Lectures 5 & 6
Physiology of Skeletal Muscle and Contraction

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The Muscle Action Potential

- 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) .
- CV = 3-5 m/s (slower than big nerves) .

Muscle Contraction

There are 4 important muscle proteins :

A/ two contractile proteins that slide upon each other during contraction:

(1) Actin

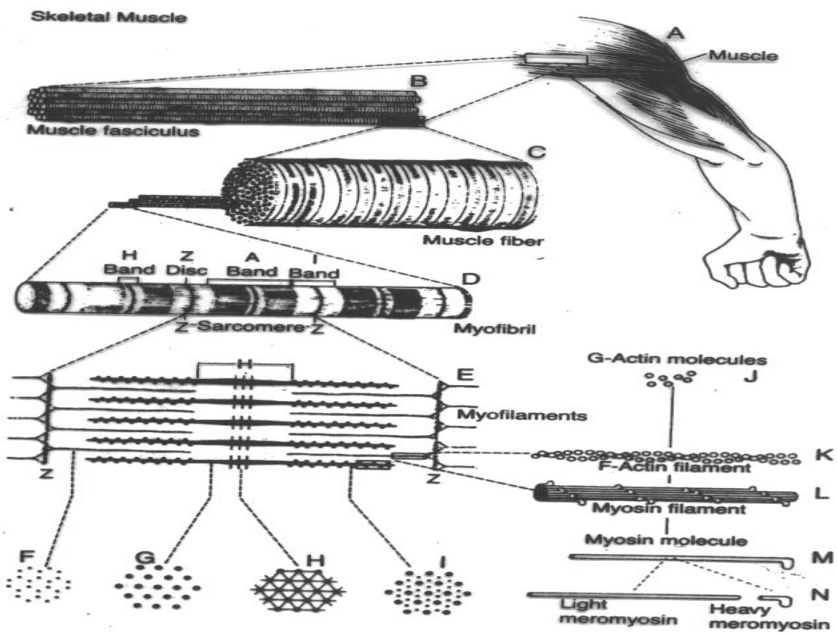
(2) Myosin ,

B/ And two regulatory proteins :

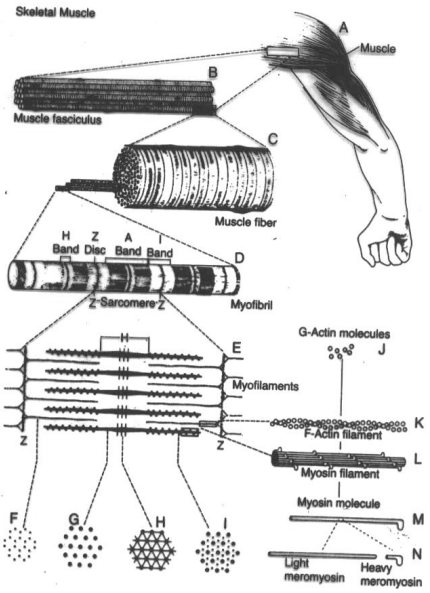
(1) Troponin → excitatory to contraction

(2) Tropomyosin → inhibitory to contraction

- Each muscle cell (fiber) is 10 -80 micrometer long & is covered by a cell-membrane called Sarcolemma.
- Each cell contains between a few hundreds to a few thousands Myofibrils.
- Each Myofibril contains 3000 Actin filaments & 1500 Myosin filaments .
- Each myofibril is striated: consisting of dark bands (called A-bands) and light (I-bands).



Muscle Structure (2)



- A-bands consist mainly of Myosin & Actin ; while I-bands consist of Actin.
- The ends of Actin are attached byZ-Discs(Z-lines).
- The part of the Myofibril lying between two Z-discs is called Sarcomere . It is about 2 mcrometers .
- When contraction takes place Actin & Myosin slide upon each other , & the distance between two z-discs decreases : This is called Sliding Filament Mechanism

Sliding Filament Mechanism: will be discussed later)

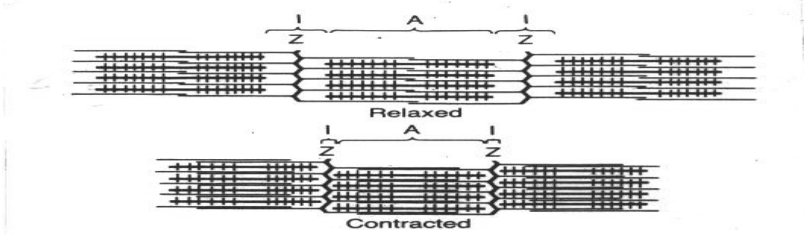
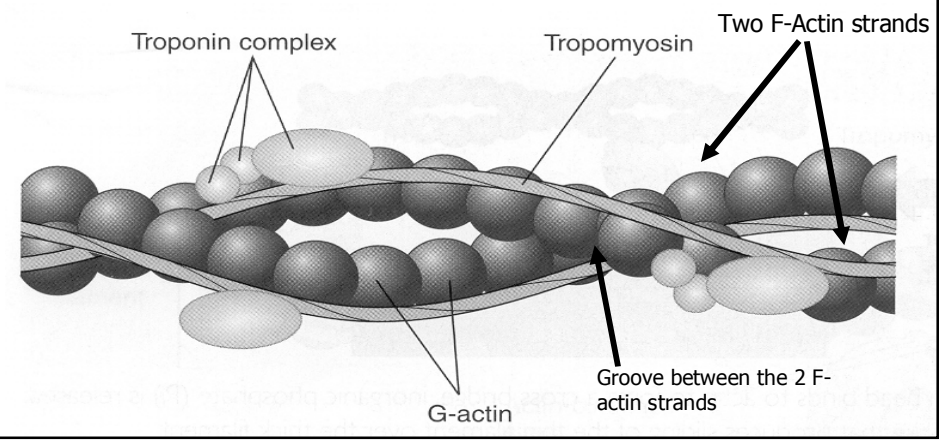
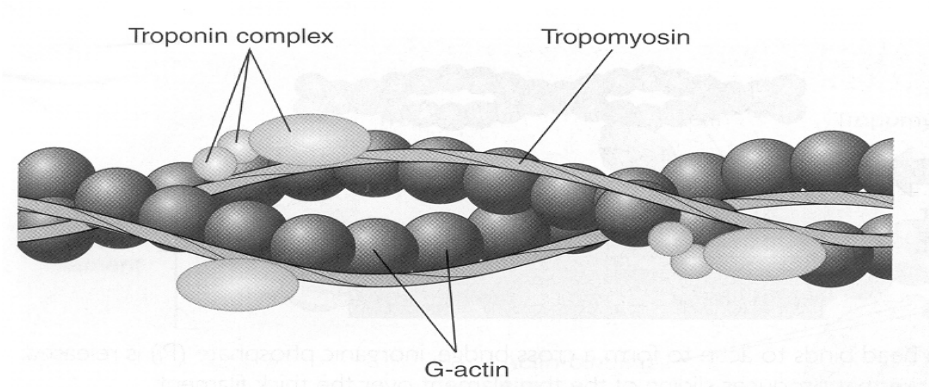


Figure 6–4 The relaxed and contracted states of a myofibril, showing sliding of the actin filaments (black) into the spaces between the myosin filaments (red).

Actin Filament consists of Globular G-actin molecules that are attached together to form a chain.
like a double helix\Each two chains wind together



> Each G-Actin molecule has a binding site for Myosin head
(called actin active sites)
> These active sites are covered and hidden from the Myosin head by the inhibitory protein Tropomyosin
> When Troponin is activated by Ca++ it will move the Tropomyosin away from these sites and expose them for Myosin.
> then myosin immediately gets attached to them .
> when the myosin head attaches to actin it forms a " cross-bridge"



The diagram of Guyton

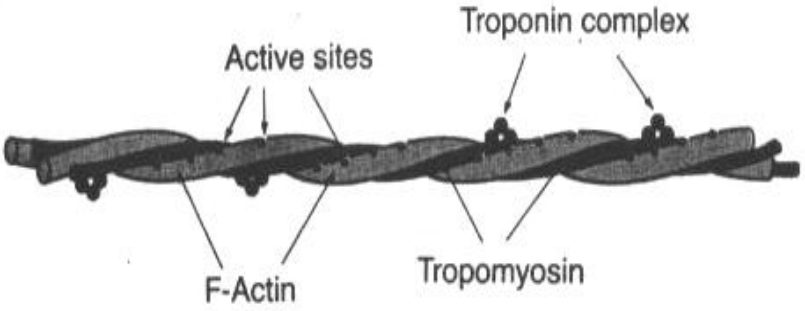


Figure 6–6 The actin filament, composed of two helical strands of F-actin and tropomyosin molecules that fit loosely in the grooves between the actin strands. Attached to one end of each tropomyosin molecule is a troponin complex that initiates contraction.

Myosin (1)

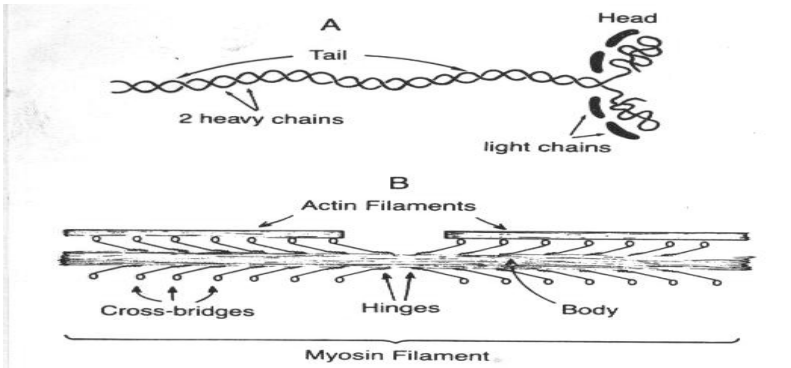


Figure 6–5 *A,* The myosin molecule. *B,* Combination of many myosin molecules to form a myosin filament. Also shown are the cross-bridges and the interaction between the heads of the cross-bridges and adjacent actin filaments.

- Each Myosin molecule has (1) Head (2) Hinge (joint) and (3) Tail ; and each myosin head contains an ATP binding site as well as ATP-ase enzyme .

Myosin (2)

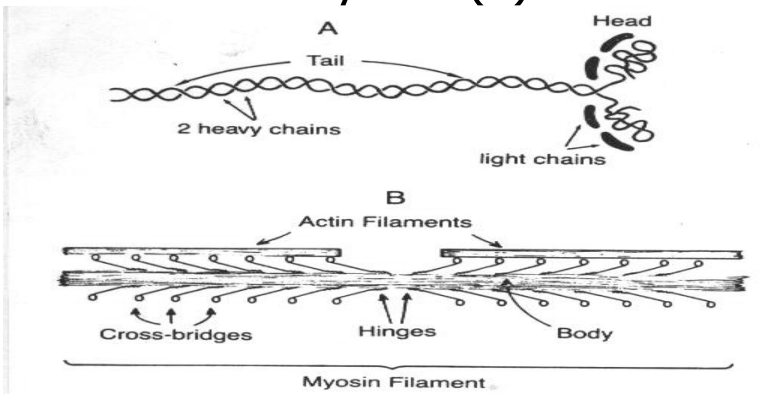
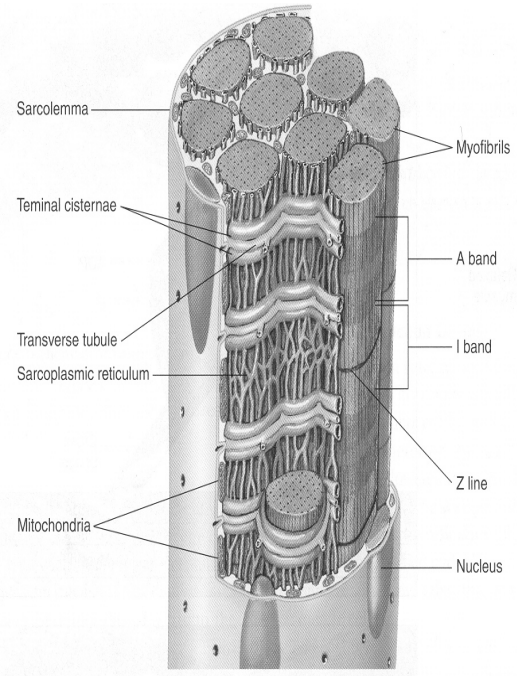


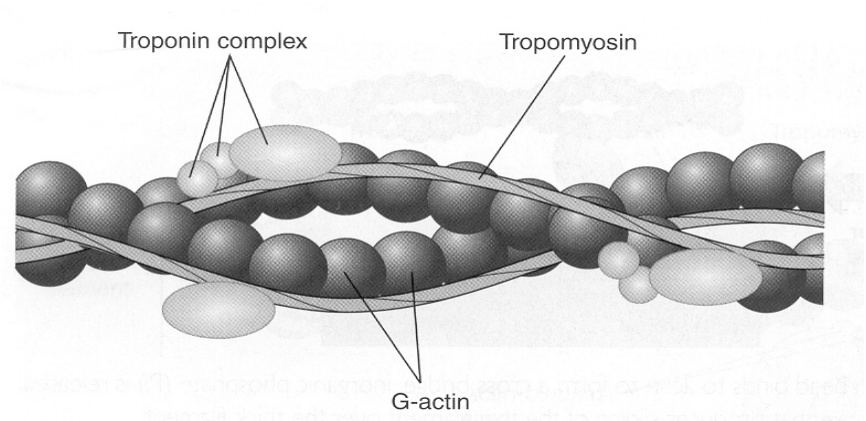
Figure 6–5 *A,* The myosin molecule. *B,* Combination of many myosin molecules to form a myosin filament. Also shown are the cross-bridges and the interaction between the heads of the cross-bridges and adjacent actin filaments.

- Each 200 myosin molecules aggregate to form a myosin filament , from the sides of which project myosin heads in all directions .

- The EPP at the motor end-plate triggers a muscle AP
- The muscle AP spreads down inside the muscle through the Transverse Tubules (T-tubules) to reach the Sarcoplasmic Reticulum (SR) .
- In the SR the muscle AP opens calcium channels (in the walls of the SR) → calcium passively flows out (by concentration gradient) of the SR into muscle cytoplasm→ Ca++ combines with Troponin



The activated troponin pulls the inhibitory protein➢ tropomyosin away from the myosin binding sites on actin → and once these sites on Actin are exposed → myosin heads quickly bind to them



This binding activates the enzyme ATPase in the Myosin Head → it breaks down ATP releasing energy → which is used in the "Power Stroke " to move the myosin head

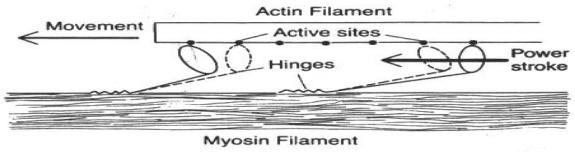


Figure 6–7 The "walk-along" mechanism for contraction of the muscle.

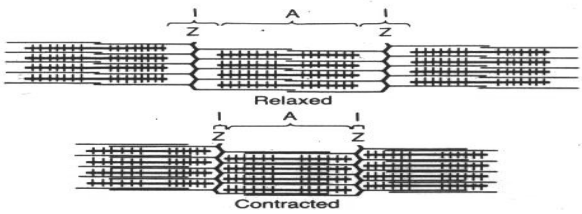
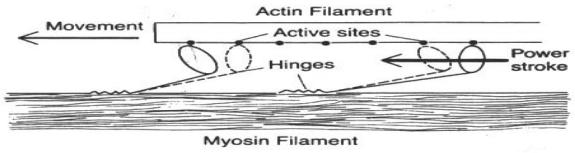


Figure 6–4 The relaxed and contracted states of a myofibril, showing sliding of the actin filaments (black) into the spaces between the myosin filaments (red).

The " power stroke " means tilting of the cross-bridge head (myosin head) and dragging (pulling) of actin filament



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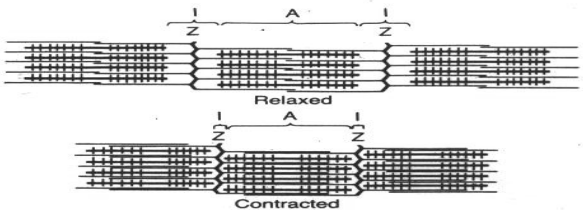

Figure 6–4 The relaxed and contracted states of a myofibril, showing sliding of the actin filaments (black) into the spaces between the myosin filaments (red).

- Then , 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 neede for 3 things : what are they ?
- Q: Is muscle relaxation a passive or active process ? Why ?
- Q: What happens to A-band and I-band during contraction ?
- Q: Ca++ is needed in nerve & muscle : when and where ?

Summary (1)

(1) Muscle AP spreads through T-tubules
(2) it reaches the sarcoplasmic reticulum where → opens its Ca++ channels → calcium diffuses out of the sarcoplasmic reticulum into the cytoplasm → increased Ca++ concentration in the myofibrillar fluid .
(3) Ca++ combines with Troponin , activating it
(4) Troponin pulls away Tropomyosin
(5) This uncovers the active sites in Actin for Myosin
(6) Myosin combines with these sites
(7) This causes breakdown of ATP and release of snergy which will be used in Power Stroke
(8) Myosin and Actin slide upon each other → contraction
(9) A new ATP comes and combines with the Myosin head .This causes detachment of Myosin from Actin .

Summary (2)

- 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 .