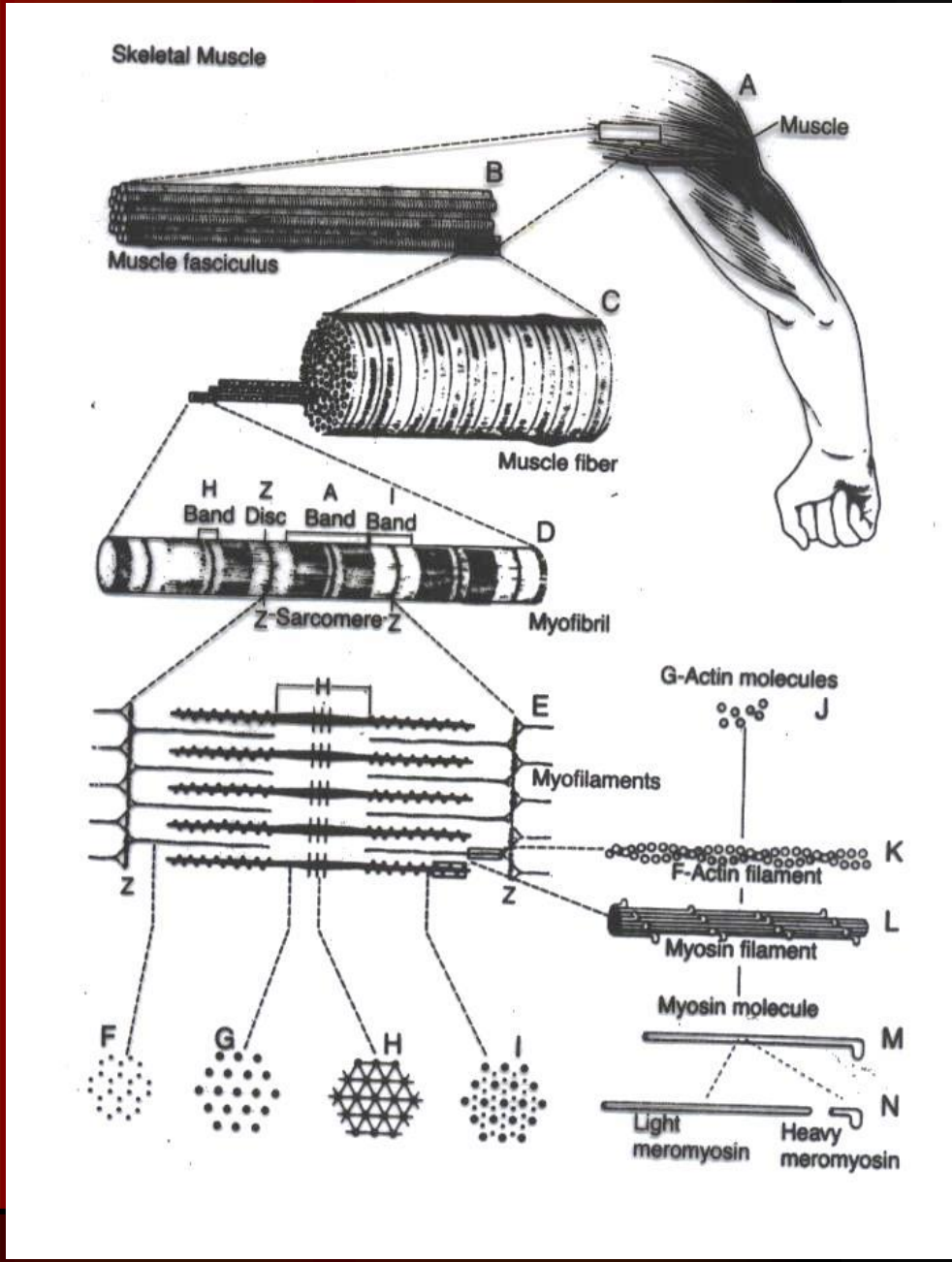
Physiology of Skeletal Muscle Contraction

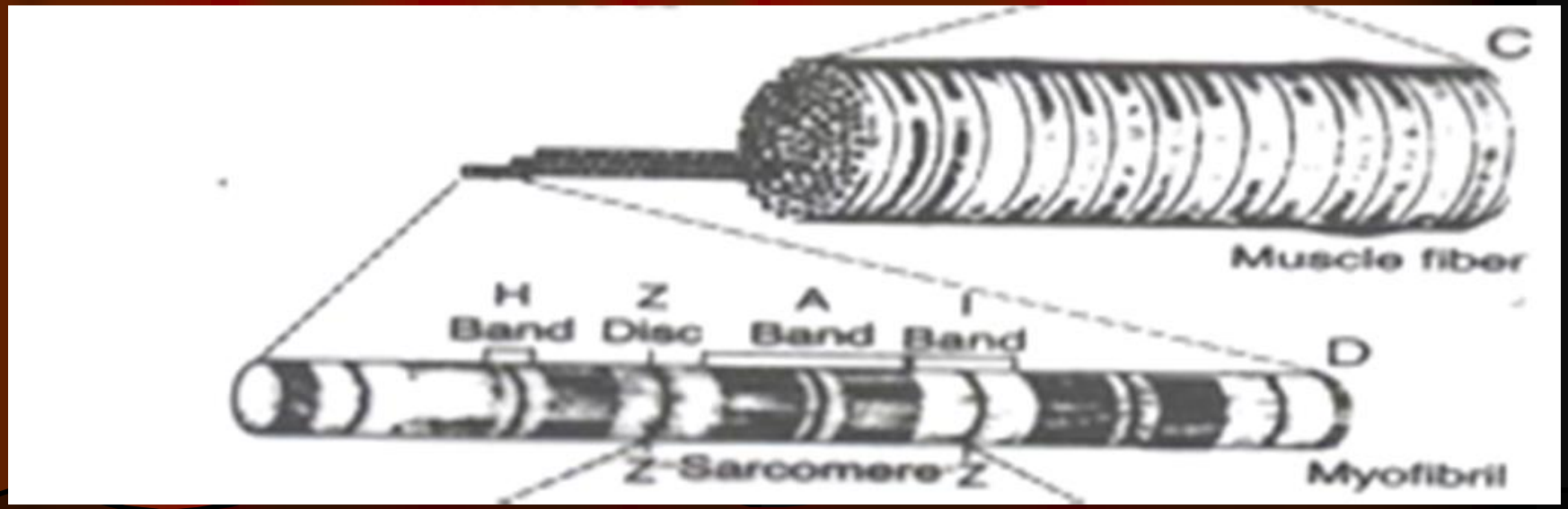
The Muscle Action Potential (AP)

- Muscle RMP = -90 mV (same as in nerves) .
- Duration of AP = 1-5 ms (longer duration than nerve AP , which is usually about 1 ms) .
- Conduction Velocity = 3-5 m/s (slower than big nerves) .

- Each muscle cell (fiber) is covered by a cell-membrane called Sarcolemma.
- Each cell contains between a few hundreds to a few thousands Myofibrils.



- Each Myofibril contains Actin filaments (thin) & Myosin (thick) filaments .
- Each myofibril is striated: consisting of dark bands (called A-bands) and light (I-bands).



Sarcoplasm=

matrix inside muscle fiber in which myofilaments susbended

Sarcoplasmic reticulum=

it is endoplasmic reticulum inside sarcoplasm full of Ca.

T- tubules:-

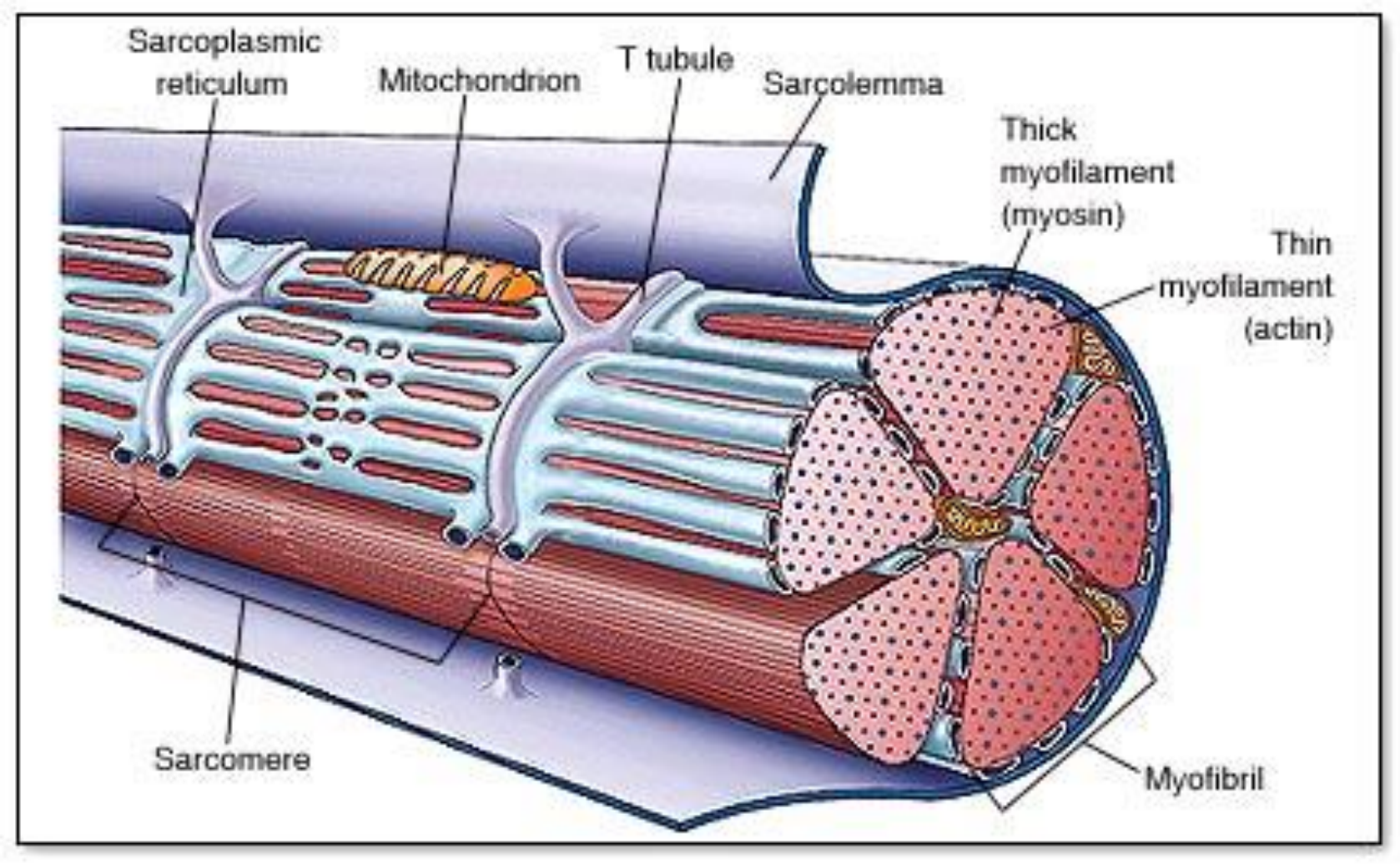
extend from one side of muscle to other (function?).

Sarcomere=

contractile unit of muscle, it is the zone between two Z lines (discs)=2 micrometer in length in resting state.

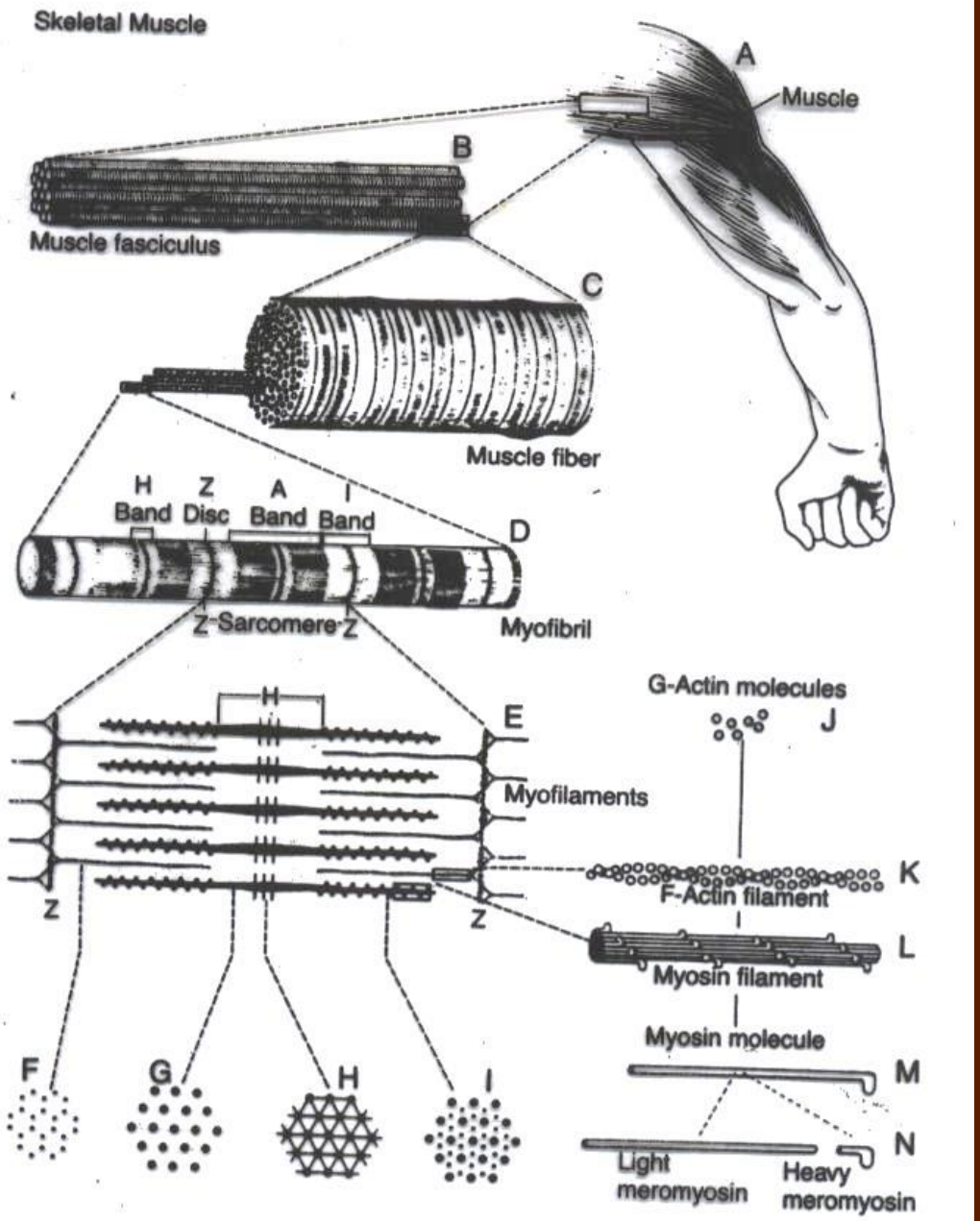
Z discs (lines) = lines extend all way across myofibrils

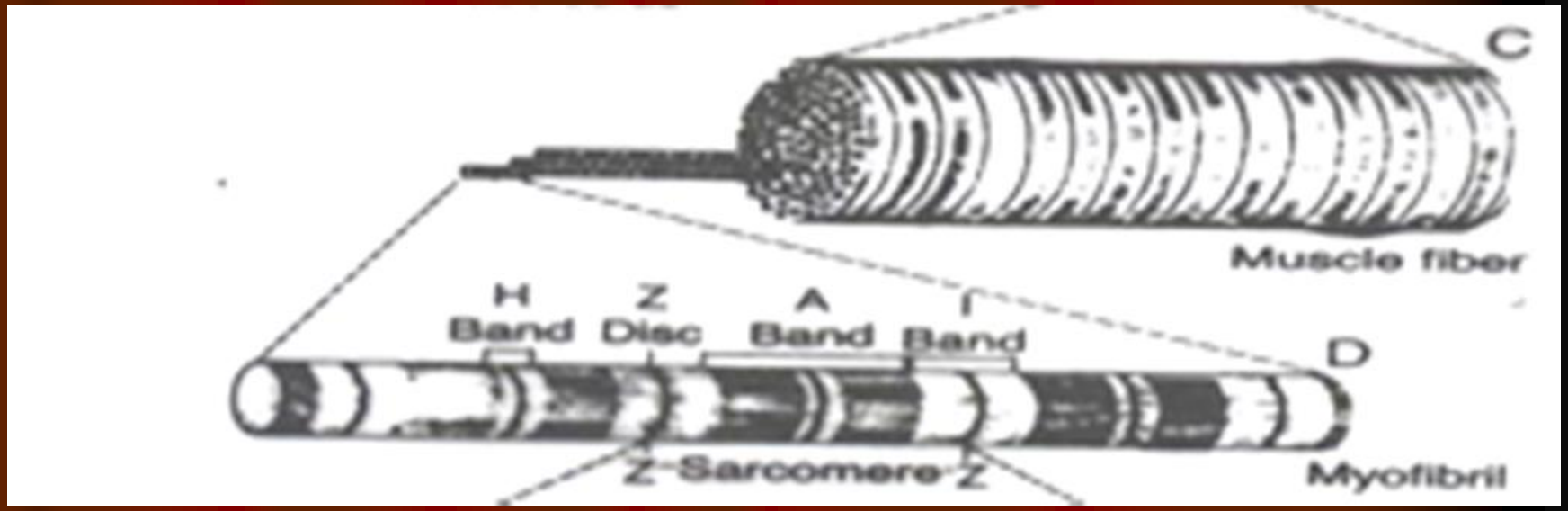
The functional unit of a myofibril is the **Sarcomere**

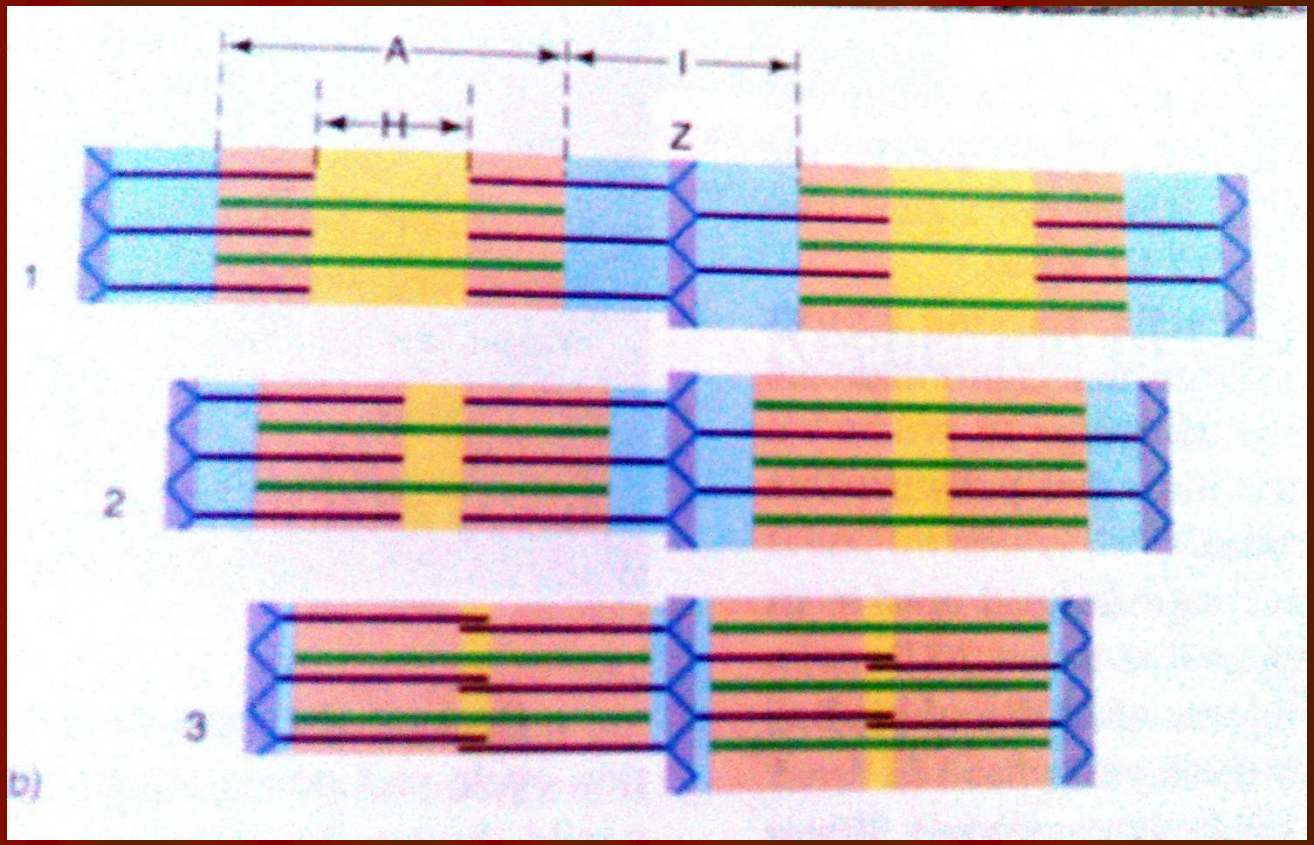


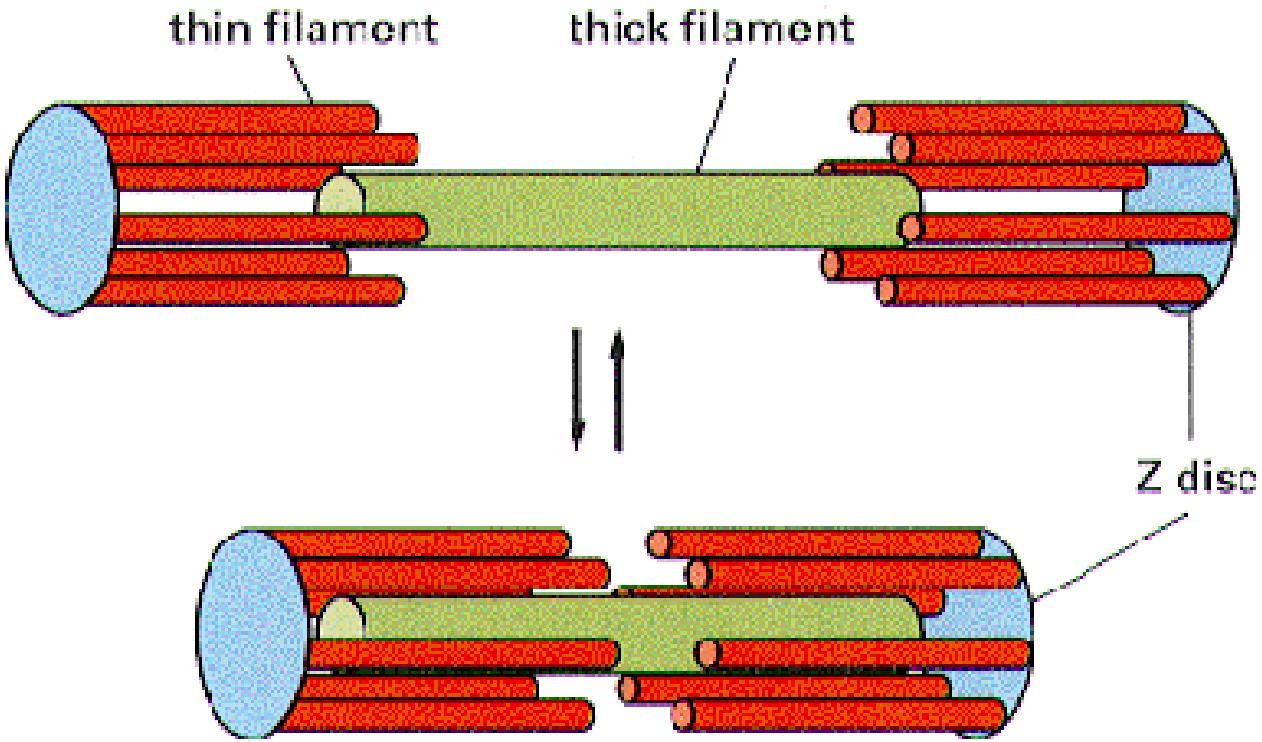
Inside each sarcomere there are 3 bands:-

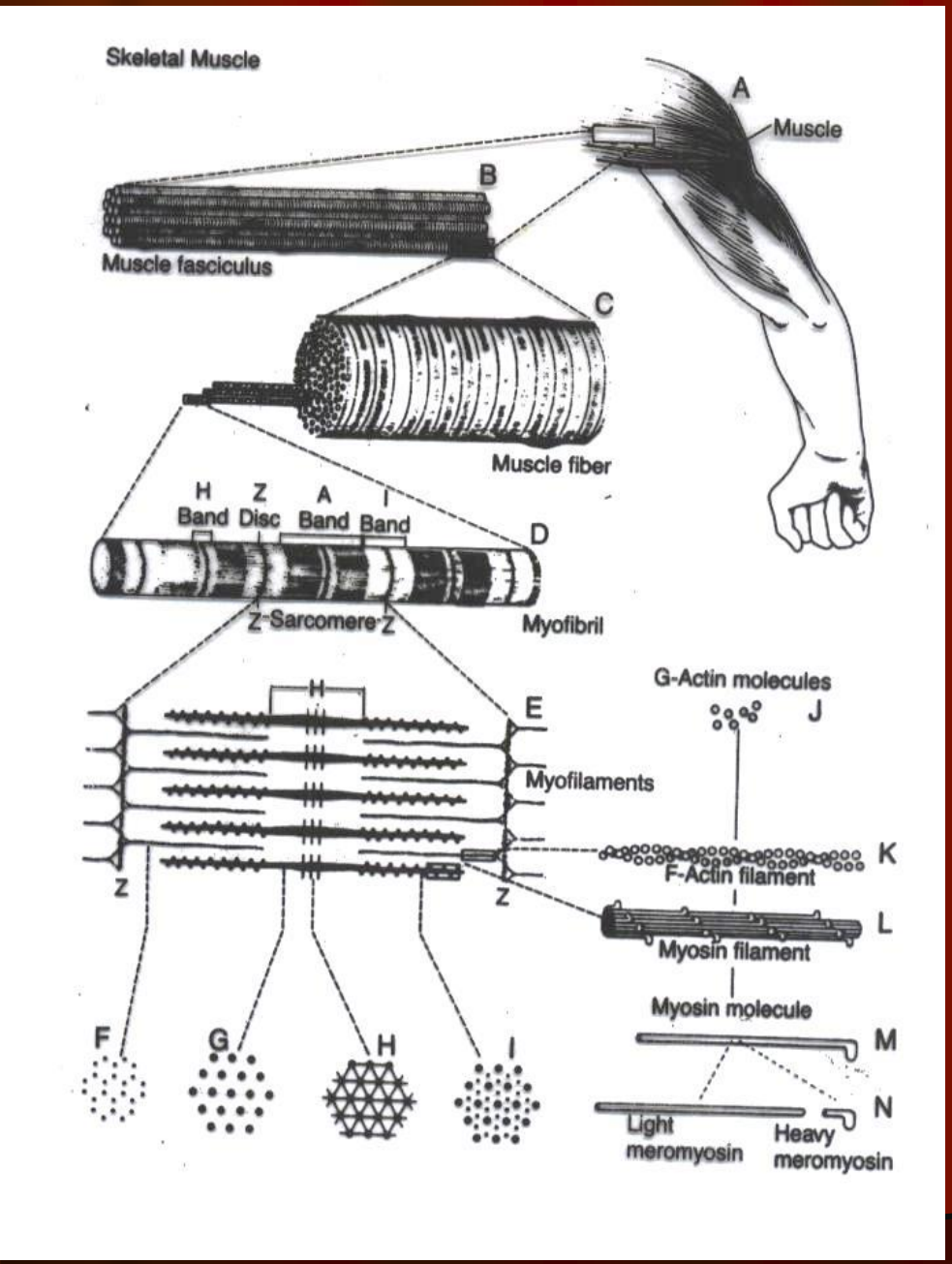
- **I band = of actin only**
- **H band = of myosin only**
- **A band = formed of actin & myosin filaments**


Skeletal Muscle
A
Muscle
B
Muscle fasciculus
C
Muscle fiber
H Band
Z Disc
A Band
I Band
D
Z-Sarcomere-Z
Myofibril
G-Actin molecules
J
E
Myofilaments
K
F-Actin filament
L
Myosin filament
Myosin molecule
M
N
Light meromyosin
Heavy meromyosin
F
G
H
I


C
Muscle fiber
H
Band
Z
Disc
A
Band
I
Band
D
Z
Sarcomere
Z
Myofibril

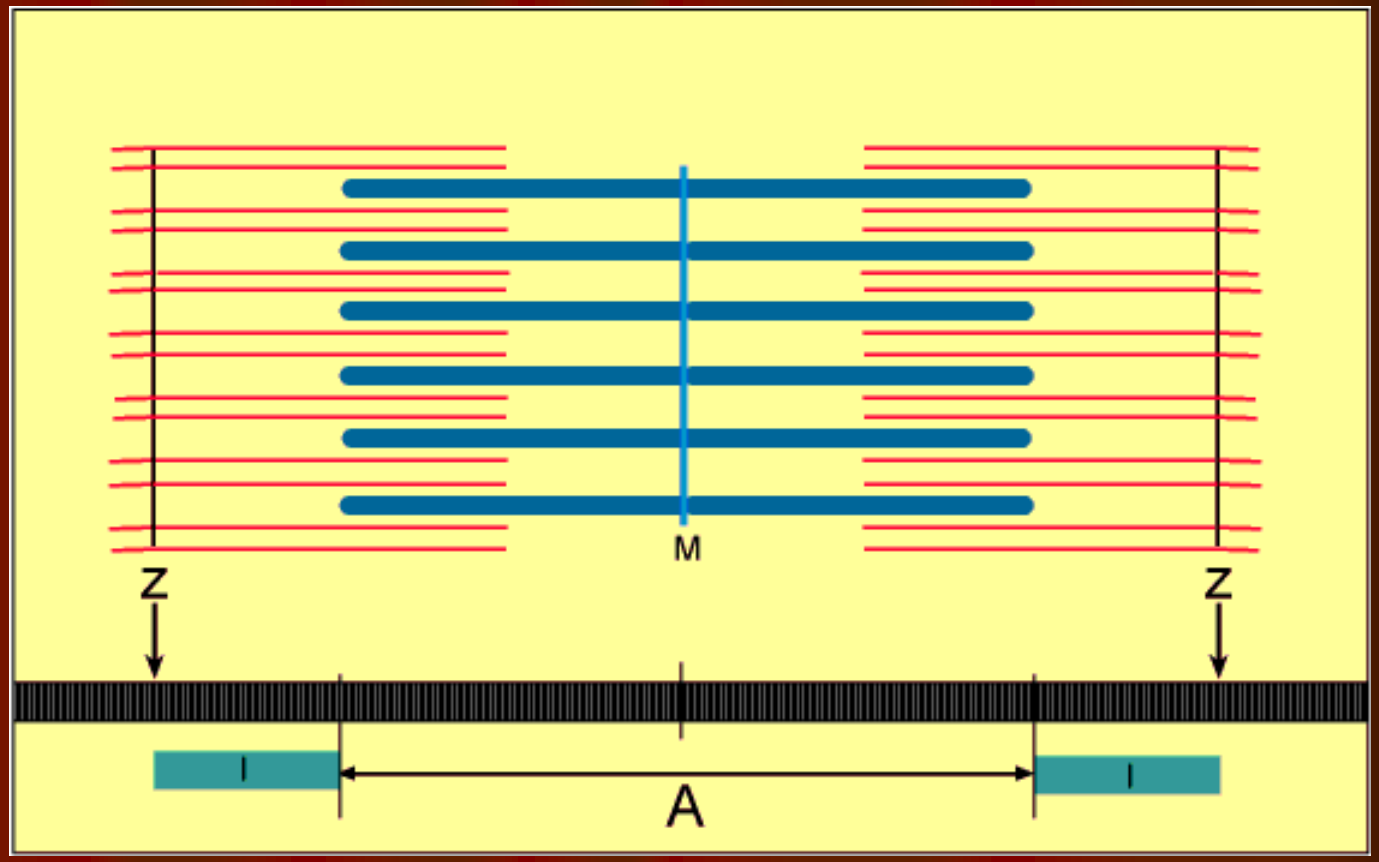

A
I
H
Z
1
2
3
b)


thin filament
thick filament
Z disc



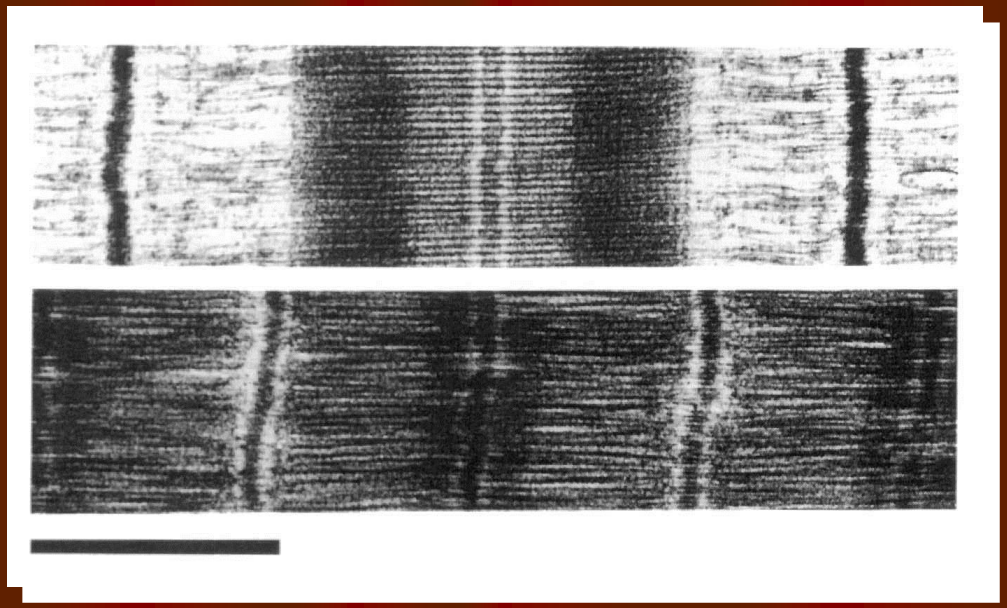
- When contraction takes place Actin & Myosin slide upon each other , & the distance between two z-discs decreases : This is called

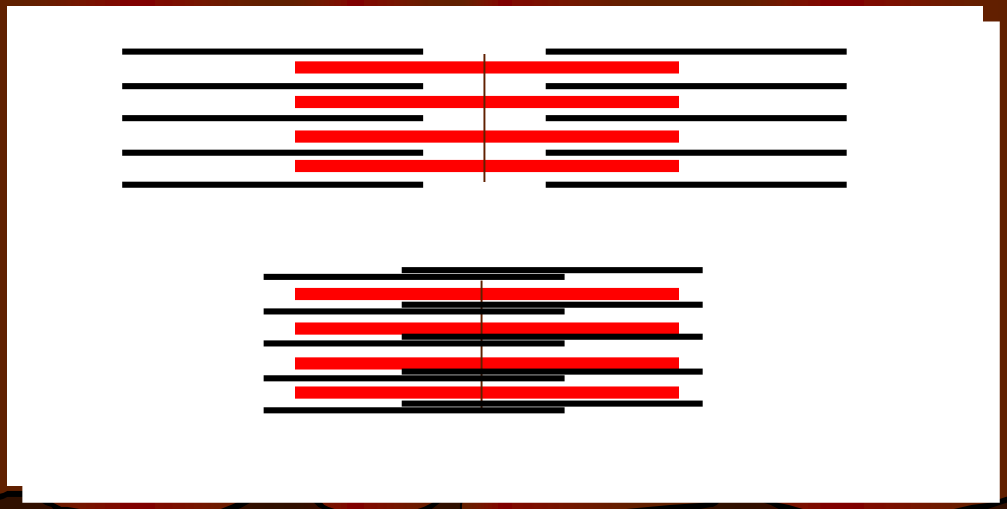
Sliding Filament Mechanism



From: http://www.3dotstudio.com/zz.html

EM Evidence for Sliding Filaments





Muscle Contraction

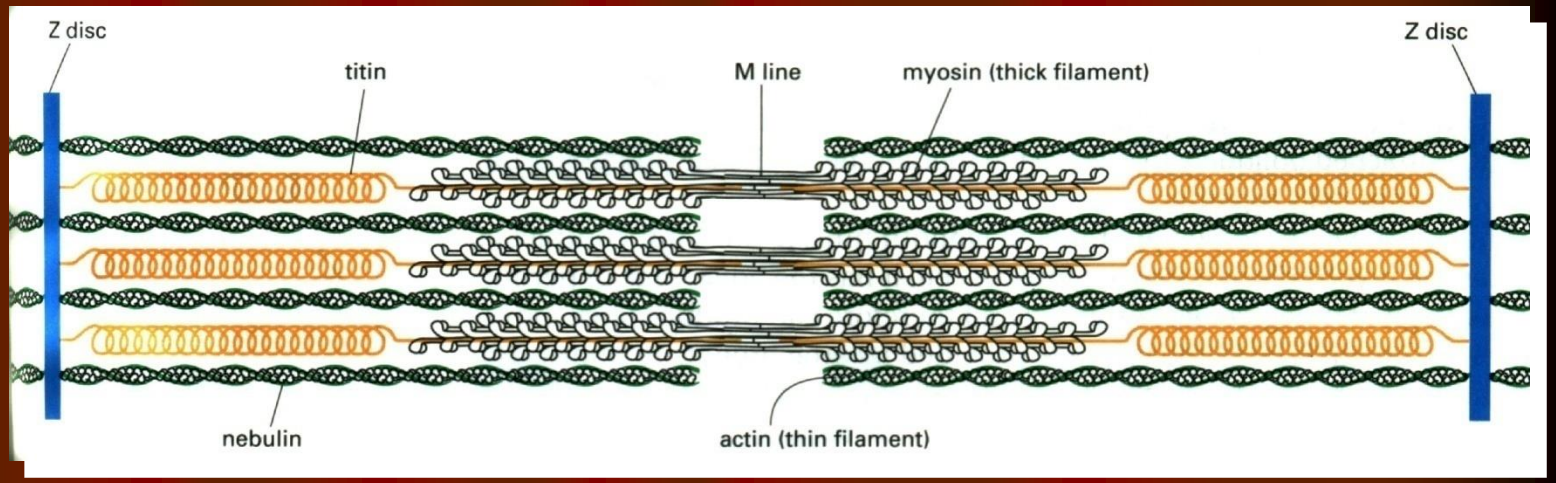
muscle proteins :

a. Thick filament: **Myosin**

b. Thin filament :

1. **Actin**
2. **Troponin** →
3. **Tropomyosin** →

Sarcomere filamentous proteins



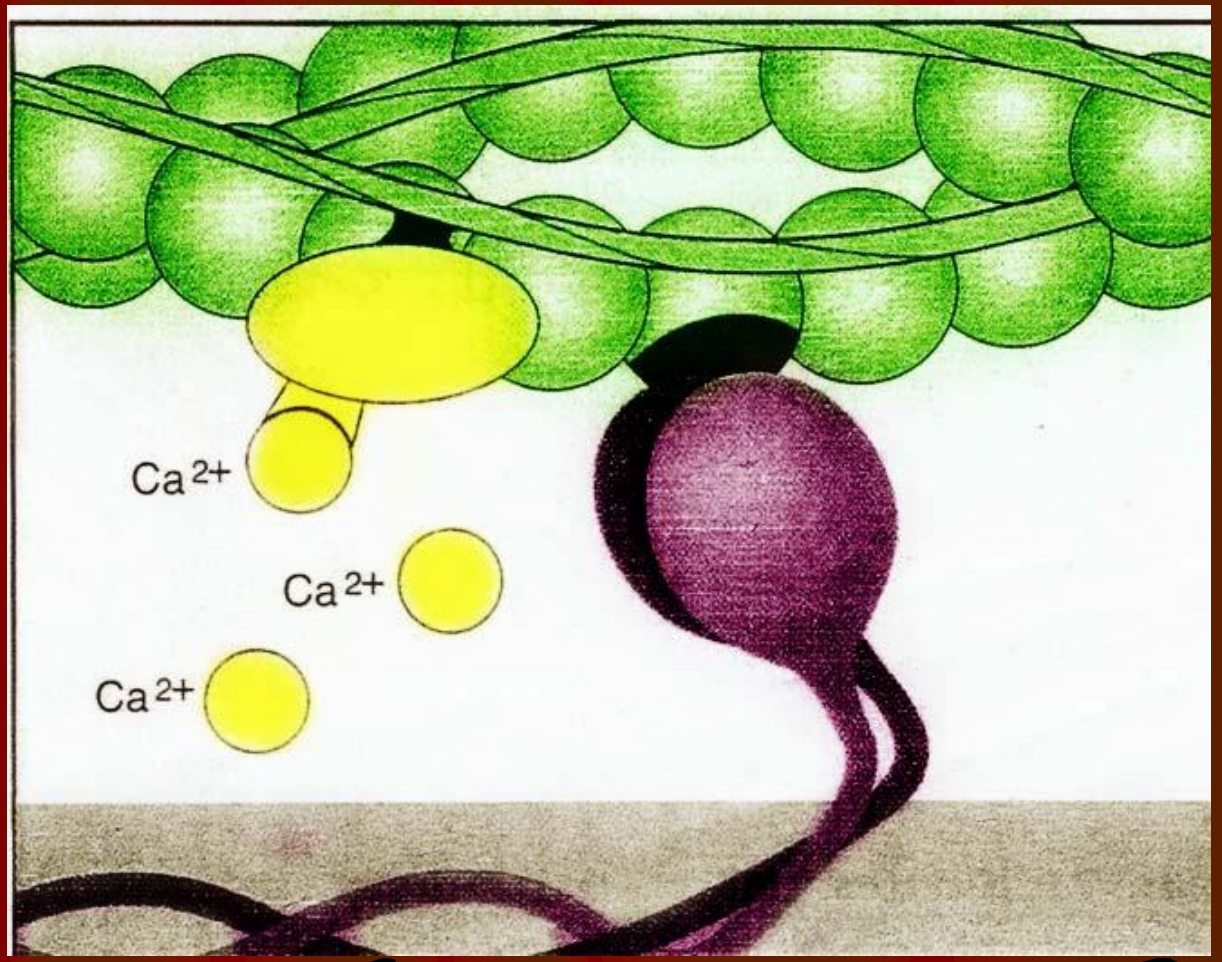
From: Alberts et al.. 1994 Molecular Biology of the Cell.

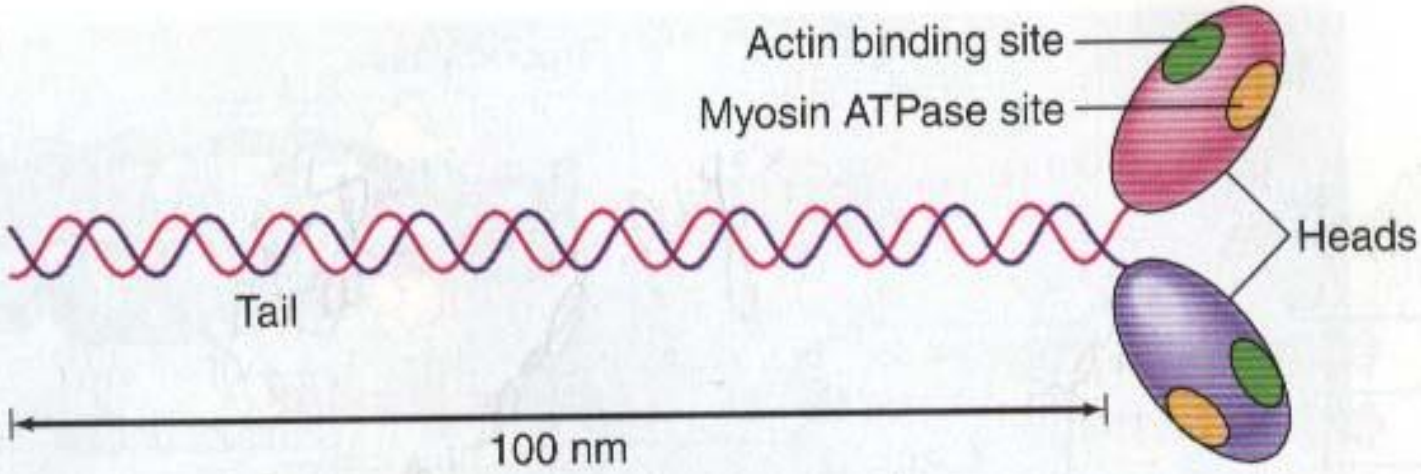
Thick filament:

Myosin filament

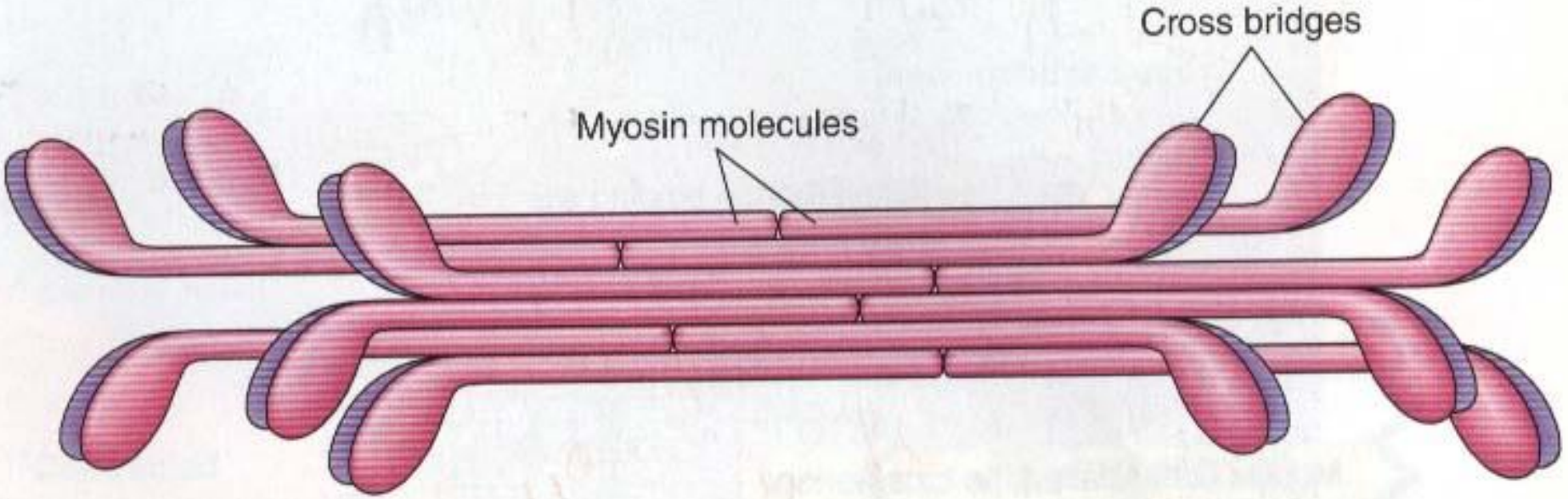
it has head + tail
cross bridges (?)

- Head has ATP site
-?


Ca 2+
Ca 2+
Ca 2+

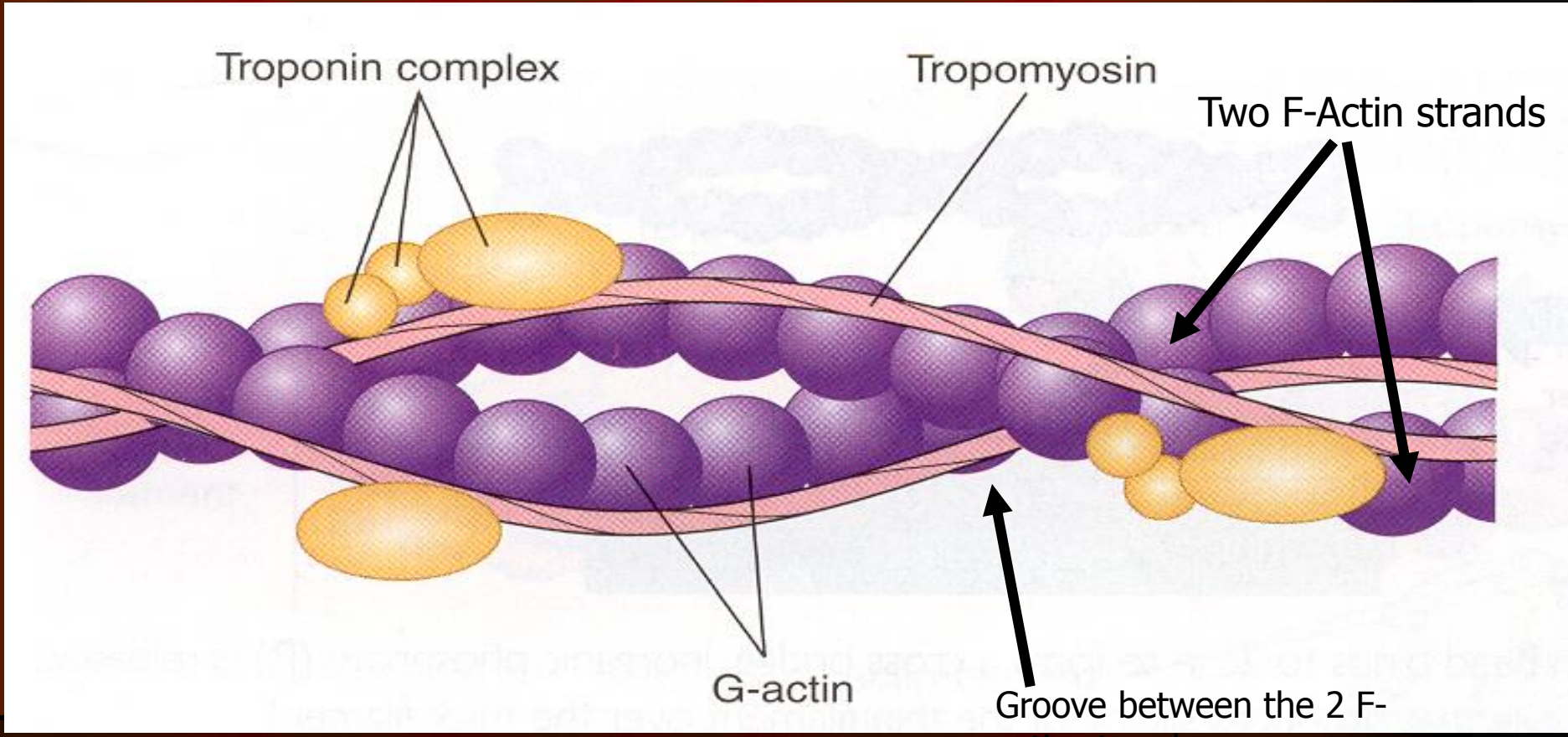


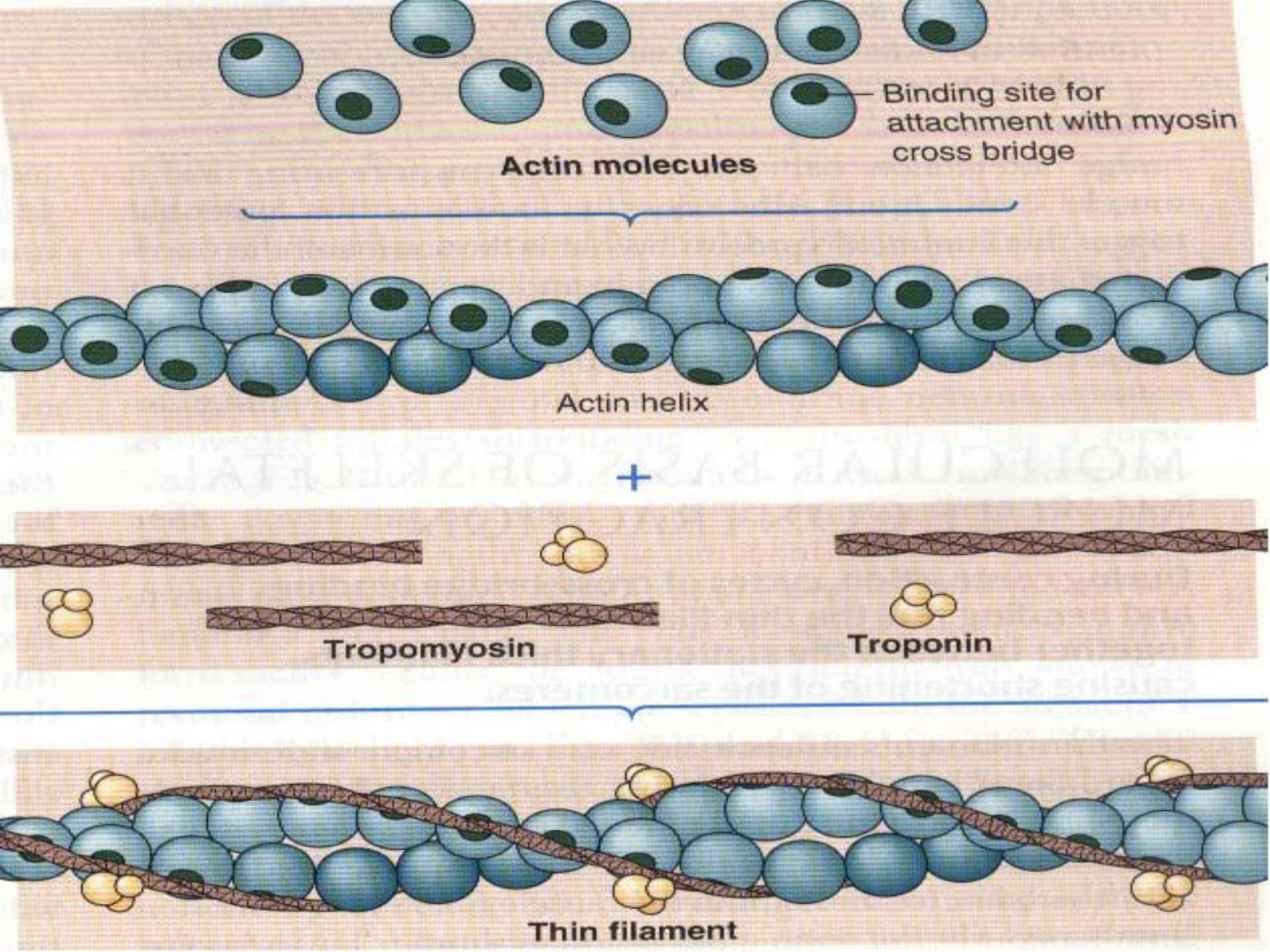
(a) Myosin molecule



(b) Thick filament

Thin filament




Binding site for attachment with myosin cross bridge
Actin molecules
Actin helix
+
Tropomyosin
Troponin
Thin filament

MOLECULAR MECHANISM OF MUSCLE CONTRACTION

Excitation –contraction coupling

Events of muscle contraction: ***

- Acetylcholine released by motor nerve »»»»»» EPP »»»»»» depolarization of CM (muscle AP) »»»»»»
- Spread of AP into T tubule »»»»»»release of Ca from sarcoplasmic reticulum into the cytoplasm
- »»»»»» Ca combines with troponin »»»»»» troponin pull tropomyosin sideway »»»»»» exposing the active site on actin »»»»»» myosin heads with ATP on them, attached to actin active site
- »»»»»» the head of myosin cross bridges bend pulling actin toward center of sarcomere (Power stroke) using energy of ATP»»»»»»ADP & P released »»»»»» Linkage between actin & myosin broken as new ATP binds to myosin cross bridge >>> ATP hydrolyzed and cross bridge go back to its original conformation.

Events of muscle contraction:

- When a new ATP occupies the vacant site on the myosin head, this triggers detachment of myosin from actin

- The free myosin swings back to its original position, & attached to another actin, & the cycle repeat its self

Events of muscle relaxation:

- When ca is pumped back into sarcoplasmic reticulum
- »»»»»» ca detached from troponin »»»»»» tropomyosin return to its original position
- »»»»»» covering active sit on actin »»»»»» prevent attachment between actin and myosin»»»»»» relaxation

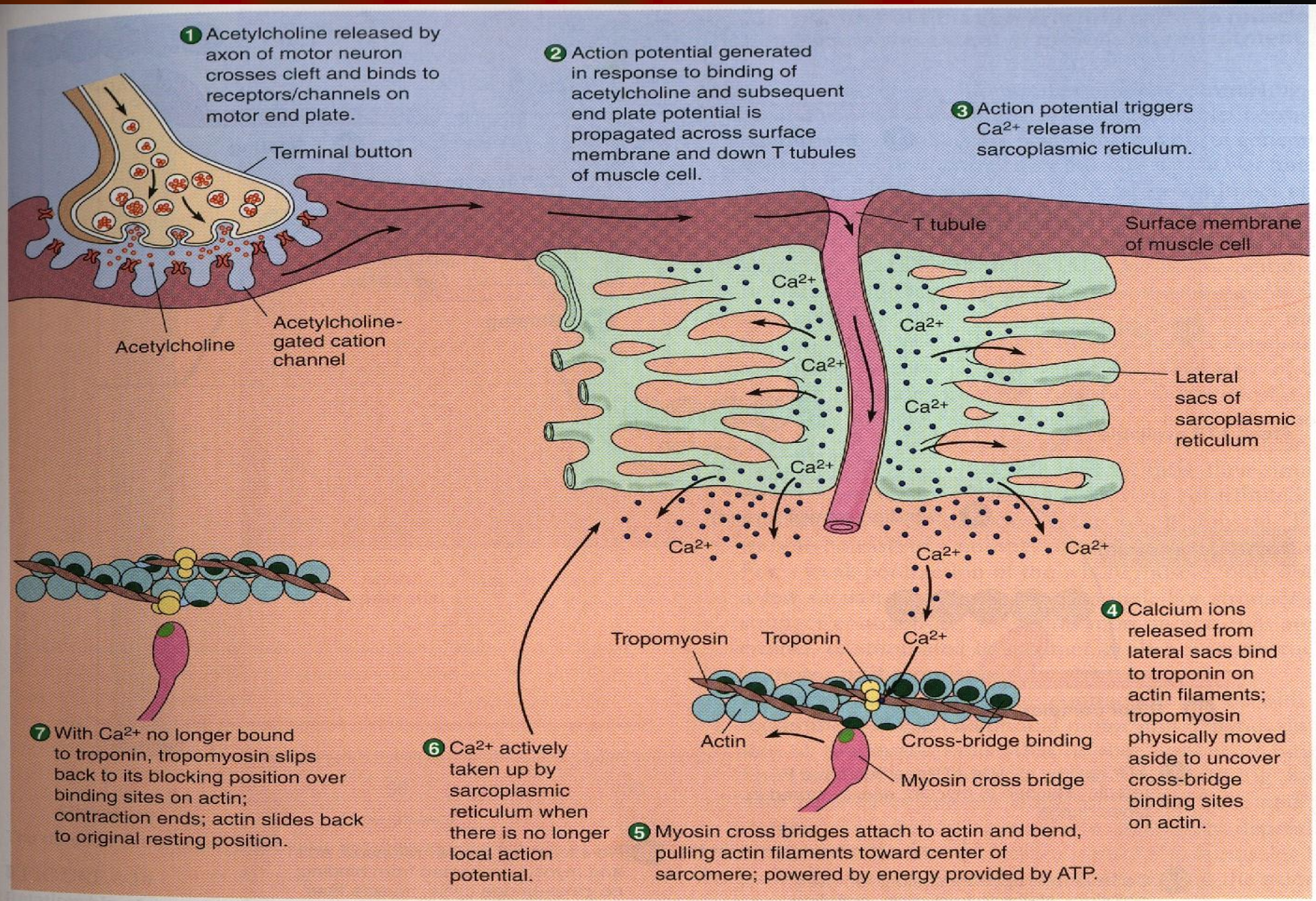


FIGURE 8-12

Calcium release in excitation-contraction coupling

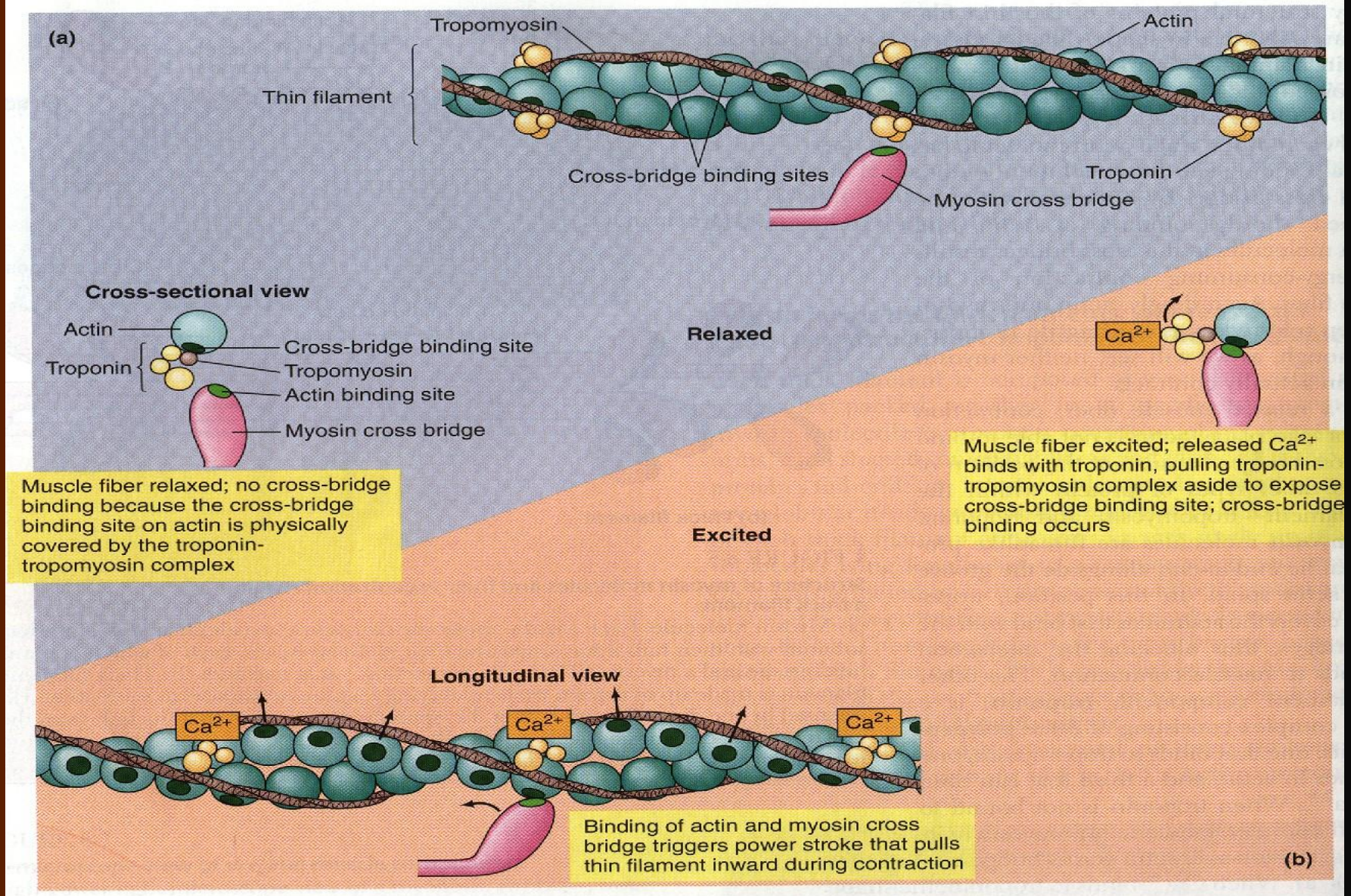
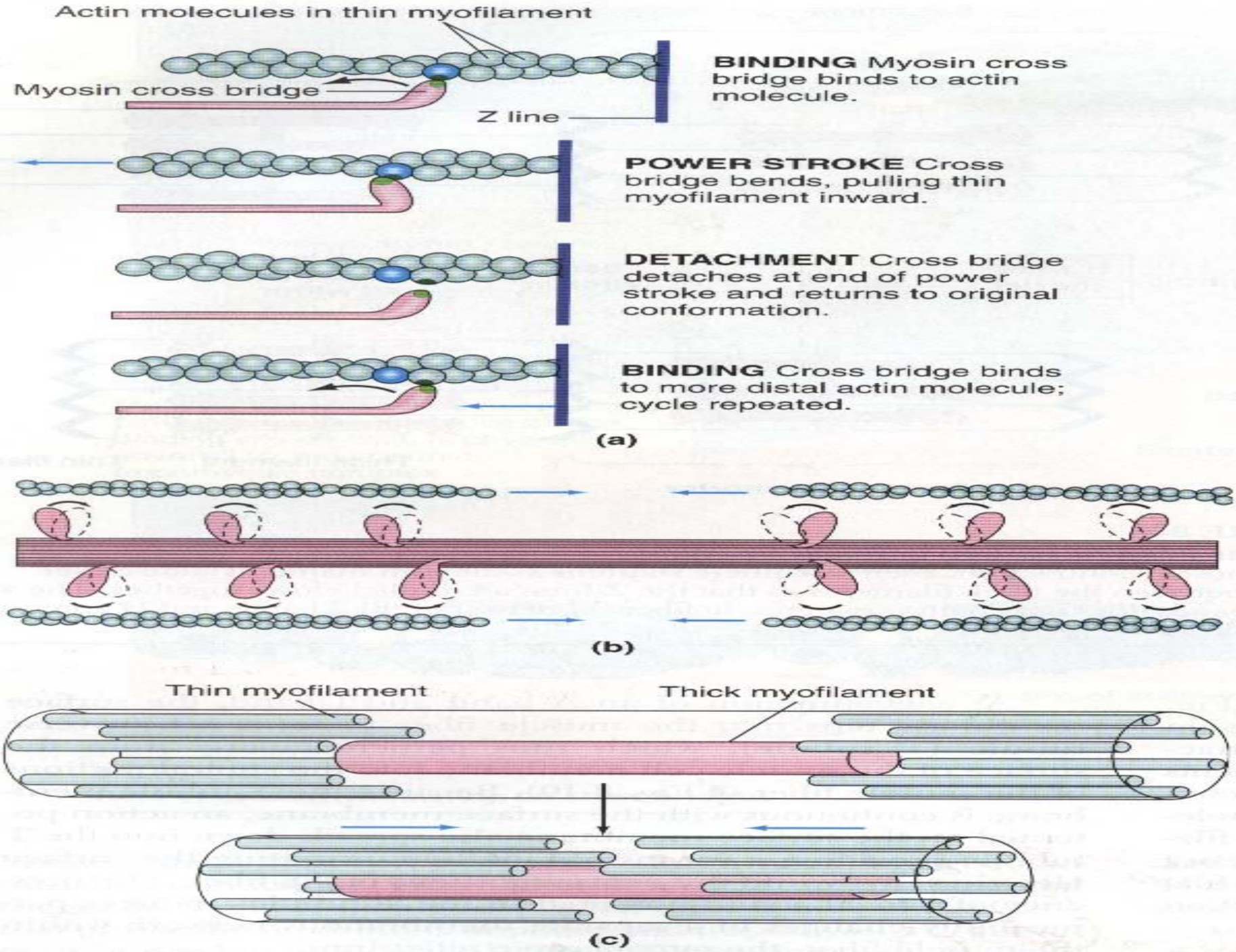
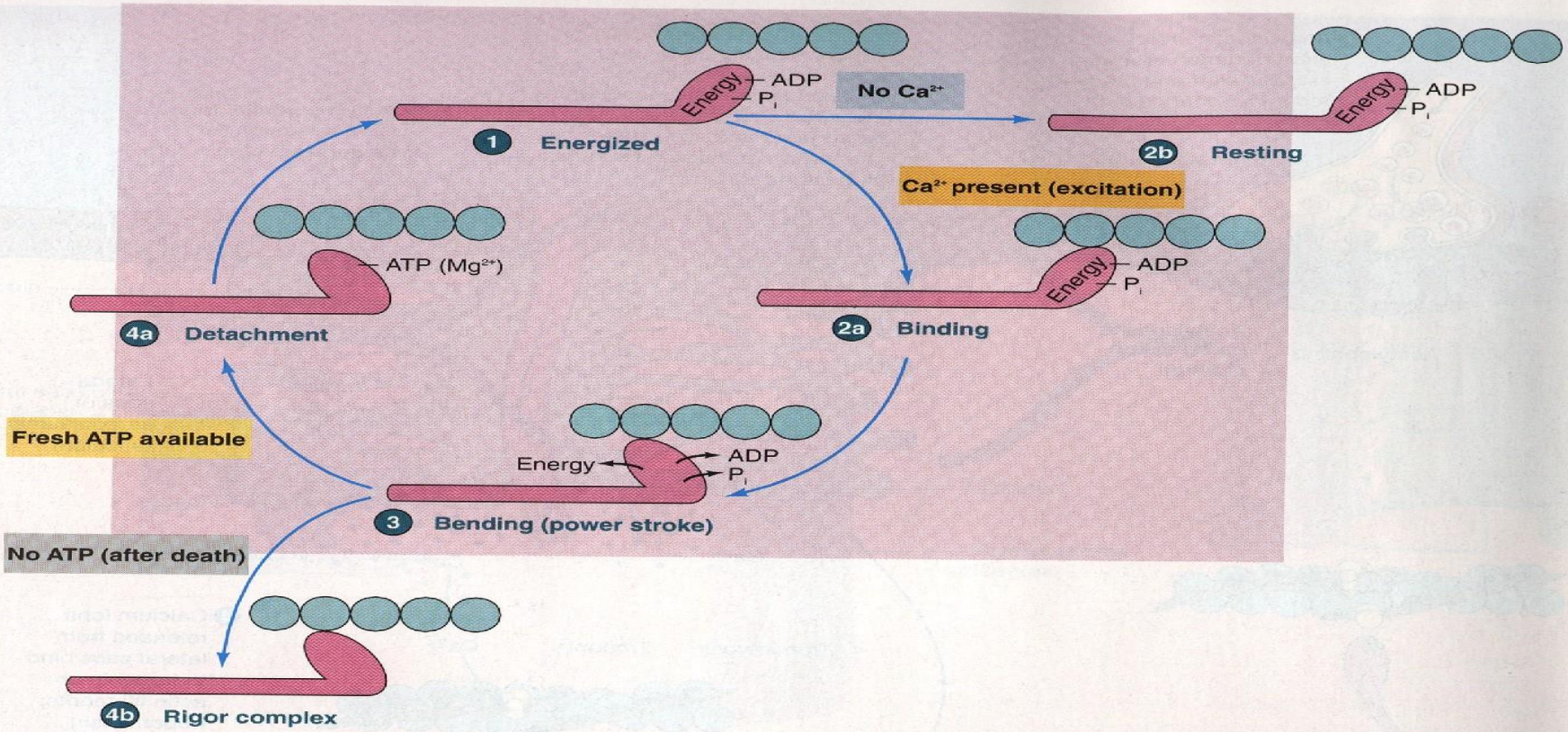


FIGURE 8-7
Role of calcium in turning on cross bridges


Actin molecules in thin myofilament
Myosin cross bridge
Z line
BINDING Myosin cross bridge binds to actin molecule.
POWER STROKE Cross bridge bends, pulling thin myofilament inward.
DETACHMENT Cross bridge detaches at end of power stroke and returns to original conformation.
BINDING Cross bridge binds to more distal actin molecule; cycle repeated.
(a)
(b)
Thin myofilament
Thick myofilament
(c)



1 ATP split by myosin ATPase; ADP and P_i remain attached to myosin; energy stored in cross bridge.

...or...

2a Ca^{2+} released upon excitation; removes inhibitory influence from actin, enabling it to bind with cross bridge.

2b No excitation; no Ca^{2+} released; actin and myosin prevented from binding; no cross-bridge cycle; muscle fiber remains at rest.

3 Power stroke of cross bridge triggered upon contact between myosin and actin; ADP and P_i released.

...or...

4a Linkage between actin and myosin broken as fresh molecule of ATP binds to myosin cross bridge; cross bridge assumes original conformation; ATP hydrolyzed (cycle starts again at step 1).

4b If no fresh ATP available (after death), actin and myosin remain bound in rigor complex.

FIGURE 8-13
Cross-bridge cycle

- Therefore , on order to release the head of Myosin from Actin , a new ATP is needed to come and combine with the head of Myosin .
- Q: What is Rigor Mortis ?
- Q: ATP is needed for 3 things : what are they ?
- ATP is needed for 3 things :
- (1) Power stroke .
- (2) Detachment of myosin from actin active sites
- (3) Pumping C++ back into the Sarcoplasmic reticulum .
- Q: Is muscle relaxation a passive or active process ?
- A : it is active ; Why ? Because it needs ATP .

- Q: What happens to A-band and I-band during contraction ?
- Q: Ca++ is needed in nerve & muscle : when and where ?
- A : In nerve → needed for exocytosis (& release of Ach)
- In Muscle → needed for contraction .

- Thanks