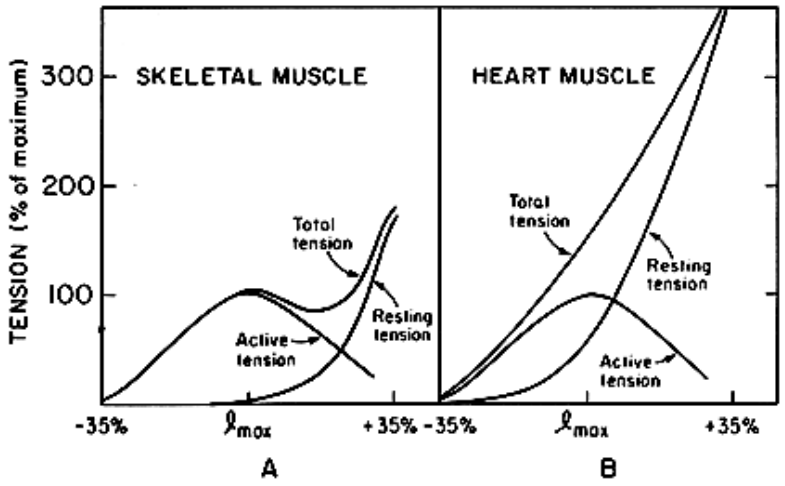


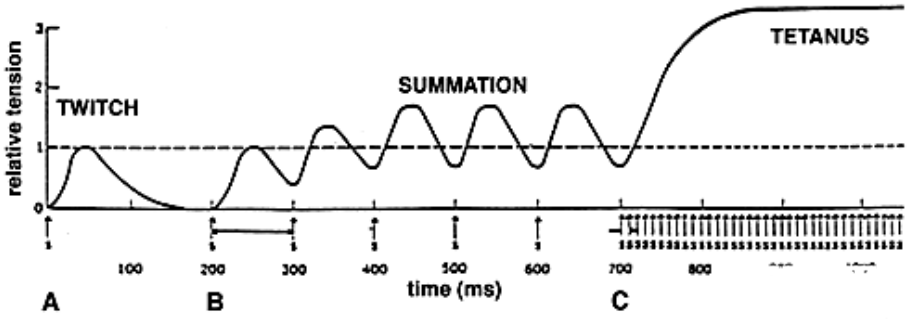


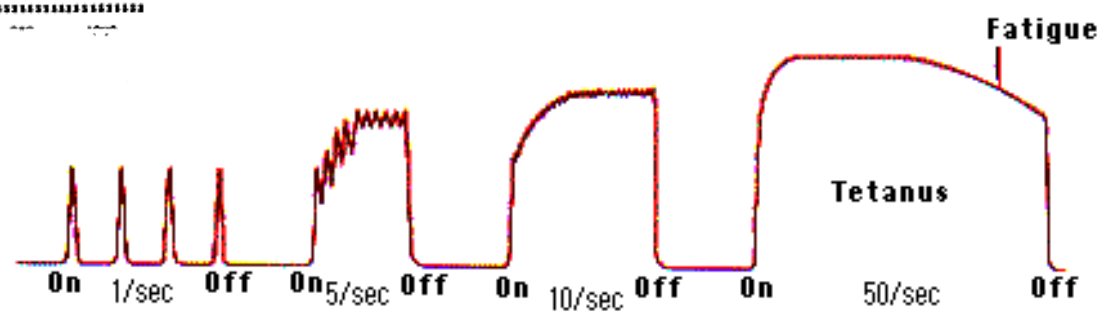




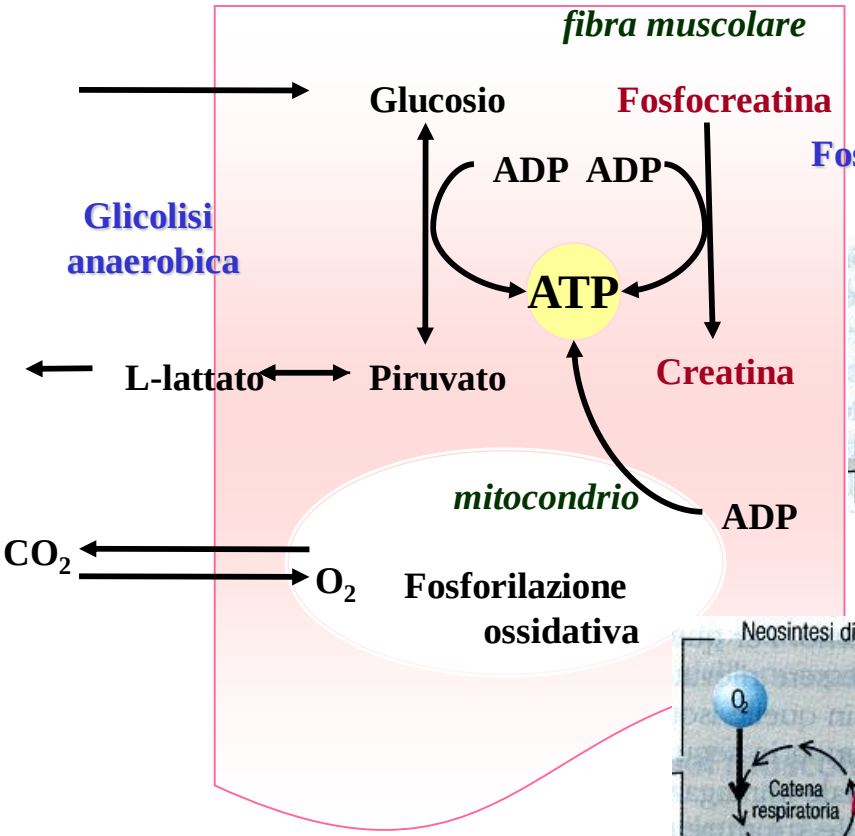

AP
$[Ca^{2+}]_i$
Twitch Force
0
100
200
TIME (msec)


TENSION (% of maximum)
300
200
100
SKELETAL MUSCLE
HEART MUSCLE
Total tension
Resting tension
Active tension
-35%
l_{max}
+35%
A
B

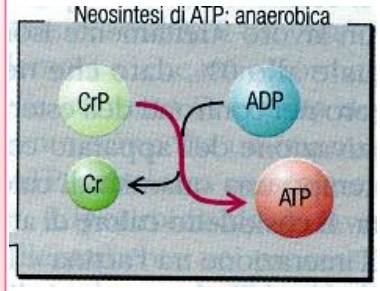

relative tension
TWITCH
SUMMATION
TETANUS
time (ms)
A
B
C

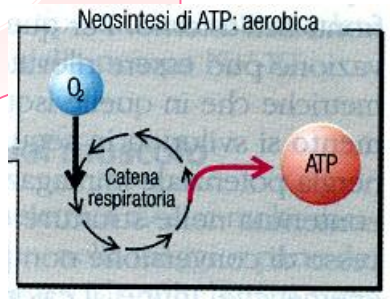

Fatigue
Tetanus
On
1/sec
Off
On
5/sec
Off
On
10/sec
Off
On
50/sec
Off

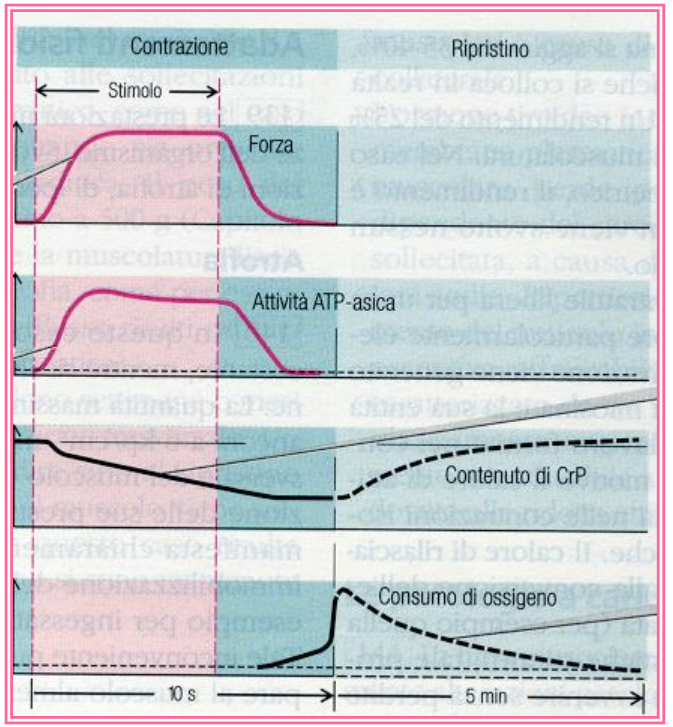
Metabolismo energetico muscolare

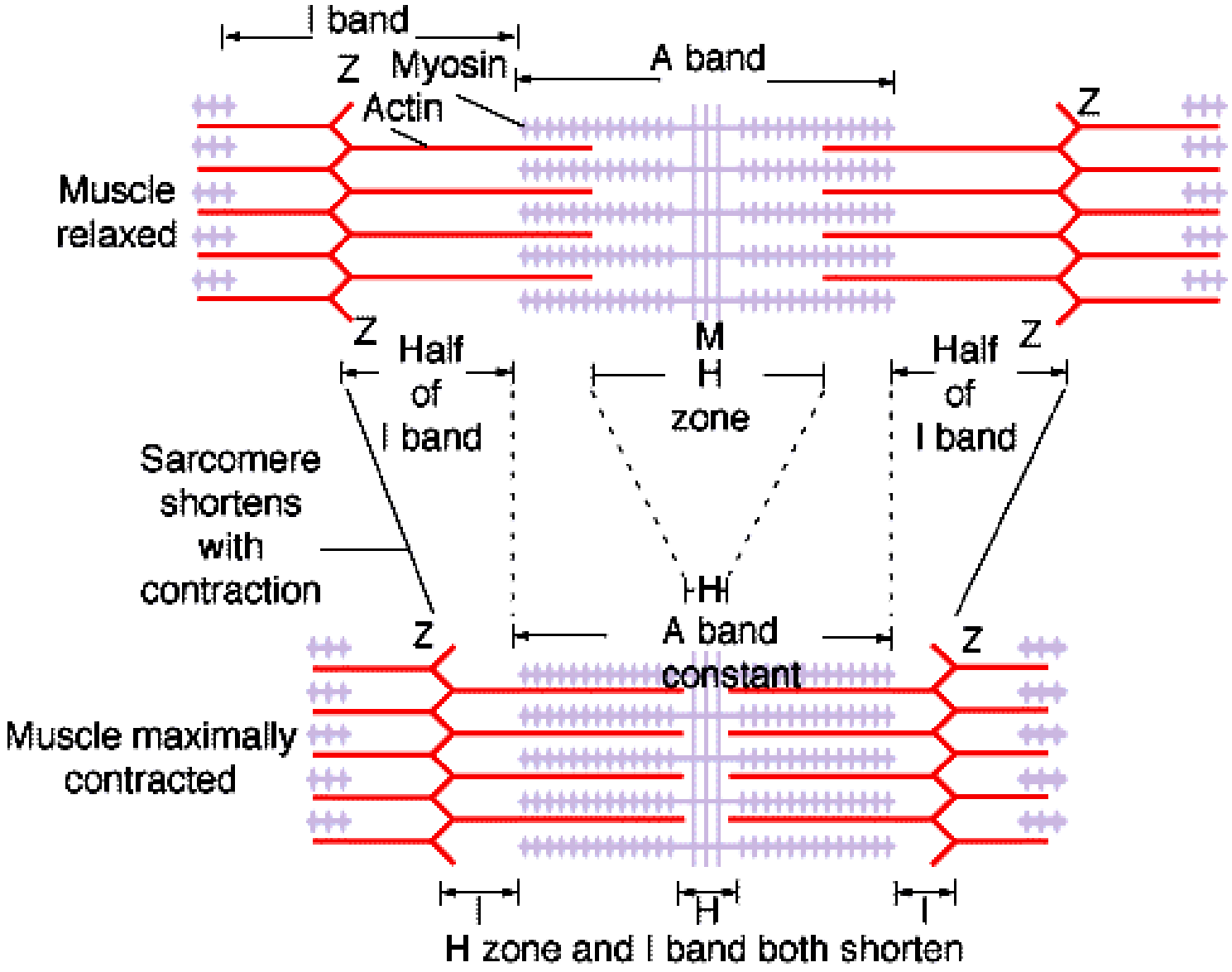


Fosforilazione diretta








I band
A band
Z
Myosin
Actin
Muscle relaxed
Z
Z
M
H zone
Half of I band
Half of I band
Sarcomere shortens with contraction
H
A band constant
Z
Z
Muscle maximally contracted
I
H
I
H zone and I band both shorten

Contrazione del muscolo liscio