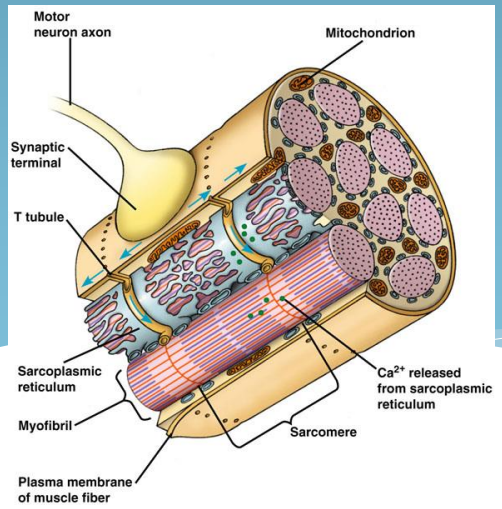
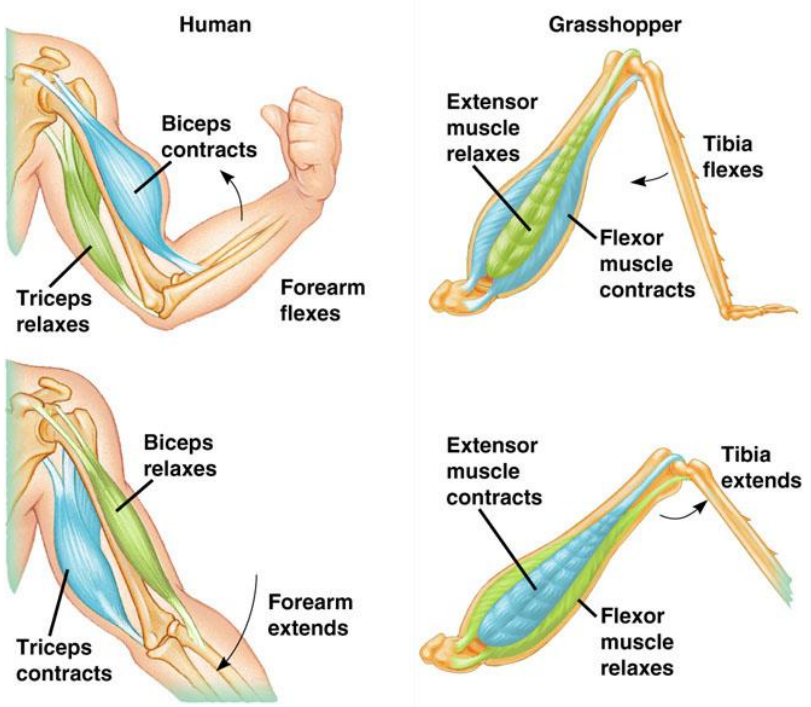
# Muscle Cells & Muscle Fiber Contractions

Packet #8



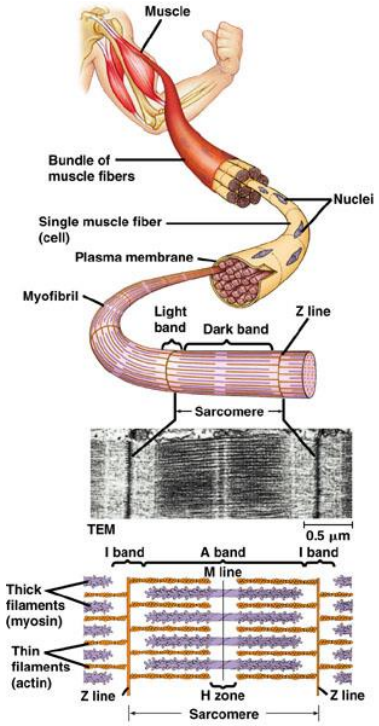
# Introduction

* ***Skeletal muscle*** is attached to bones and is **responsible for movement.**



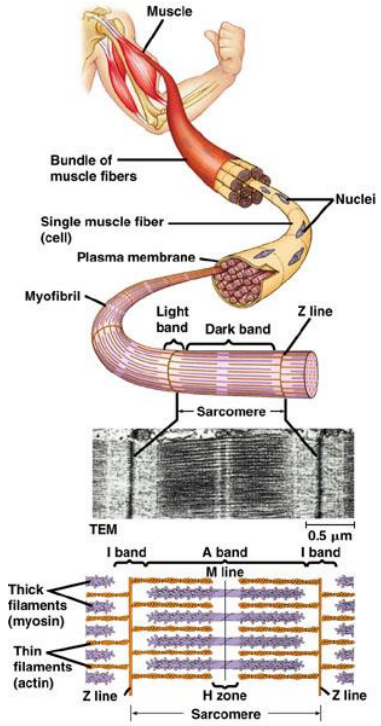
# Introduction II

* Skeletal muscle is composed of **bundles of muscle fibers**
* A single muscle fiber = a muscle cell
* **Muscle fiber (cell)** composed of **myofibrils**



# Introduction III

* Myofibrils are composed of **multiple sarcomeres**.
* Sarcomeres are **separated by Z lines**.
* Sarcomeres composed of
  * **Thick filaments**
    * **Myosin**
  * **Thin filaments**
    * **Actin**

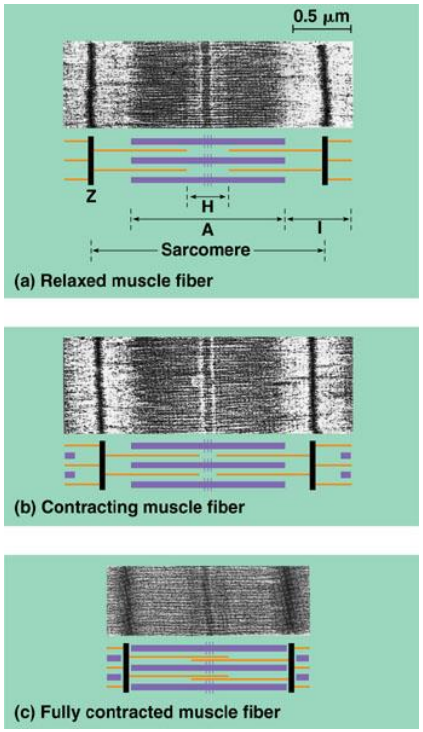


How do muscle cells contract?

# The Sliding Filament Model and Muscle Contraction

# Introduction

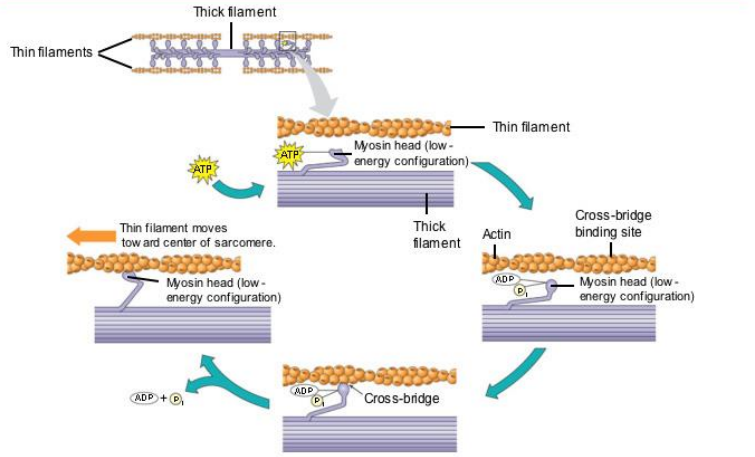
* The **contraction of a muscle** cell is caused by a simultaneous ***shortening*** **of all the sarcomeres.**
  * Caused by the actin filaments sliding past the myosin filaments with no change in length of either type of filament.
    * The myosin filament crawls along the actin filament.



# Introduction II

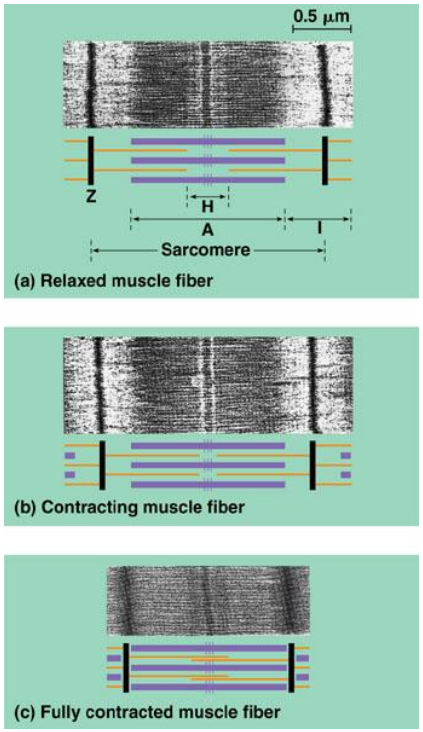
* When a muscle is stimulated to contract, the **myosin heads start to "walk" along the actin filament** in **repeated cycles** of attachment and detachment.

**Figure 49.30 Myosin-actin interactions underlying muscle fiber contraction (layer 4)**



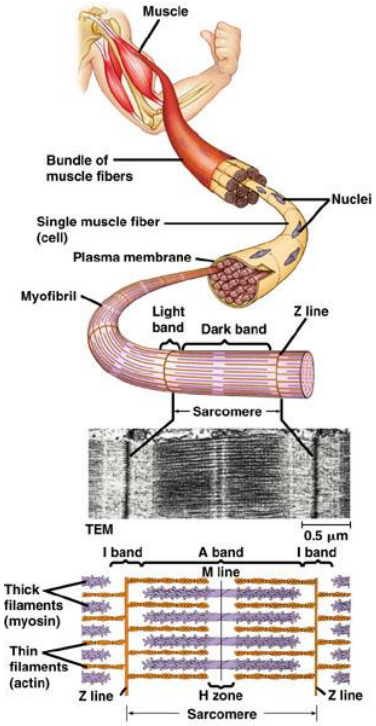
# Sliding Filament Model I

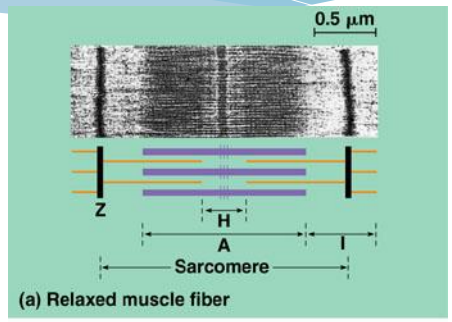
* Muscles, according to the sliding filament model, have the actin and myosin filaments that slide past each other during contraction.
  * **This produces *more overlap* between the two filaments.**

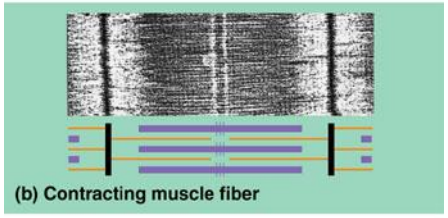


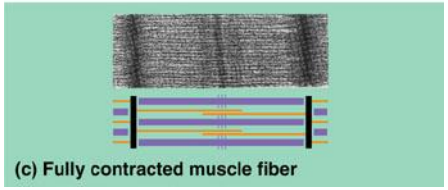
# Sliding Filament Model II

* **A band** = length of thick (myosin) filaments.
* **I band** = area where **ONLY thin (actin) filaments** are found.
* **H zone** = area where **ONLY thick (myosin) filaments** are found.
* During contraction, the **H zone and I bands disappear.**
* What are the steps involved in the "stretching" of these filaments?



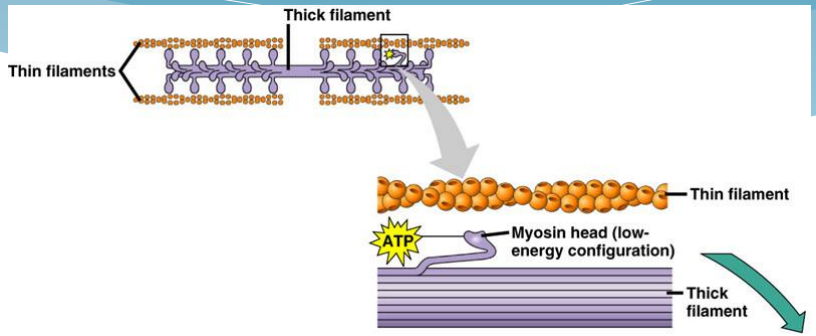



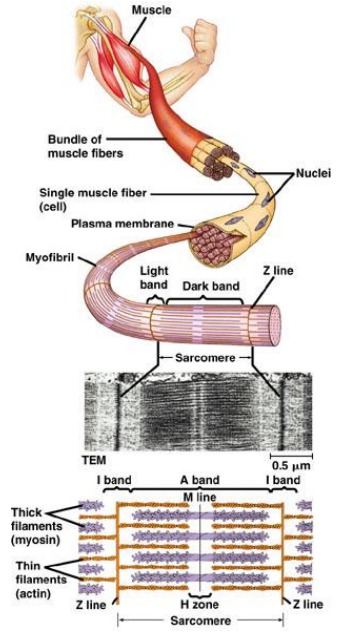



# Muscle Fiber Contraction I

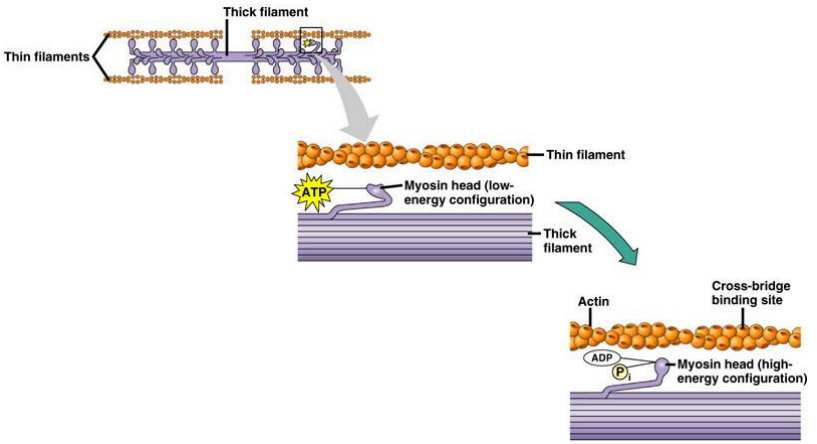
* Myosin head is bound to ATP
  * Low energy state.



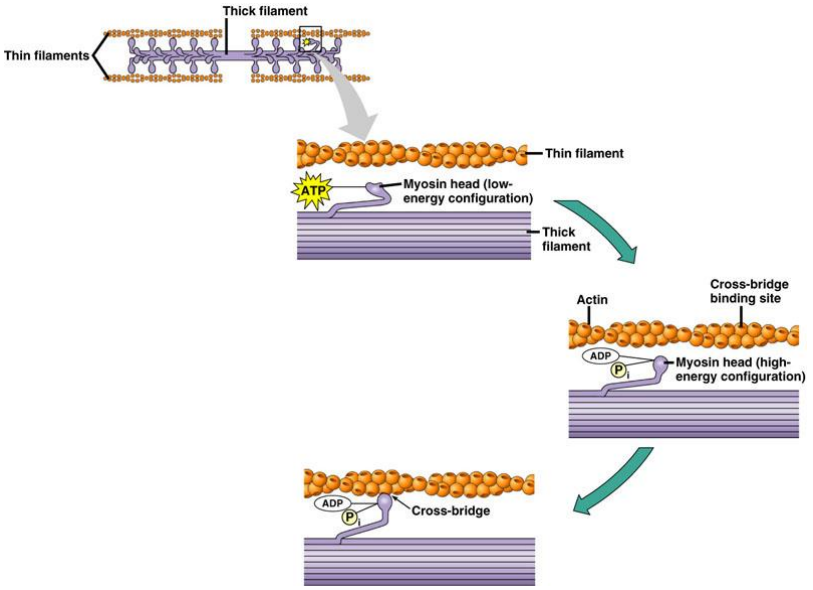
# Muscle Fiber Contraction II

* ATP is hydrolyzed to ADP + P
  * Myosin in a high energy state



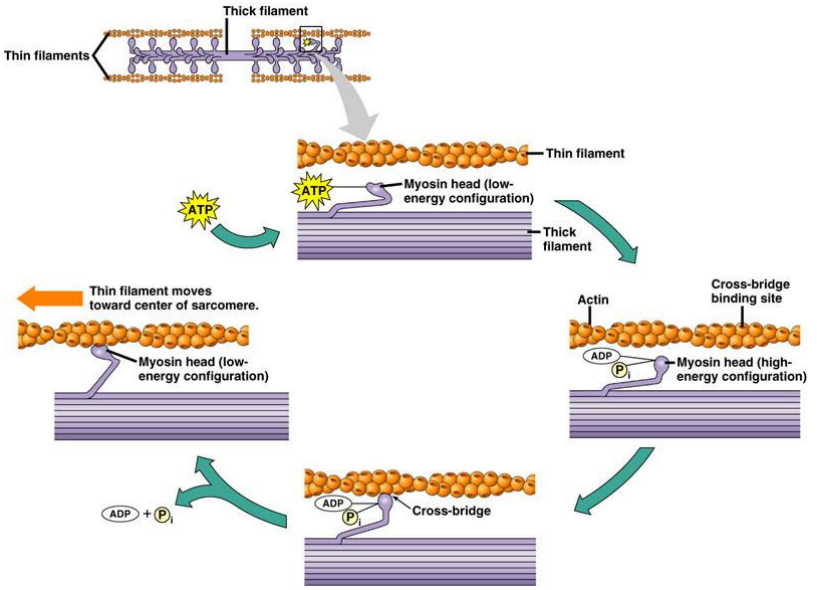
# Muscle Fiber Contraction III

* Myosin head binds to actin
  * Cross bridge formed



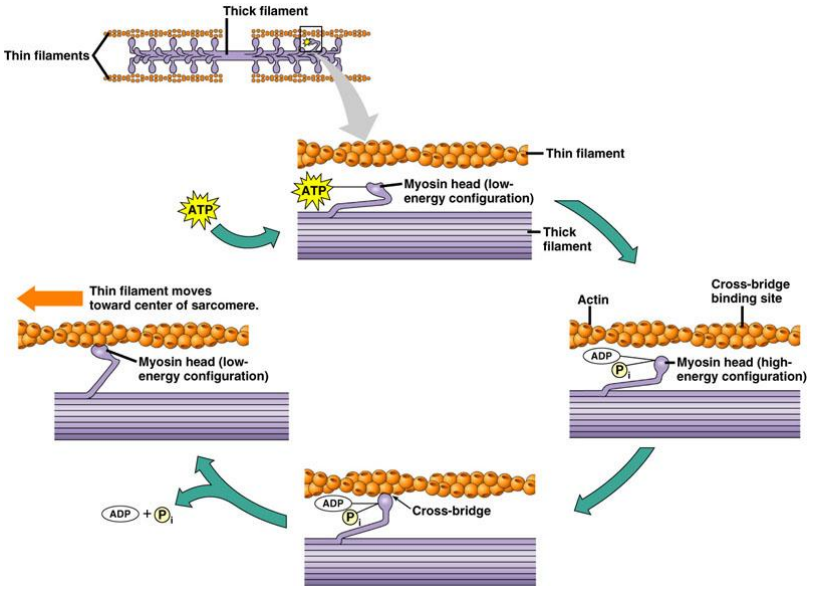
# Muscle Fiber Contraction IV

* ADP & P released from myosin head
* Myosin returns to low energy state
* Thin filament slides towards the sarcomere
  * Myosin moves towards what is called the + end of the actin filament
  * The plus ends are located by the Z lines



# Muscle Fiber Contraction IV

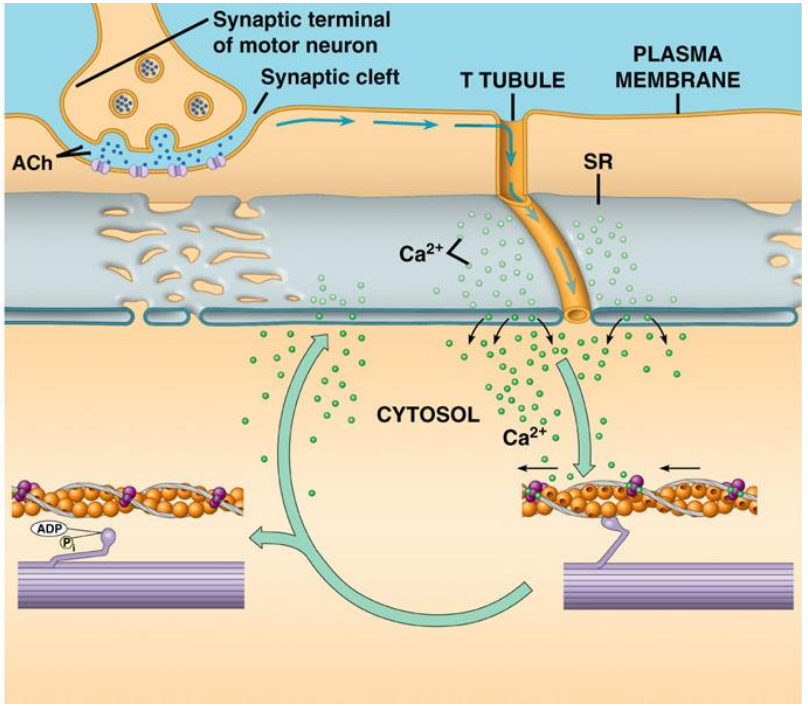
* New molecule of ATP binds to myosin head
* Myosin head released from actin



# Calcium & Regulatory Proteins

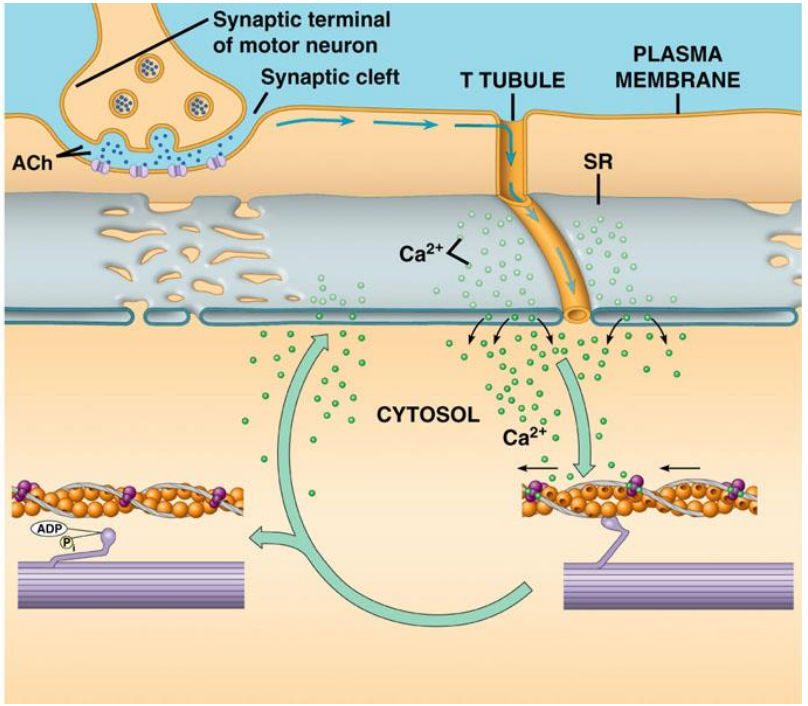
# Introduction I

* The force generating molecular interaction between myosin and actin filaments takes place **ONLY** when the **skeletal muscle receives a message from the nervous system.**
* The signal triggers an action potential in the muscle cell.



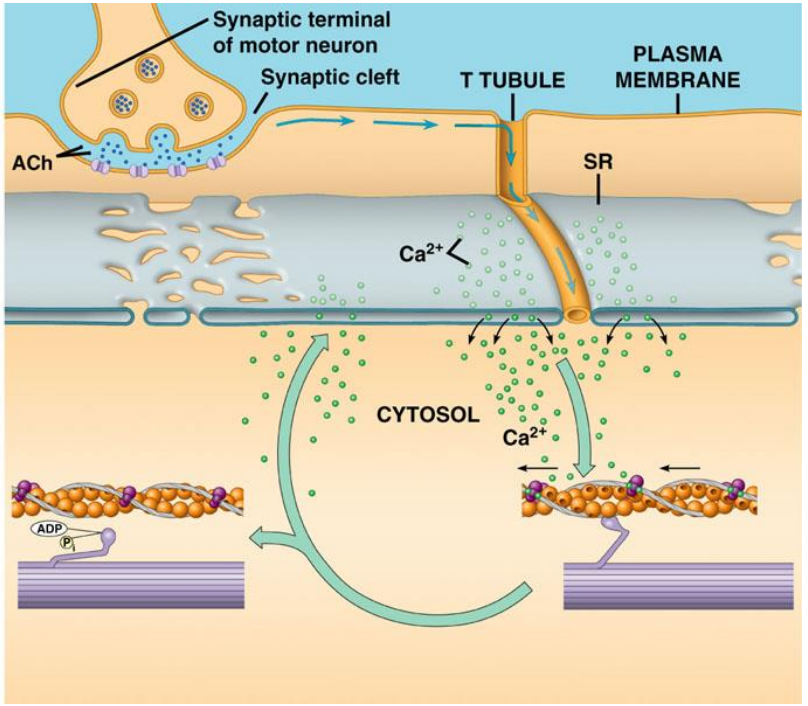
# Introduction II

* **Electrical signal passes through transverse tubules.**
* Electrical signal **relayed to sarcoplasmic reticulum.**
  * **Specialized region of endoplasmic reticulum muscle cells.**
  * Contains a **high concentration of $Ca^{+}$**



# Introduction III

* **$Ca^{+}$, in response to electrical excitation**, is **released into the cytosol** through ion channels that open.
  * These **ion channels are located in the membrane of the sarcoplasmic reticulum membrane**.
  * The opening of the voltage channels occur in response to the change in voltage.



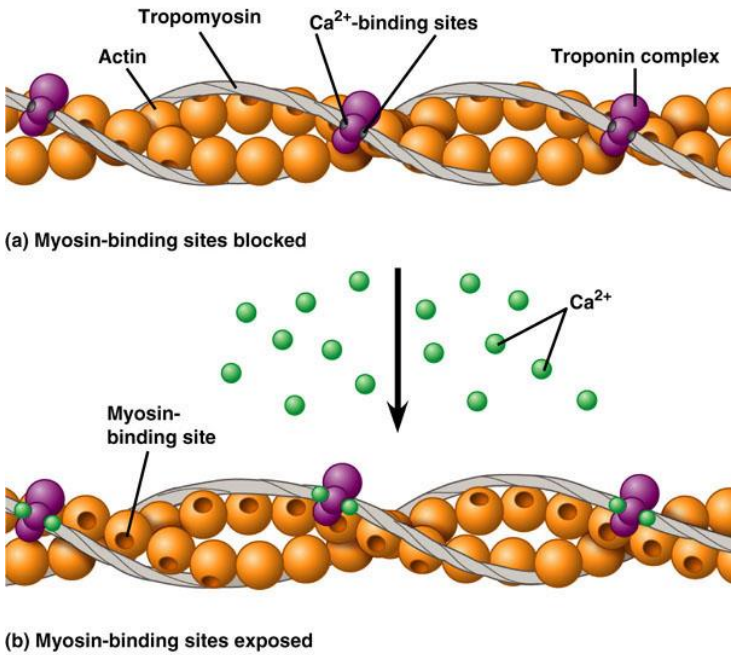
# The Role of Calcium and Regulatory Proteins

# Introduction I

* During muscle contraction, **$Ca^{2+}$ interact**, and work with two **proteins that are closely associated with actin**.
  * The name of the proteins are
    * **Tropomyosin**
      * Rod shaped molecule that is bound to the grove of the actin helix.
    * **Troponin**
      * Protein complex that is associated with the "end" of tropomyosin.
* When **$Ca^{2+}$ binds to troponin**, it induces a change in the its shape.

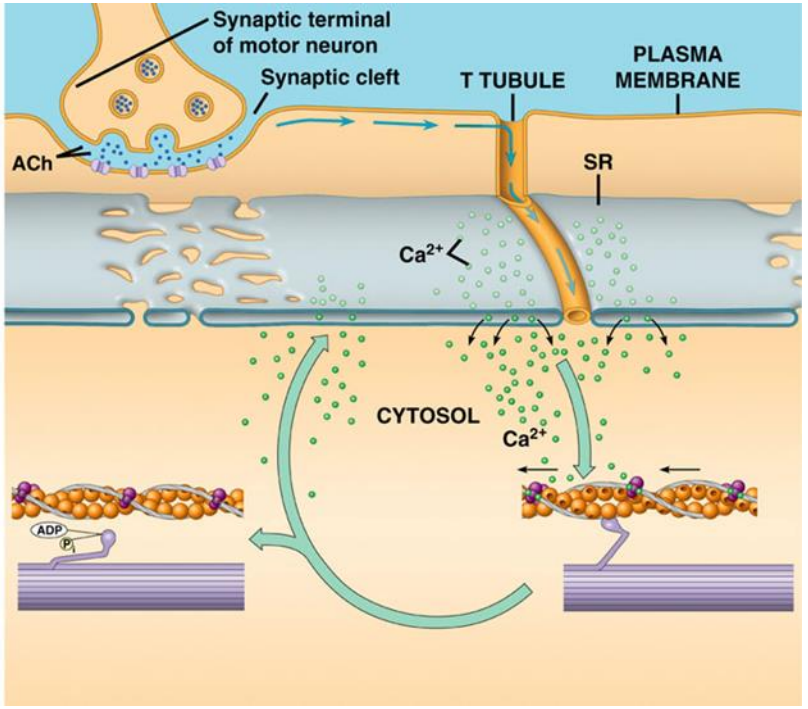
# Role of Calcium & Regulatory Proteins I

* **$Ca^{2+}$ ions bind** on **troponin**
* **Troponin changes shape**
* **Tropomyosin is removed**
  * Myosin binding sites are exposed.
* **Myosin binding sites (heads) bind to the actin filaments and initiates muscle contraction.**



# Role of Calcium & Regulatory Proteins II

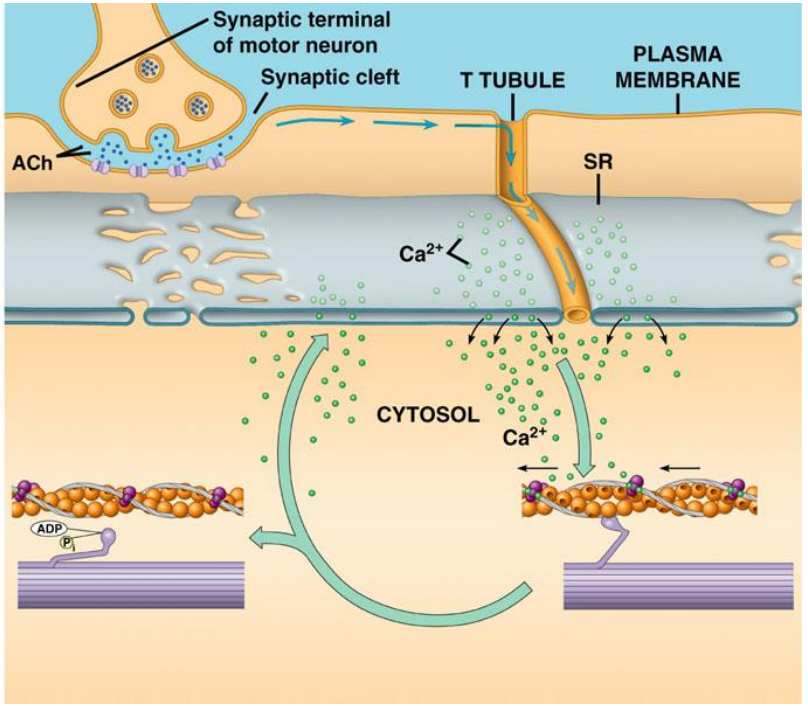
* The **increase in $Ca^{2+}$ ions**, within the cytosol, **stops as soon as the nerve signal stops.**
* **$Ca^{2+}$ is pumped back into the satcoplasmic reticulum.**



# Putting it Together
# Nerve and Muscle Cells

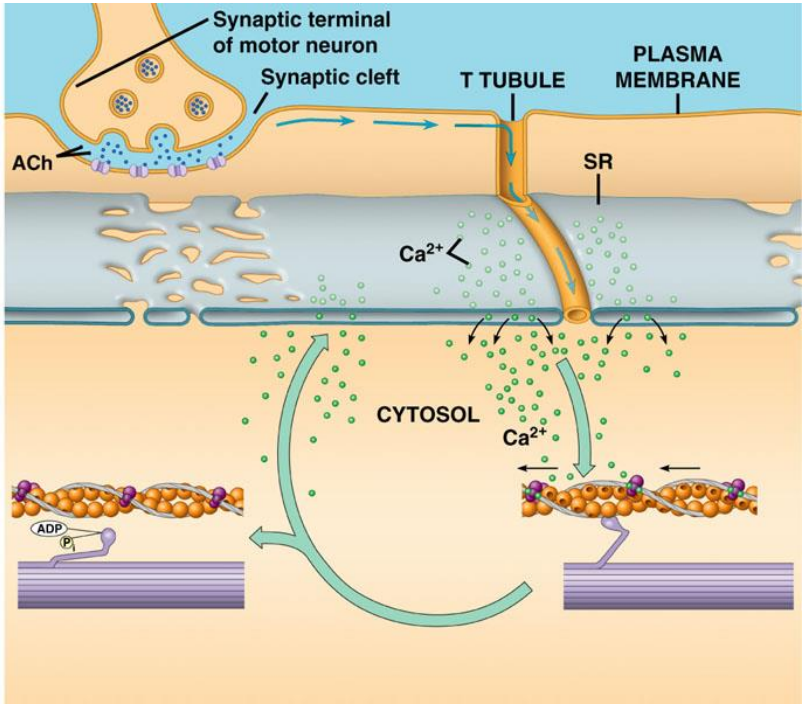
# Nerve and Muscle Cells Working Together I

* **ACH (acetylcholine) released my synaptic terminal**
* **ACH binds to receptor proteins** found on plasma membrane of muscle fiber
* ***Action potential*** triggered in muscle cell



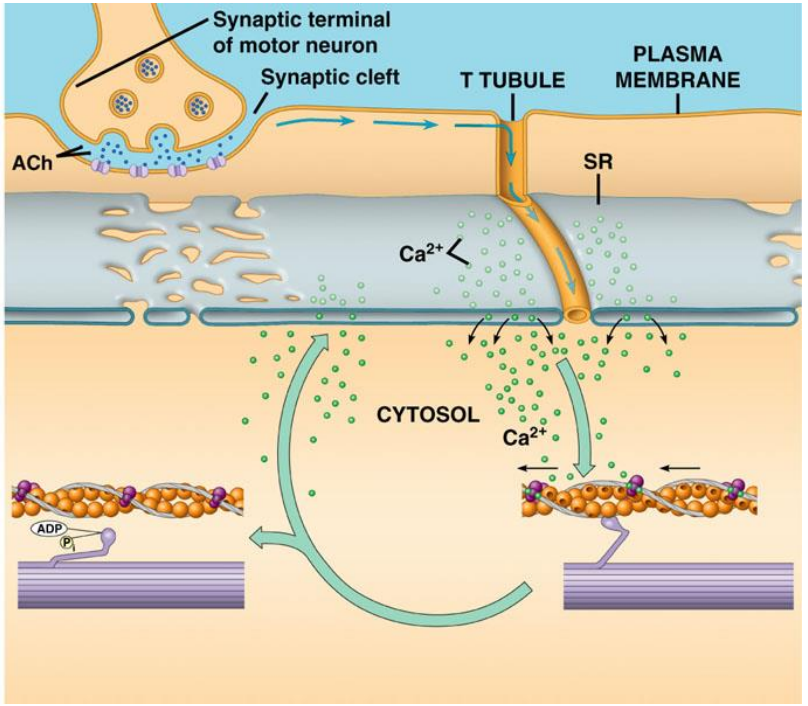
# Nerve and Muscle Cells Working Together II

* **Action potential moves down T tubule** and causes the **release of $Ca^+$ ions from sarcoplasmic reticulum (SR).**



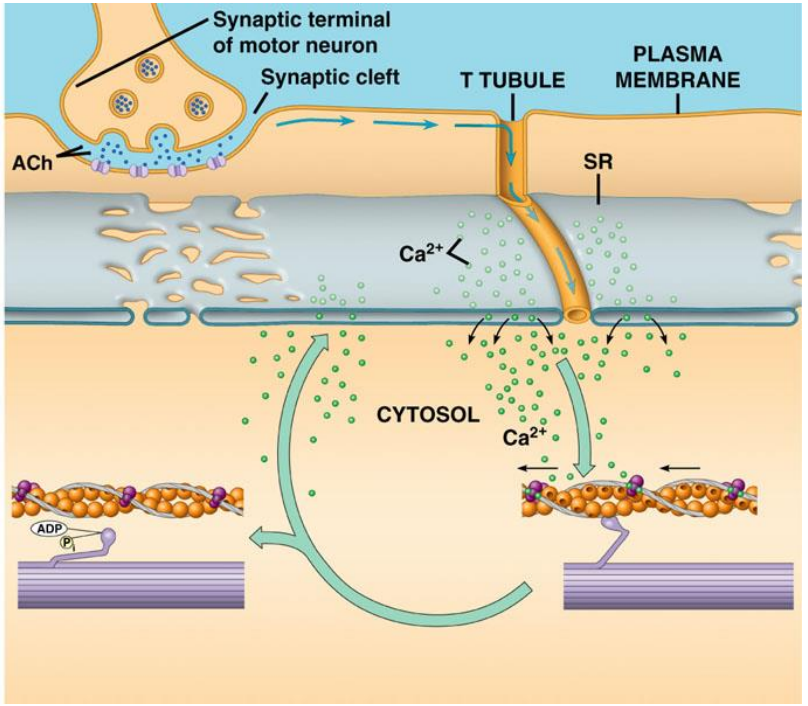
# Nerve and Muscle Cells Working Together III

* $Ca^{+}$ ions bind on troponin
* Troponin changes shape
* Tropomyosin is removed
* Myosin binding sites are exposed.



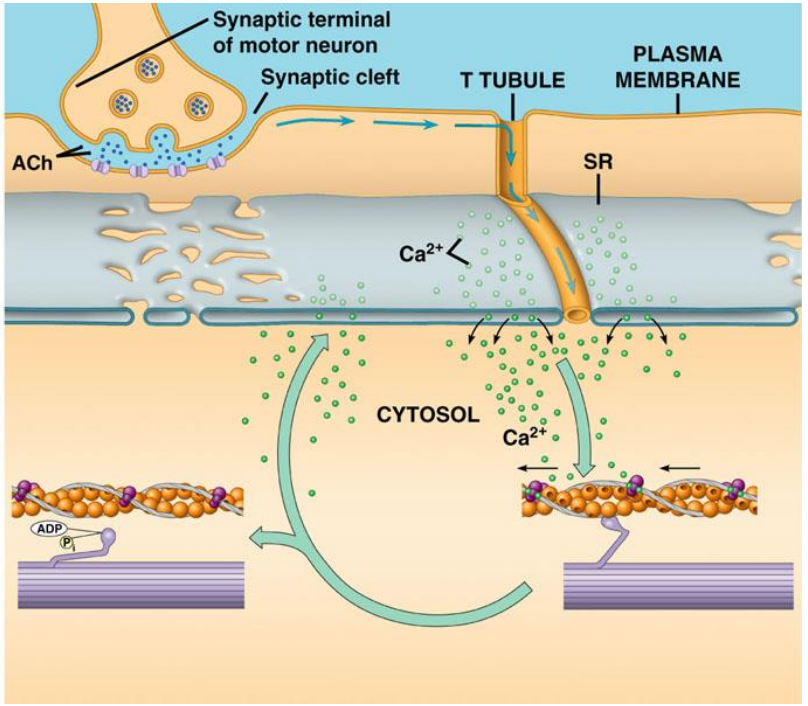
# Nerve and Muscle Cells Working Together IV

* Myosin cross bridges alternatively attach to actin and detach
  * Actin filaments are pulled towards the center of sarcomere



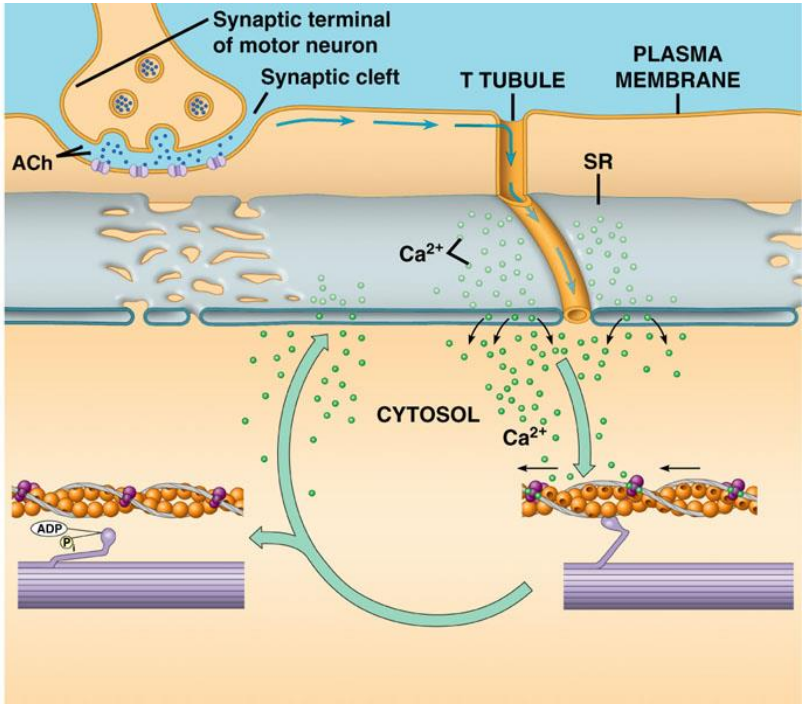
# Nerve and Muscle Cells Working Together V

* Cytostolic calcium ions are removed back into the SR via active transport *after* SR action potential ends.

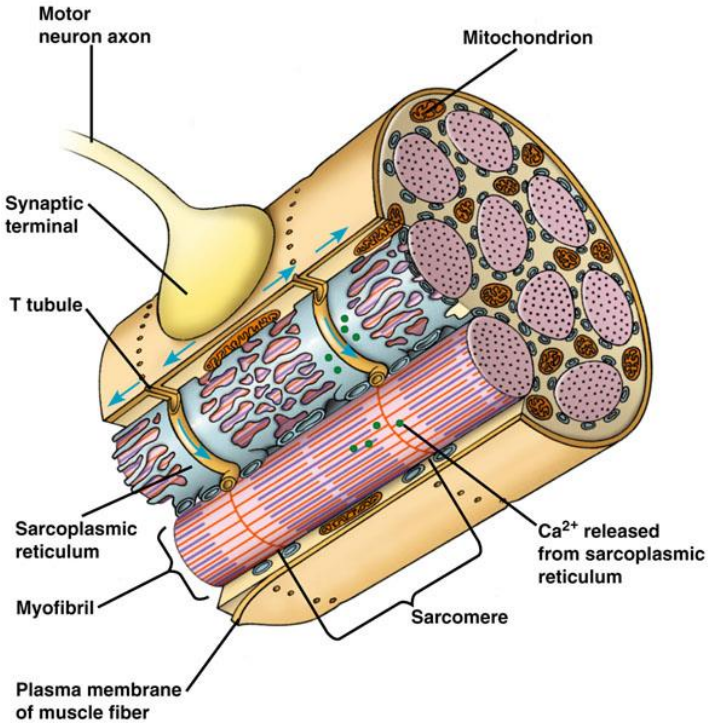


# Nerve and Muscle Cells Working Together VI

* Tropomyosin blockage of myosin binding sites is restored.
* Contraction ends
* Muscle fiber relaxes.



# The Big Picture



# Other Important Information

# Types of Muscle

* Skeletal Muscle Fibers
  * Slow oxidative
  * Fast oxidative
  * Fast glycolytic
* Cardiac muscle
  * Heart
* Smooth muscle
  * Walls of hollow organs
    * Blood vessels
      * Arteries
    * Digestive tract

Characteristics of the Three Muscle Fiber Types

| | Slow-Twitch (Type I) | Fast-Twitch A (Type IIa) | Fast-Twitch B (Type IIb) |
|---|---|---|---|
| contraction time | slow | fast | very fast |
| size of motor neuron | small | large | very large |
| resistance to fatigue | high | intermediate | low |
| activity | aerobic | long-term anaerobic | short-term anaerobic |
| force production | low | high | very high |
| mitochondrial density | high | high | low |
| capillary density | high | intermediate | low |
| oxidative capacity | high | high | low |
| glycolytic capacity | low | high | high |
| major storage fuel | triglycerides | creatine phosphate, glycogen | creatine phosphate, glycogen |

# Review