Physiology Team

MEDICAL COLLAGE 433

Muscle Contraction

Color Index

Red = important

Purple = Addition

Orange = Explanation

@PhysiologyTeam

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Objectives :

✓To give reasonable comprehension of the mechanism of excitation-concentration coupling with reference to neurotransmitters, receptors Ca++ and esterase.

✓To comprehend muscle contraction on the basis of molecular structures.

✓To explain biophysics in terms of length-tension and force velocity-relationship.

Some facts about Skeletal muscle:

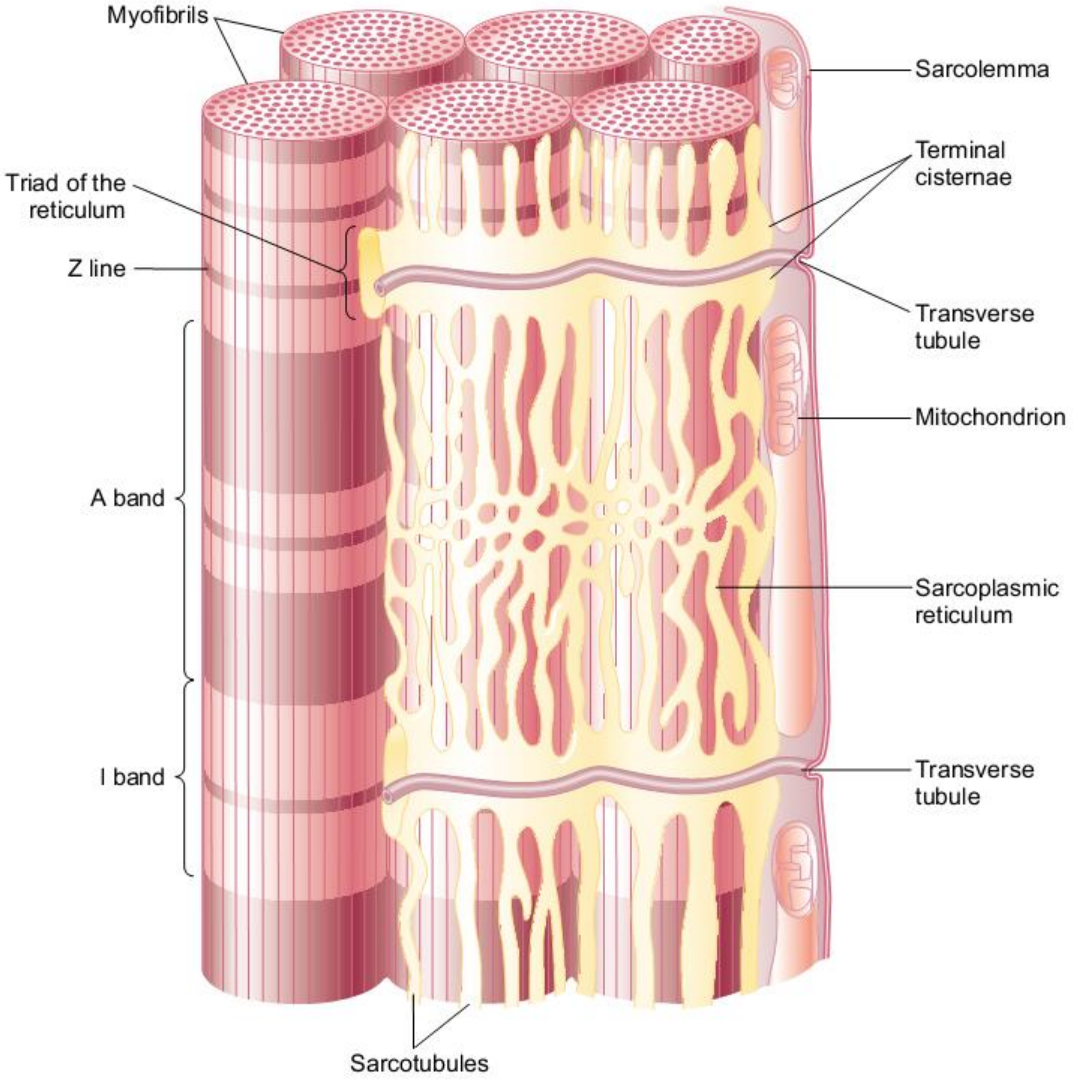
- **About 50% of the body are muscles:** 40% is composed of skeletal and 10% is smooth and cardiac muscles.
- Muscle RMP = -90 mV
  (same as in nerves) .
- All skeletal muscles are composed of numerous fibers ranging from 10-80 µM in diameter.
- Skeletal muscle can be hundreds of centimeters long & is covered by a cell-membrane called **Sarcolemma**.
- The whole muscle is composed of fasciculi »»»»»» muscle fiber »»»»»» myofibril

Histology of muscle

Sarcoplasm: Matrix inside muscle fiber in which **myofilaments** suspended, it is filled with ICF and contains K, Mg, Phosphate, and proteins. Also present are large number of mitochondria to supply ATP.

Sarcoplasmic reticulum: Surrounding each myofibril is an extensive membrane-enclosed intracellular compartment called the SR, which plays a key role in activating muscle contraction

Transverse tubules (T-tubule): The T-tubule membrane is continuous with the surface membrane.



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Muscle Fibers & Myofibril

Each muscle fibres contains between several hundreds to several thousands Myofibrils, the myofibril is striated :

- **Each Myofibril contains Actin filaments (thin) & Myosin filaments (thick) which are partially interdigitated.**
- **Dark bands → (called A-bands)**
- **Light bands → (called I-bands)**
- **Each Myofibril is made of 3000 Actin filaments and 1500 Myosin filaments.**

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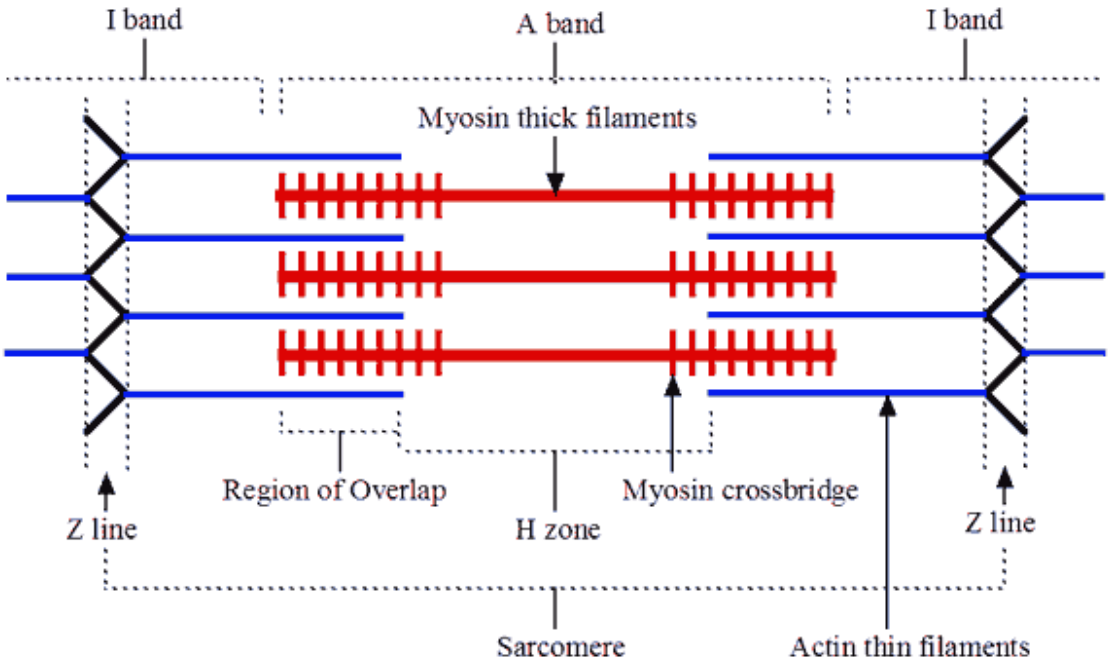
What is the sarcomere ?

Contractile unit of muscle, it is the zone between two Z lines

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

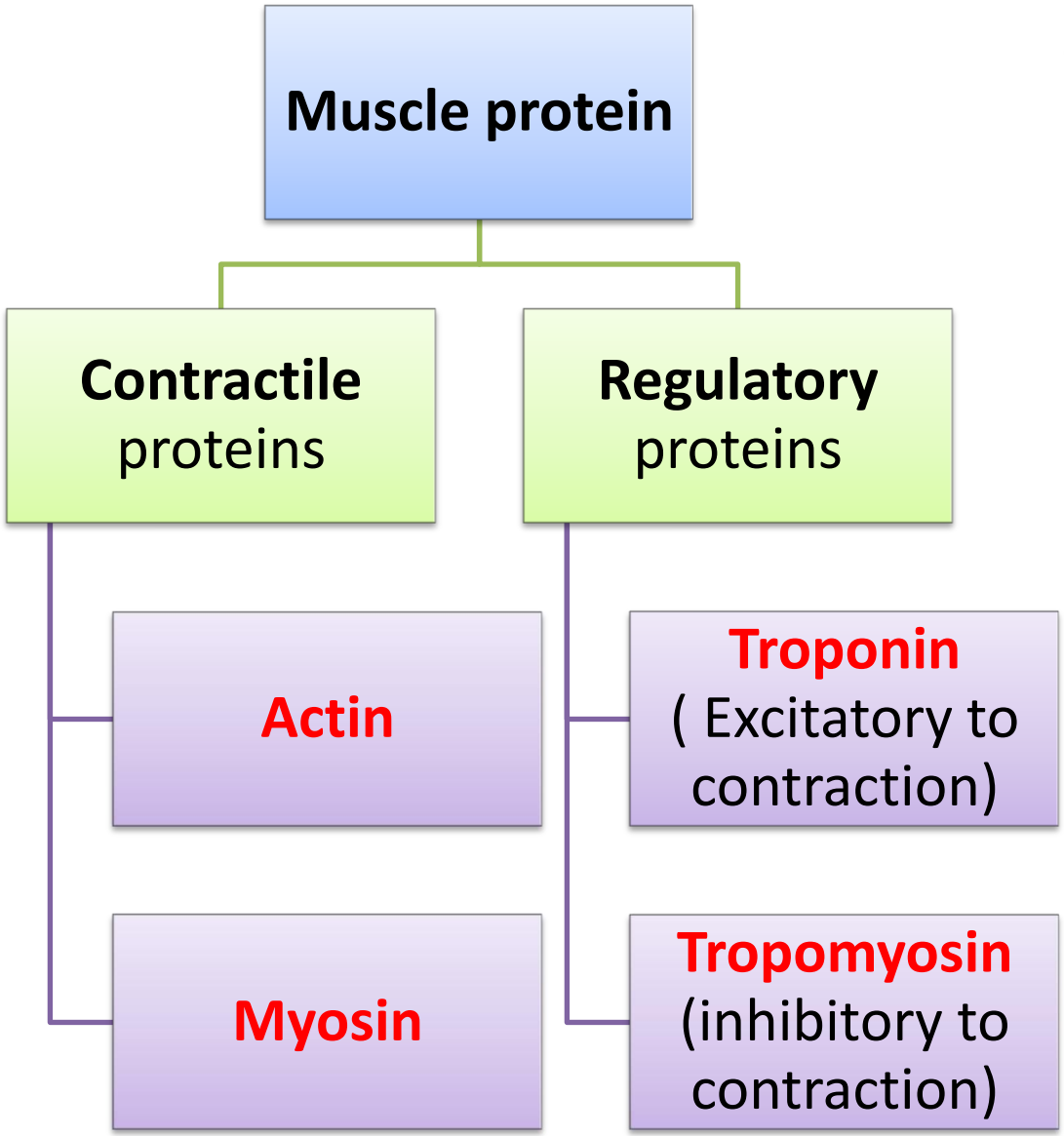


Inside sarcomere three bands

I band =
Actin only

H band =
Myosin Only

A band =
Actin & myosin



Myosin (Thick Filament)

- **Each Myosin molecule has :**

(1) Head
(2) Tail
(3) Hinge (joint)

- **The head contains :**

(1) Actin binding site
(2) ATPase site .

Actin (Thin Filament)

- Actin is made of globular protein called G-actin :

1- G-actins are attached together → form F-actin strand → Each two strands wind together → form double helix called Actin Filament.
2- Tropomyosin lies in the groove between the F-actin strands to cover the active sites on actin that bind the head of myosin.
3- Troponin is attached to Tropomyosin and to actin.

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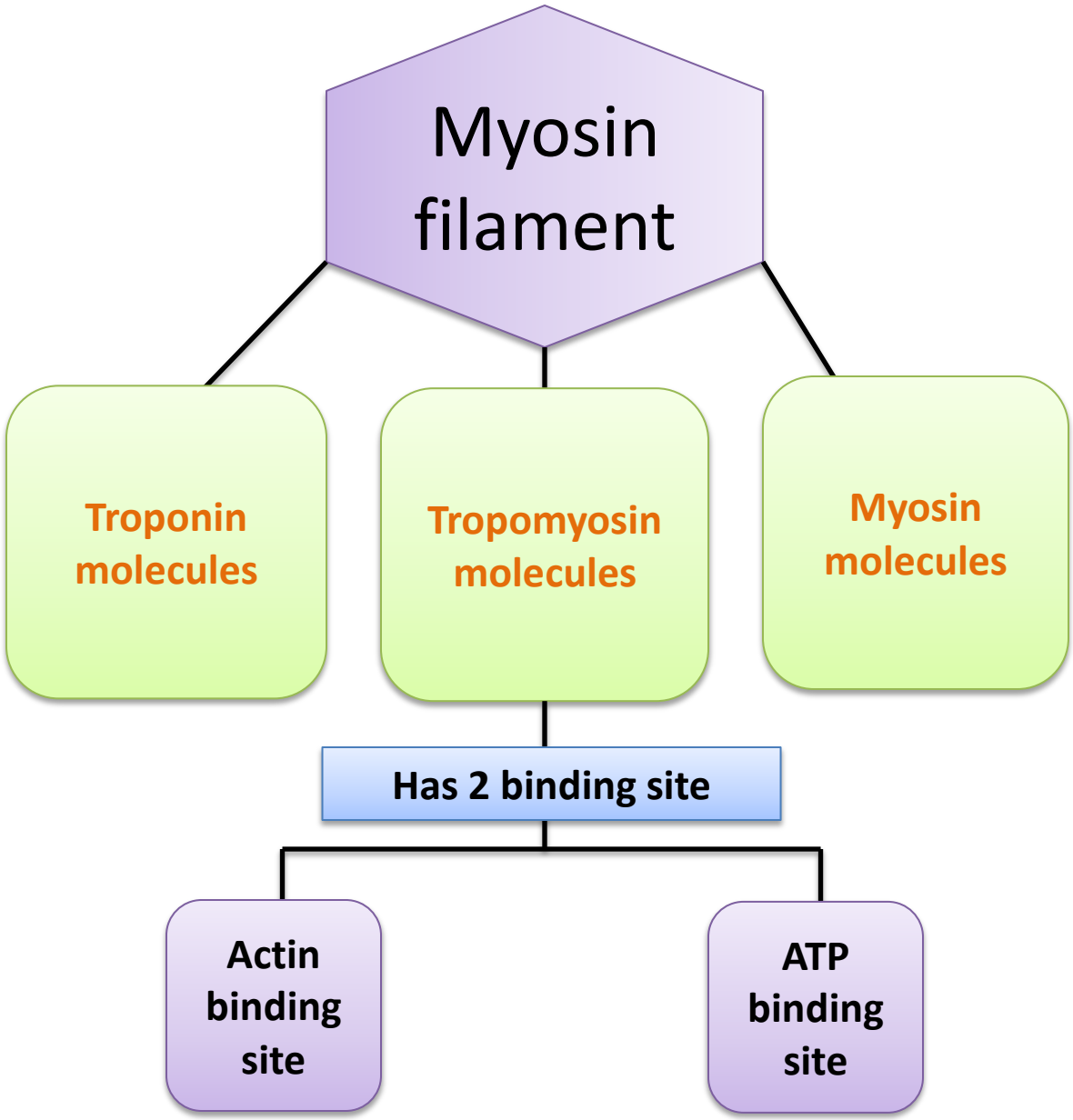
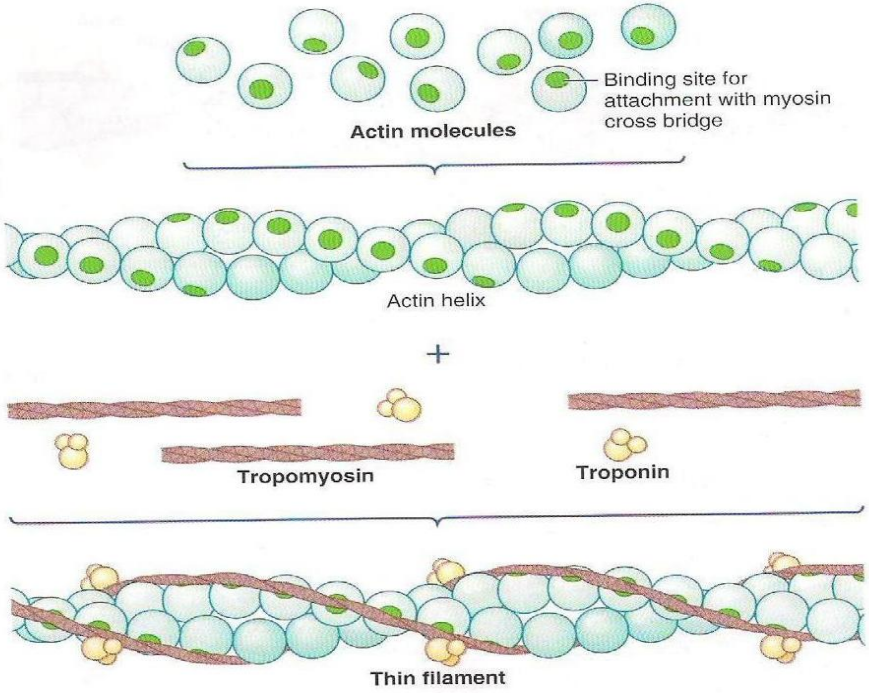
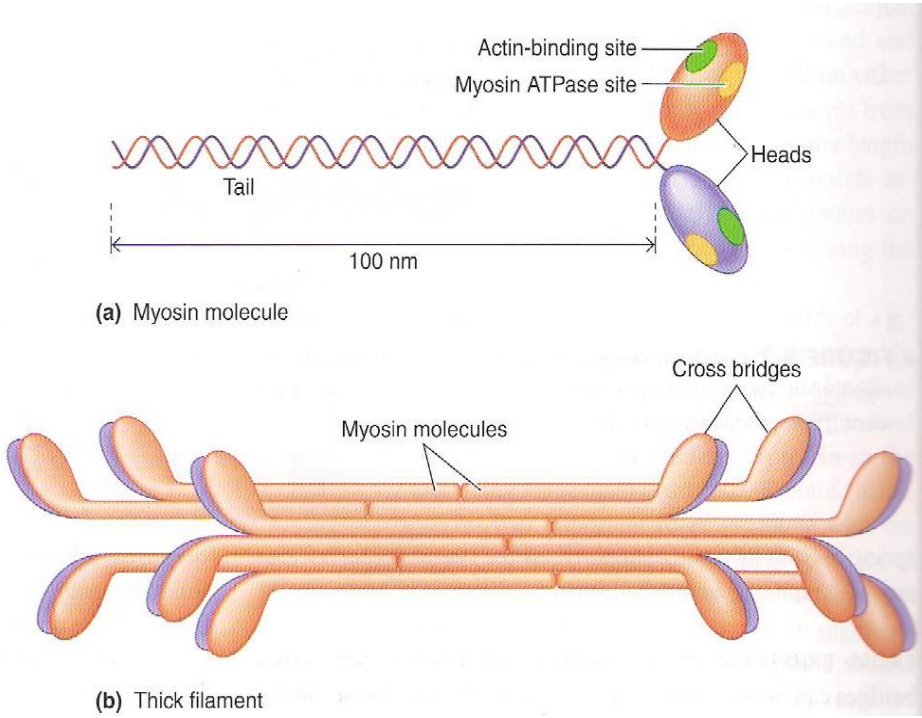

Myosin filament
Troponin molecules
Tropomyosin molecules
Myosin molecules
Has 2 binding site
Actin binding site
ATP binding site

Actin (Thin Filament)



Myosin (Thick Filament)



Sliding Filament Mechanism

When contraction takes place: Actin & Myosin slide upon each other & the distance between two Z-lines decreases. This is called Sliding Filament .

Z-lines come closer to each other :

1- **I-band gets smaller , and eventually may disappear,**

2- **A-band DOES NOT become smaller or bigger**

Walk-along Theory

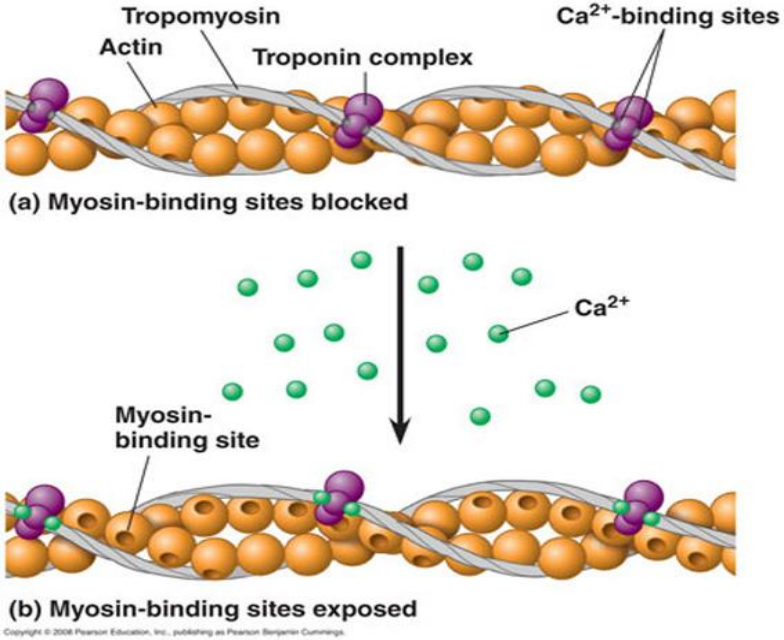
Attachment of Myosin to Actin:

1-activates the enzyme **ATPase** in the **Myosin Head** → ATPase breaks down ATP releasing energy.

2-This energy is used in the "**Power Stroke** " to move the myosin head → leading to pulling & dragging of actin → sliding of actin on myosin

3-The " **power stroke** " means tilting of the Myosin cross-bridge and dragging (pulling) of actin filament

Role of Calcium in turning on Cross bridges



- **Muscle fiber relaxed : no cross-bridge binding** because the cross -bridge binding site on **Actin** is covered by the **troponin-tropomyosin complex**

- **Muscle fiber excited:** released **Calcium** binds with **troponin** and pulling **troponin-tropomyosin complex** to exposure **cross-bridge binding site**

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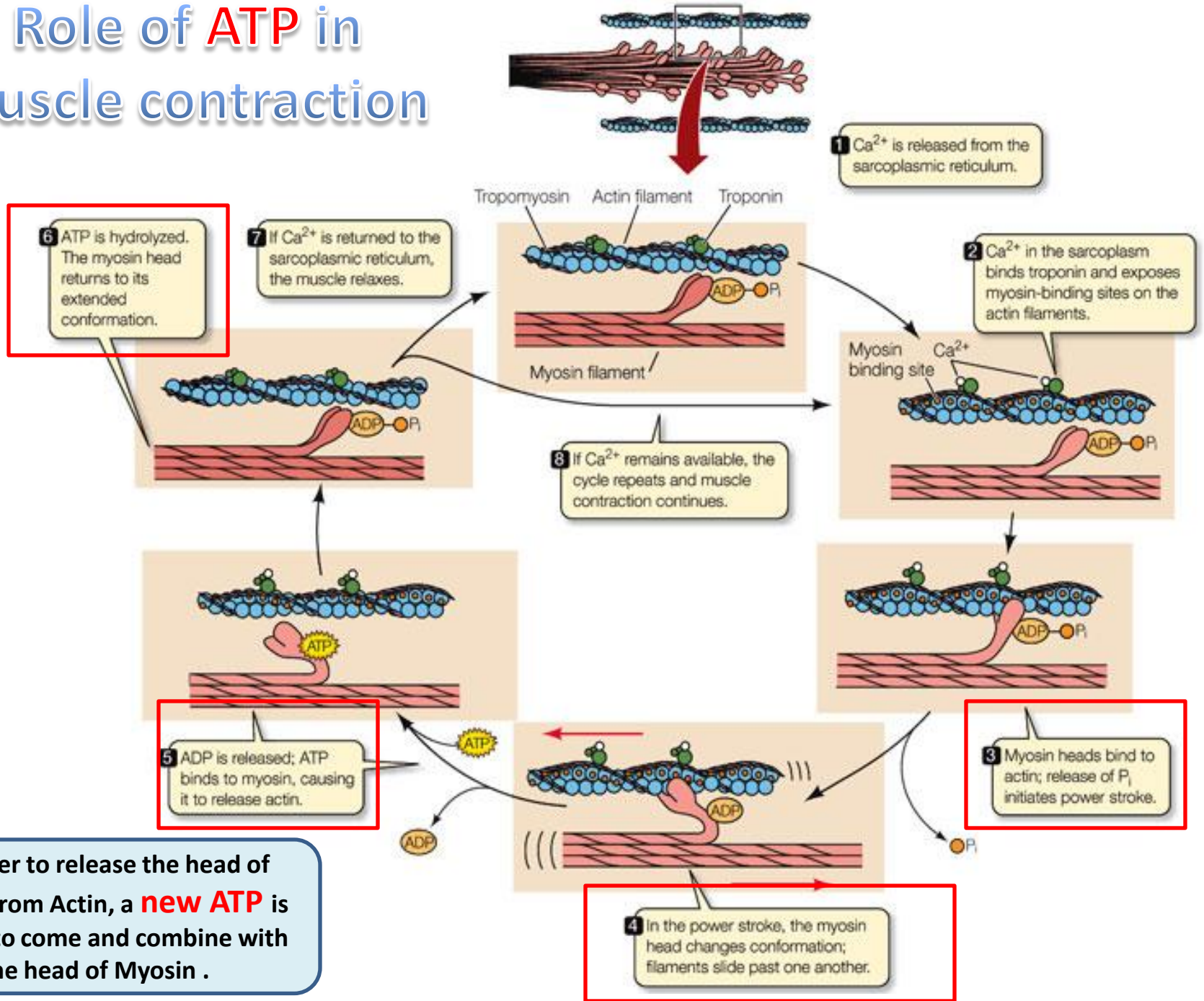
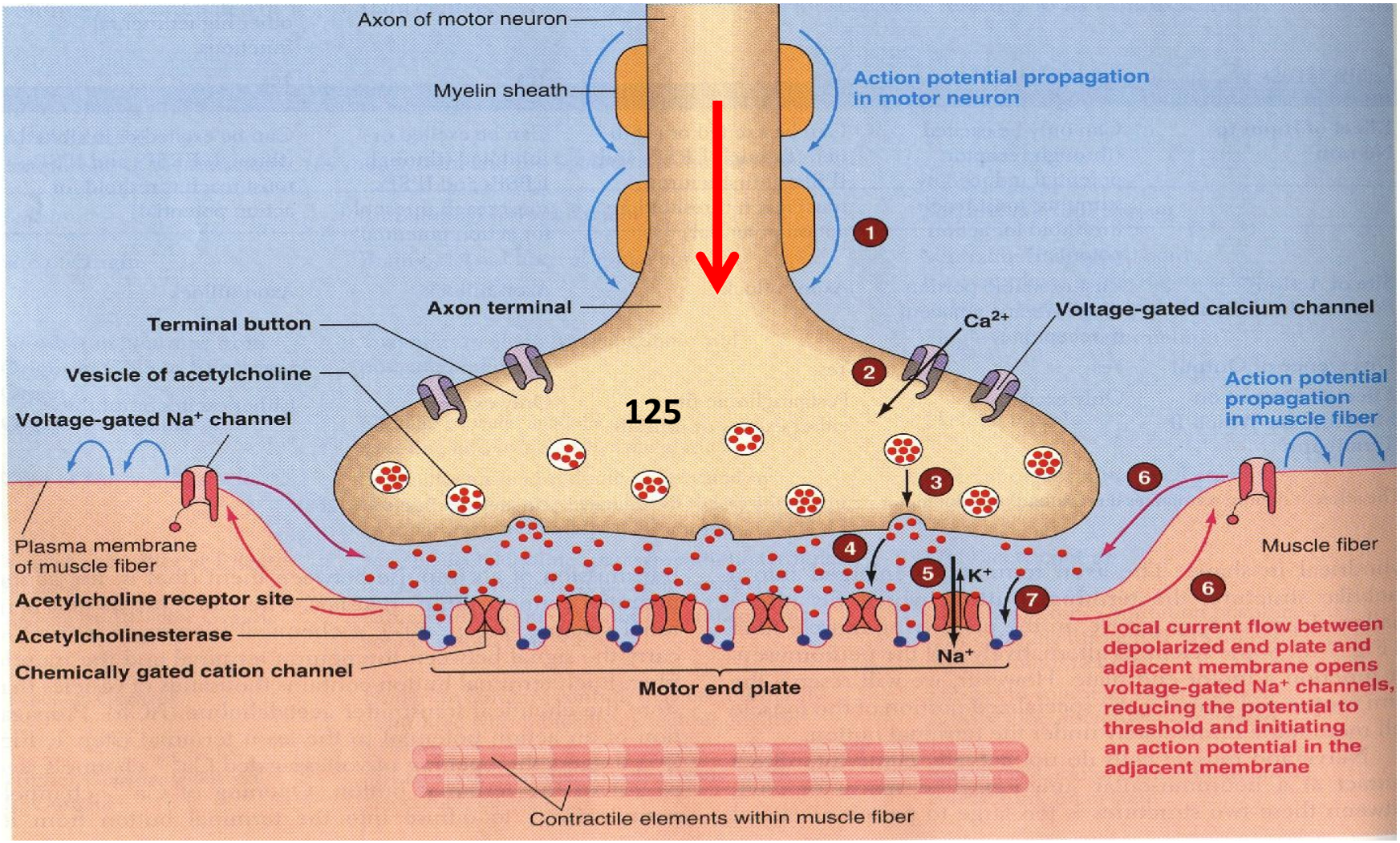
Role of ATP in muscle contraction

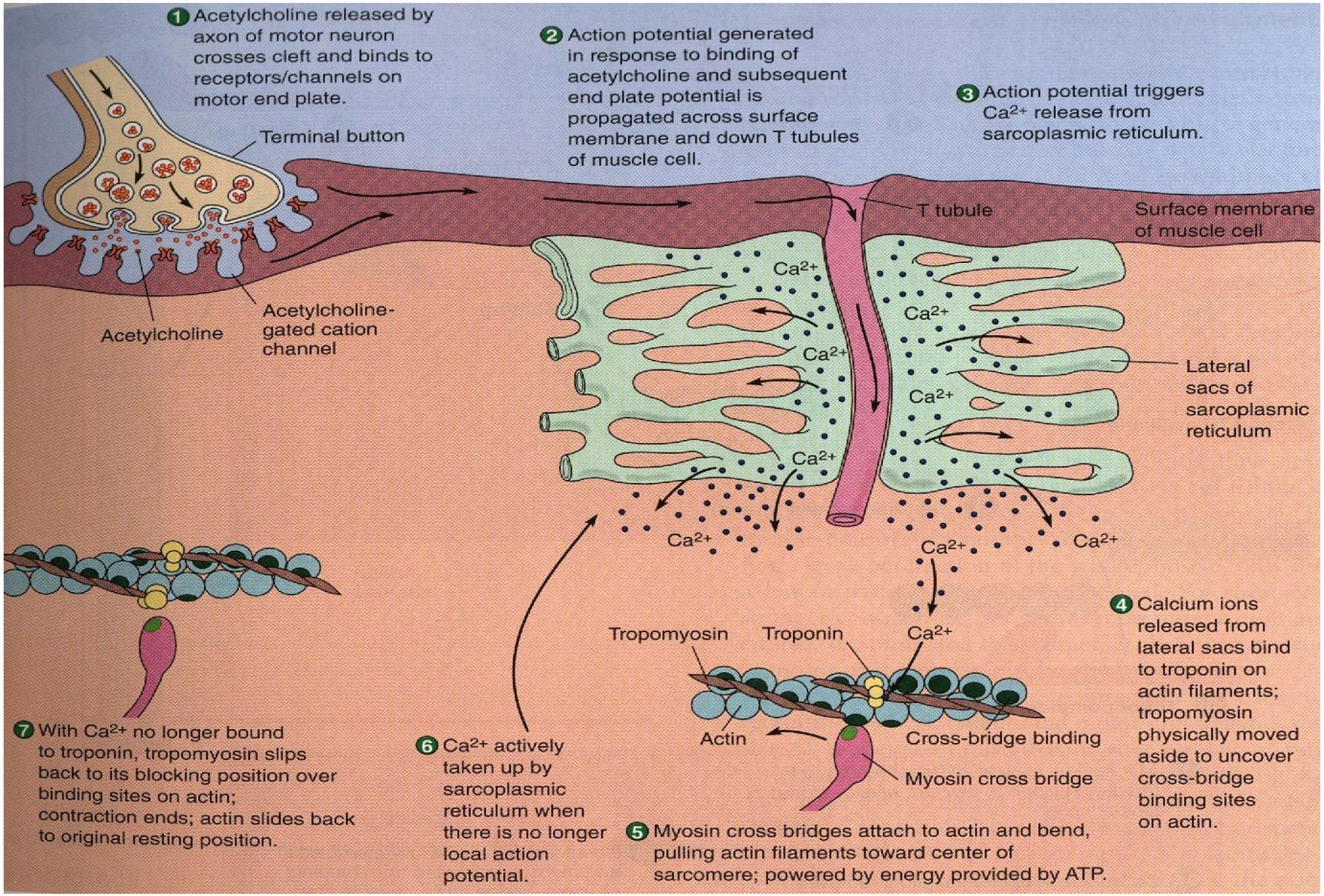


On order to release the head of Myosin from Actin, a new ATP is needed to come and combine with the head of Myosin .

Neuromuscular Junction



Events of muscle contraction (Summary)



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Events of muscle contraction and relaxant (Summary)

(1) **Acetylcholine** is released from **α-motor neuron** → **End Plate potential (EPP)** → **depolarization** of CM (muscle AP) It reaches the **sarcoplasmic reticulum** → opens **calcium** channels → calcium diffuses out of the sarcoplasmic reticulum into the **cytoplasm** → increased calcium concentration in the sarcoplasm.

(2) **Calcium** combines with **Troponin** , activating it

(3) **Troponin** pulls away **Tropomyosin**

(4) This uncovers the **active sites in Actin for Myosin**

(5) **Myosin** combines with these sites

(6) This causes cleavage (breakdown) of **ATP** and the release of energy

(7) This released energy is used to produce **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 (separation)of Myosin from Actin .

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Muscle contraction

1- simple muscle twitch :

The mechanical response (contraction) to single AP (single stimulus)

2- Summation of contraction:

Spatial summation:

the response of single motor unites are added together to produce a strong muscle contraction

Temporal summation:

when frequency of stimulation increased (on the same motor unite), the degree of summation increased, producing stronger contraction

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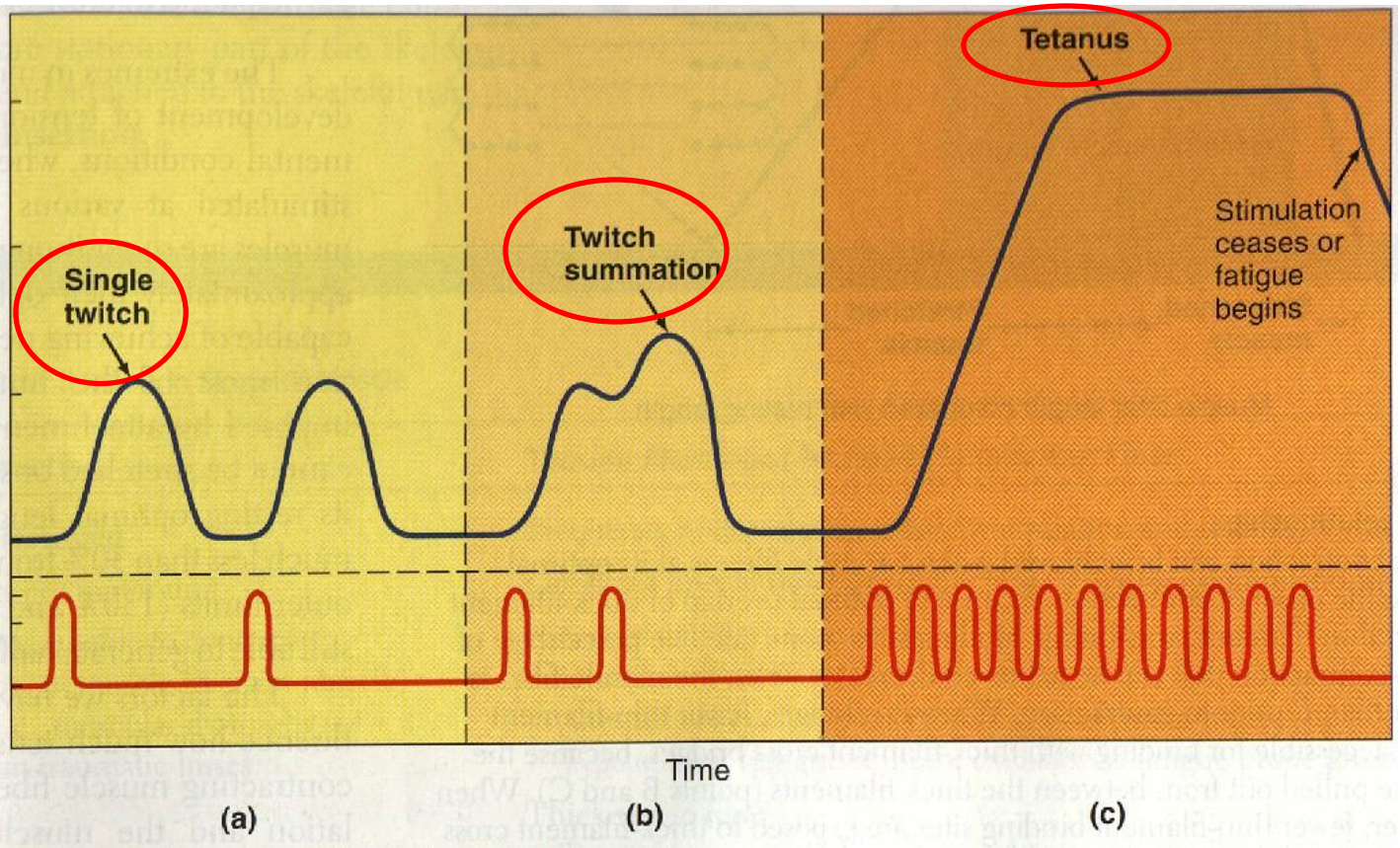

Tetanus: **The continuing of twitch summation due to increase in frequency**

Types of muscle contraction

1- Isometric contraction :
No change in muscle length, but increase in muscle tension (e.g. standing)

To provide a balance in the body.

2- Isotonic contraction :
Constant tension, with change in muscle length (e.g. lifting a loud)

Enable the body to do something useful, Like pick up a pin

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Important Notes & Questions

- **Q: What is Rigor Mortis ?**

The stiffening of skeletal muscles that begins several hours after death

- **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 Calcium 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 ?**

I-band becomes shorter, and A-band does not change

- **Q: Calcium is needed in nerve & muscle : when and where ?**

A : In nerve : needed for exocytosis (release of Ach)
In Muscle : needed for contraction .

On order to release the head of Myosin from Actin, a new ATP is needed to come and combine with the head of Myosin .

Summary :

•The Molecular basis of muscle contraction are:

1. Muscle fibre,
2. Sarcomere,
3. Myosin (thick filament):Cross-bridge
4. Actin (thin filament)Regulatory protein: (Troponin,Tropomyosin)

- When the Muscle fiber is **excited** → released **Calcium** binds with **troponin** and pulling **troponin-tropomyosin complex** to exposure **cross-bridge binding site.**

- Types of muscle contraction are**:** Isometric contraction , Isotonic contraction

Watch these Animations
They are really helpful ☺

Muscle contraction animation + Muscle protein
http://youtu.be/WVuW560nRII

http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter10/animation__action_potentials_and_muscle_contraction.html

http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter10/animation__breakdown_of_atp_and_cross-bridge_movement_during_muscle_contraction.html

http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter10/animation__function_of_the_neuromuscular_junction__quiz_1_.html

http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter10/animation__myofilament_contraction.html

http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter10/animation__sarcomere_contraction.

Multiple Choice Questions

1- Which of the following does not change during Power Stroke?

A) Z lines
B) I bands
C) A bands
D) None of above

2- Which of the following covers the active sites on actin?

A) Troponin
B) Tropomyosin
C) Calcium
D) F-actin

3- Which of the following will bind with troponin to exposure the active site?

A) Ach
B) Calcium
C) Sodium
D) Esterase

4- Releasing the head of myosin require?

A) New ATP
B) Action potential
C) ADP
D) Calcium

5- Transfer of Action potential to Sarcoplasmic reticulum through?

A) Myofibril
B) Sarcolemma
C) Longitudinal tubules
D) Transverse tubules

6- Rigor mortis is the stiffening of skeletal muscles that begins several hours before death

A) True
B) False

7- Contractile unit of muscles?

A) Sarcolemma
B) Sarcomere
C) Actin
D) Myosin

8- to breakage the ATP we need for?

A) Calcium
B) ATPase
C) Action Potential
D) None of above

9- Which of the following component stimulate opening Sodium channel?

A) Calcium
B) Ach
C) cholinesterase
D) All of above

1-C 2-B 3-B 4-A 5-D 6-B 7-B 8-B 9-B

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