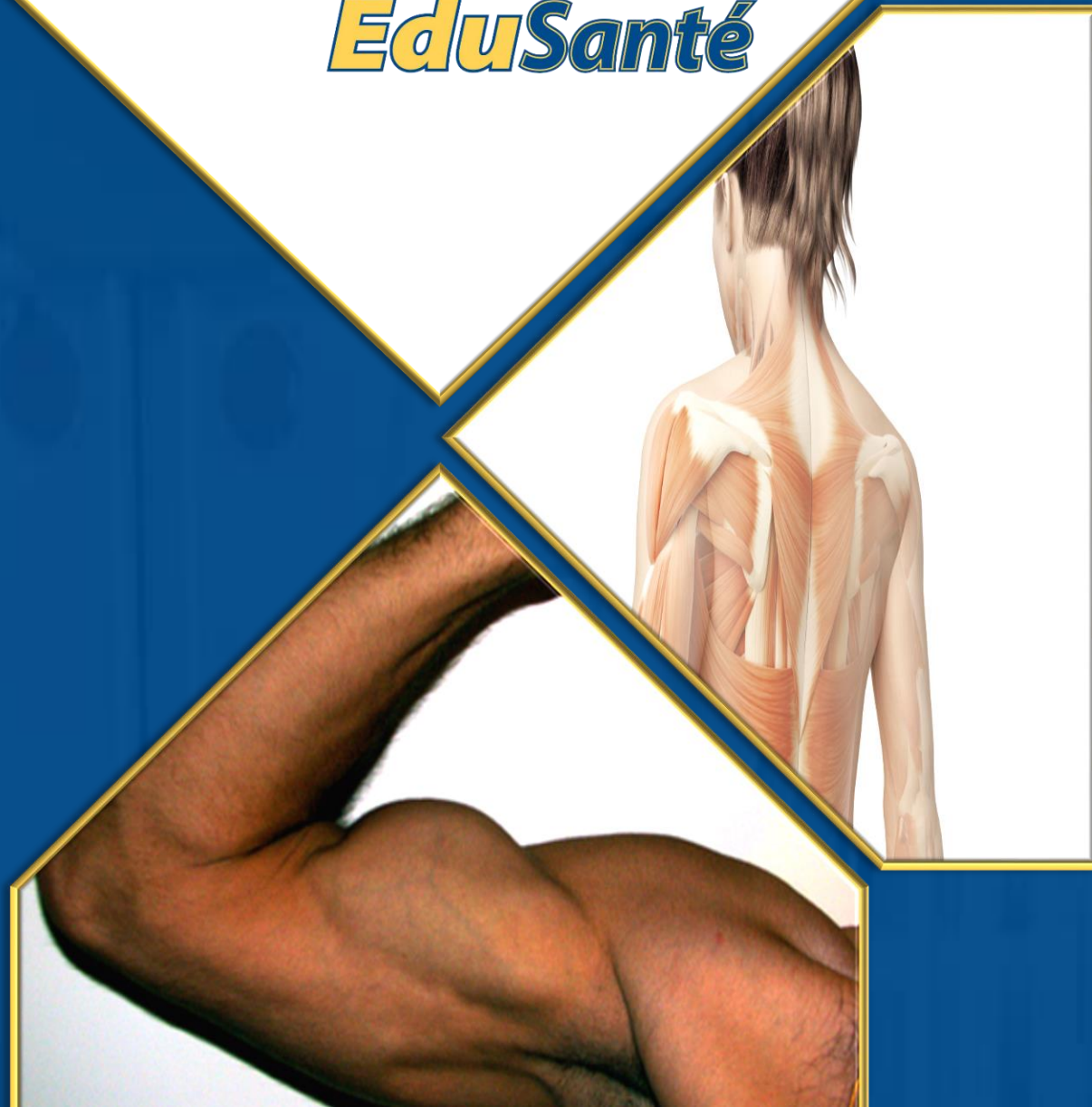
MEDAVIE HealthEd ÉduSanté

# Muscular System

## Primary Care Paramedicine



Module: 14

Section: 01c

# Characteristics

## Excitability

- The ability to receive and respond to stimulus

## Contractility

- The ability to contract

## Extensibility

- The ability to stretch (opposing pairs)

## Elasticity

- The ability to recoil to original shape

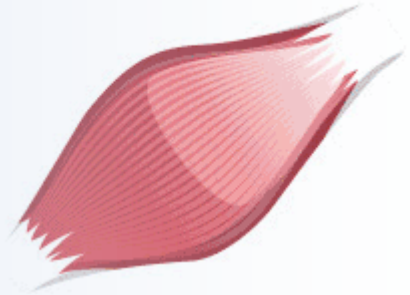
MEDAVIE HealthEd ÉduSanté

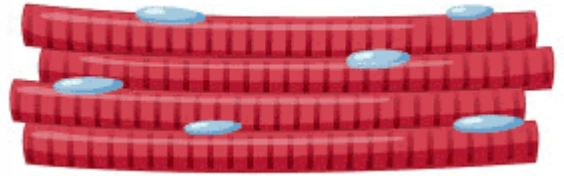
# Functions

- Movement
- Posture
- Joint stability
- Heat Production

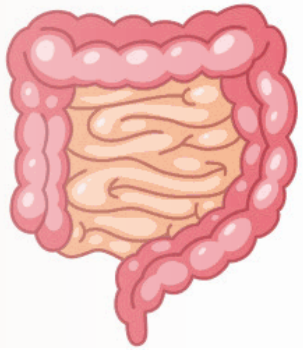
# Types

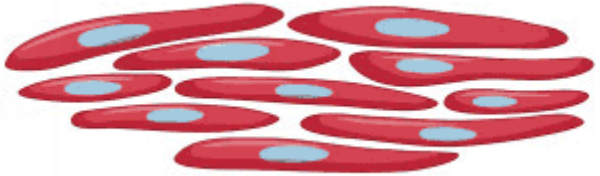
Skeletal Muscle



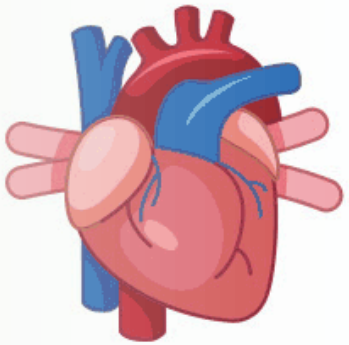


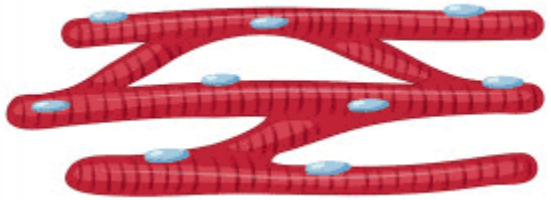
Smooth Muscle





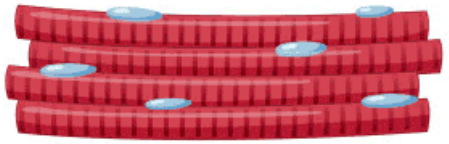
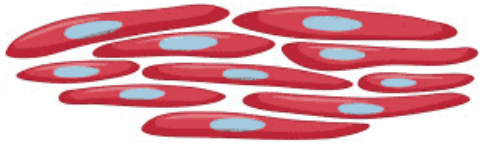
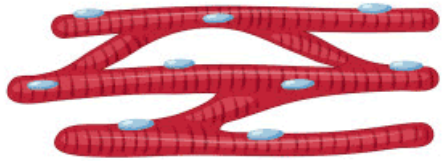
Cardiac Muscle





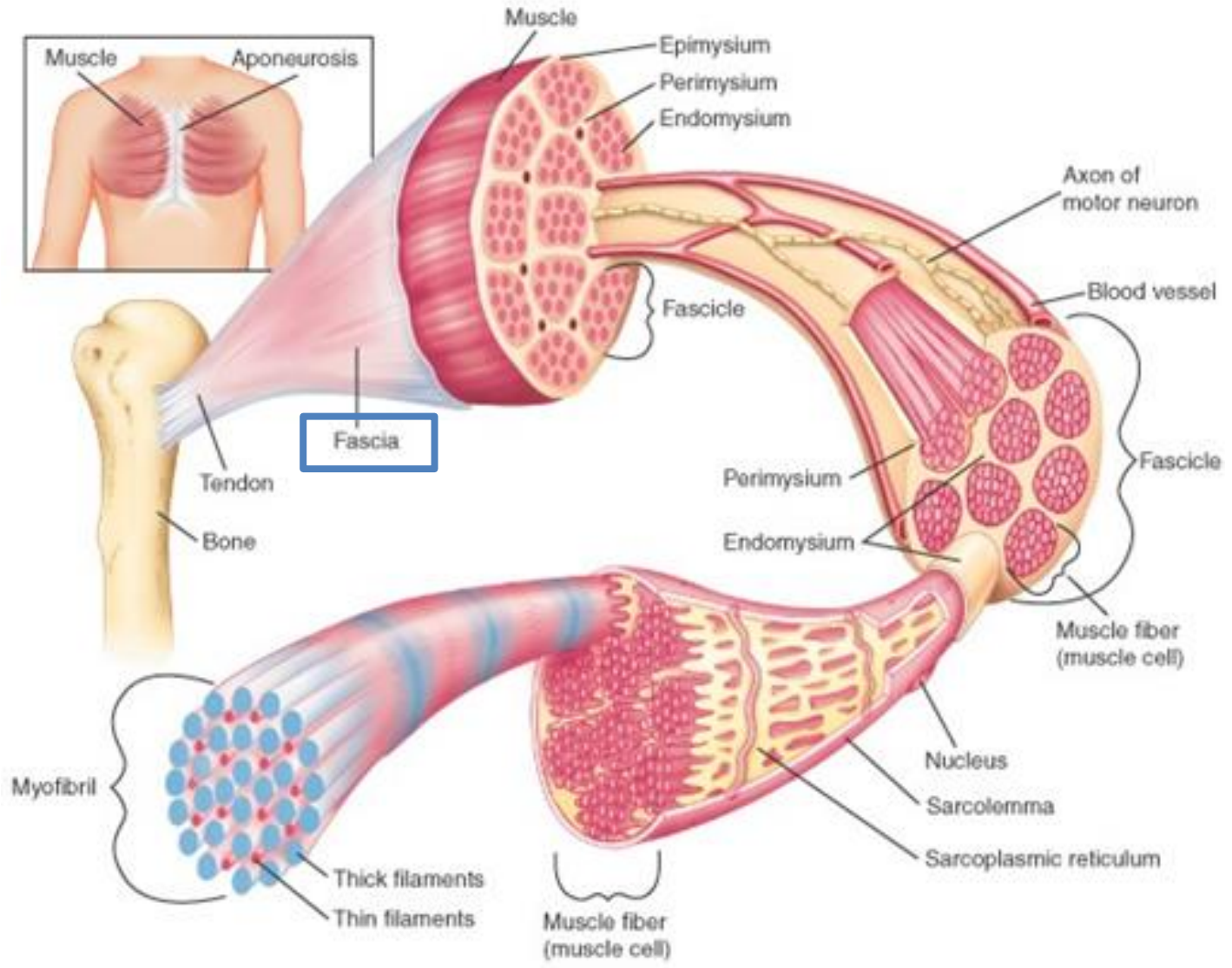
MEDAVIE HealthEd ÉduSanté

# Types

| Type | Location | Function | Appearance | Control |
|---|---|---|---|---|
| **Skeletal**  | Skeleton | Movement, heat, posture | • Striated<br>• Multi-nucleated (eccentric)<br>• Fibers parallel | **Voluntary** |
| **Smooth**  | Heart | Pump blood continuously | • Striated<br>• One central nucleus | **Involuntary** |
| **Cardiac**  | G.I. tract, uterus, eye, blood vessels | Peristalsis, blood pressure, pupil size, erects hairs | • No striations<br>• One central nucleus | **Involuntary** |

## Fascia

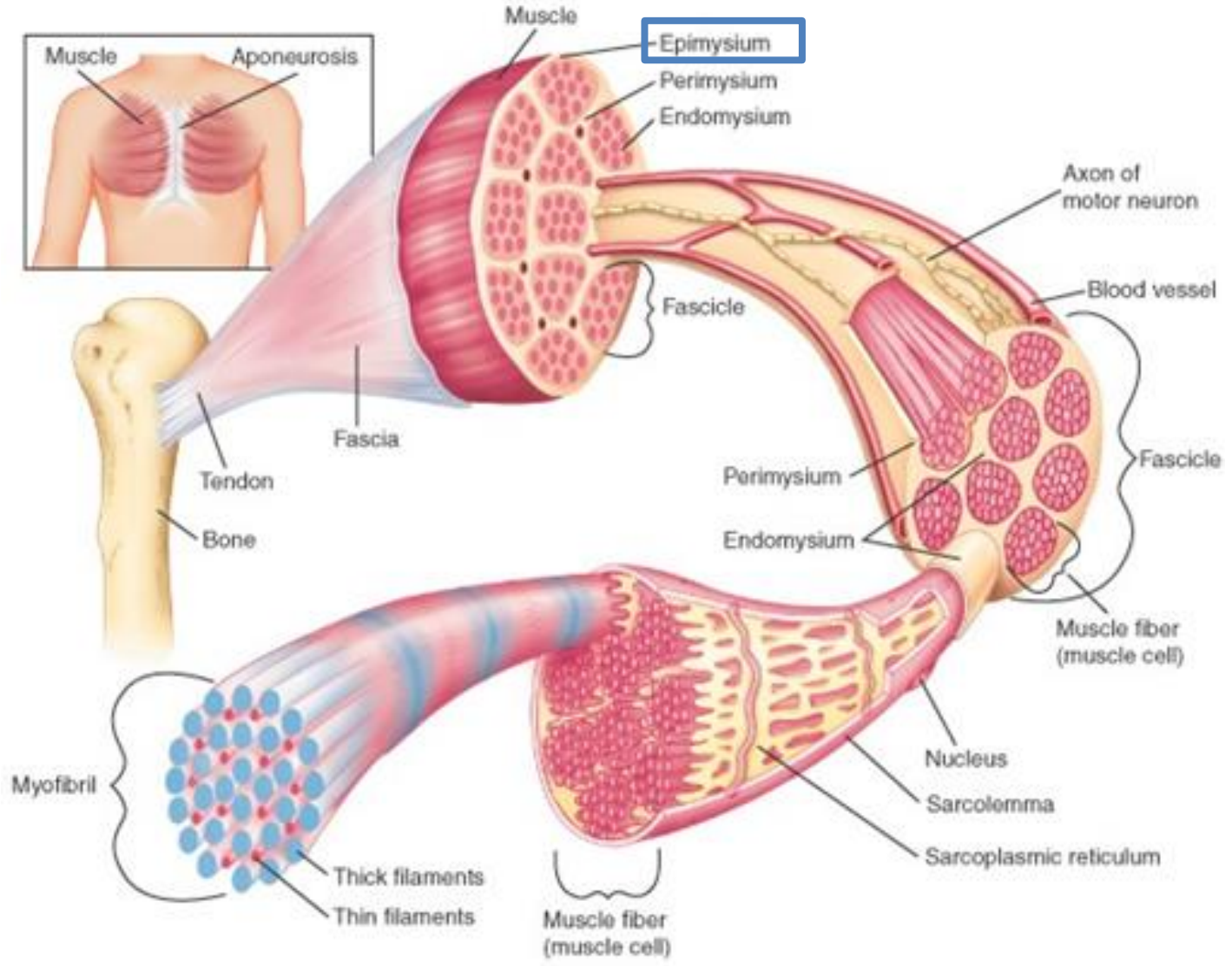
- Surrounds and separates each muscle



# Structure

## Epimysium

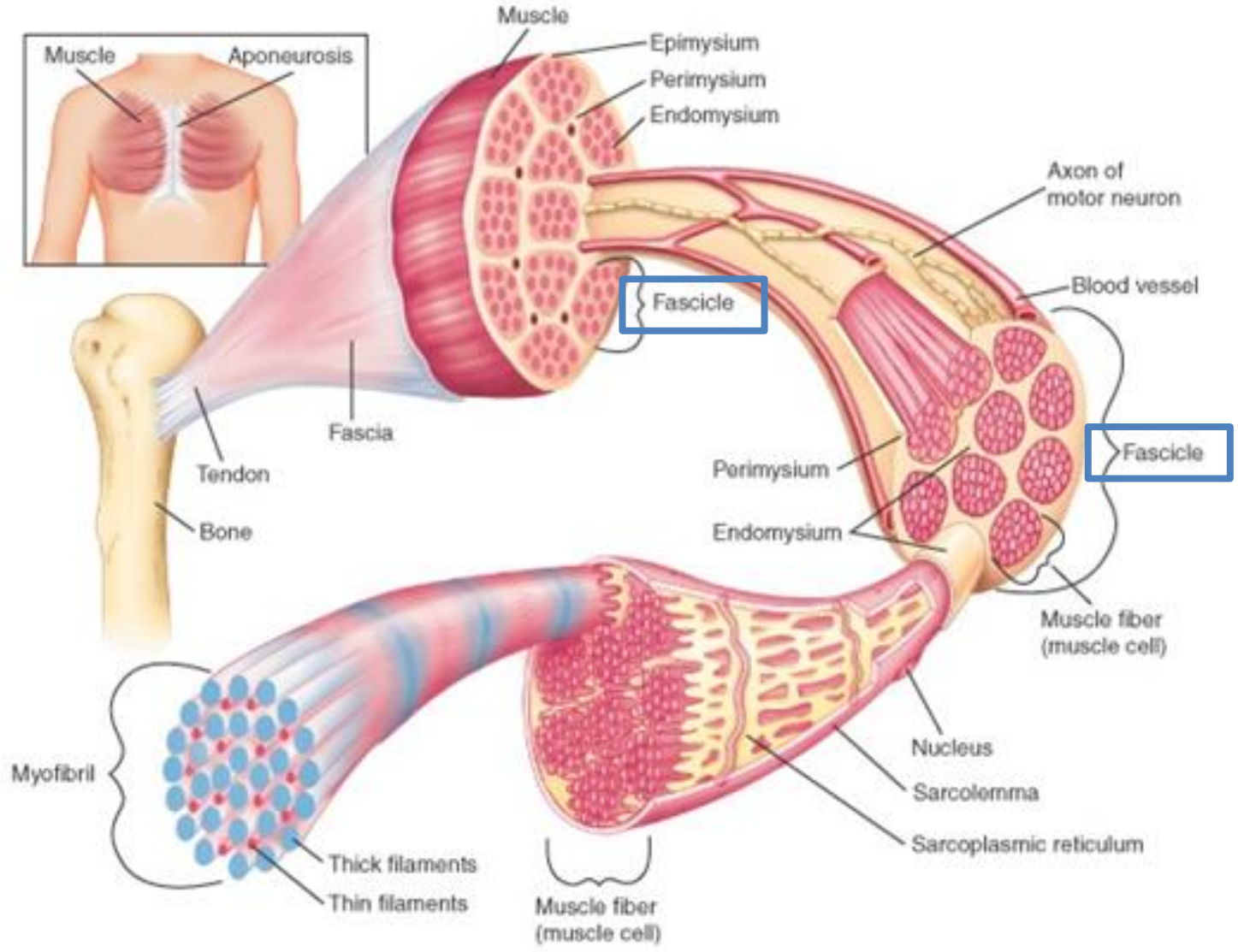
- Surrounds each muscle
- A protective sheath
- Divides the muscle into compartments



# Structure

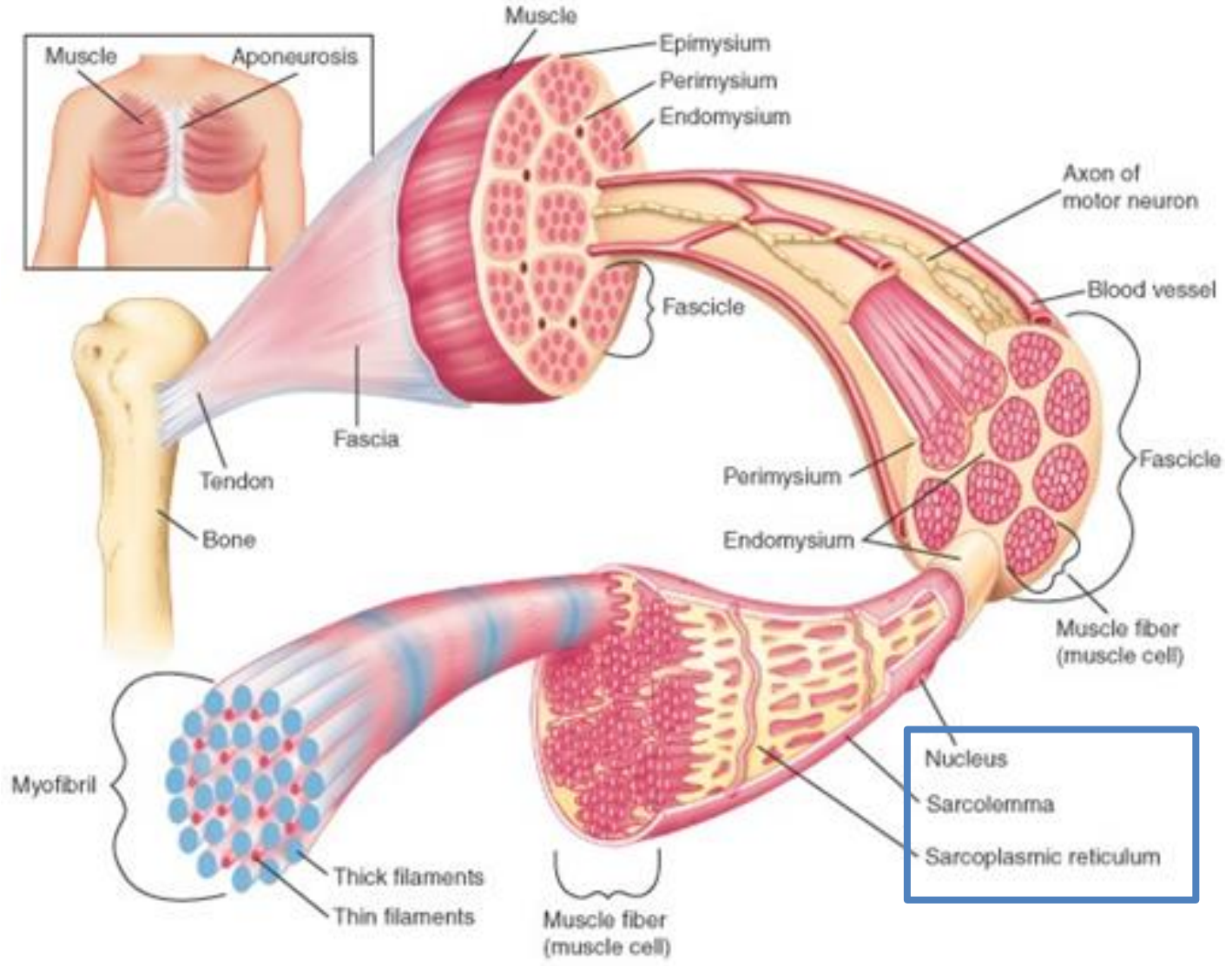
## Fasciculus

- Bundle of fibers called a **fasciculus** found in each compartment
- Surrounded by a layer of tissue called **perimysium**
- Each fiber in the **fasciculus** is surrounded by a layer of tissue called the endomysium
- The coverings also contain blood vessels and nerves



## Muscle Fibers

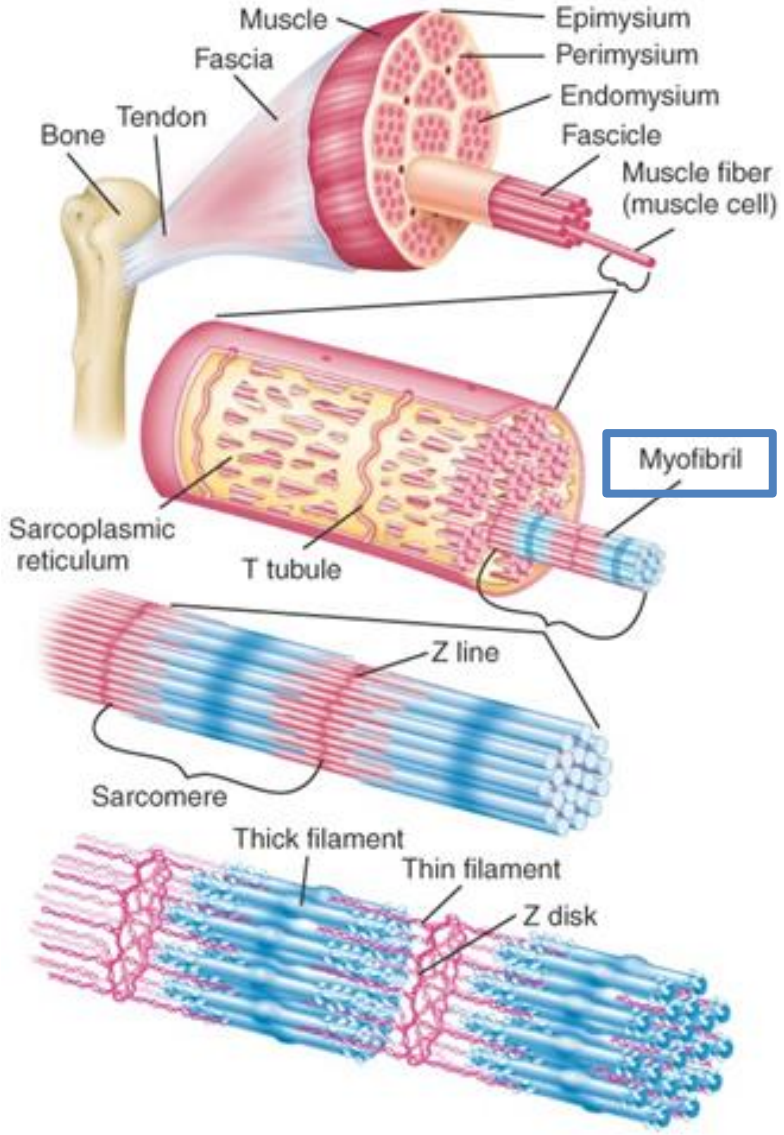
- Each fiber is a cylindrical cell
  - Sarcolemma (Cell membrane)
  - Sarcoplasm (Cytoplasm)
  - Sarcoplasm Reticulum (Endoplasmic Reticulum)
- The sarcolemma has multiple nuclei and mitochondria (for energy production)
- Inward extensions of the sarcolemma are called T-tubules



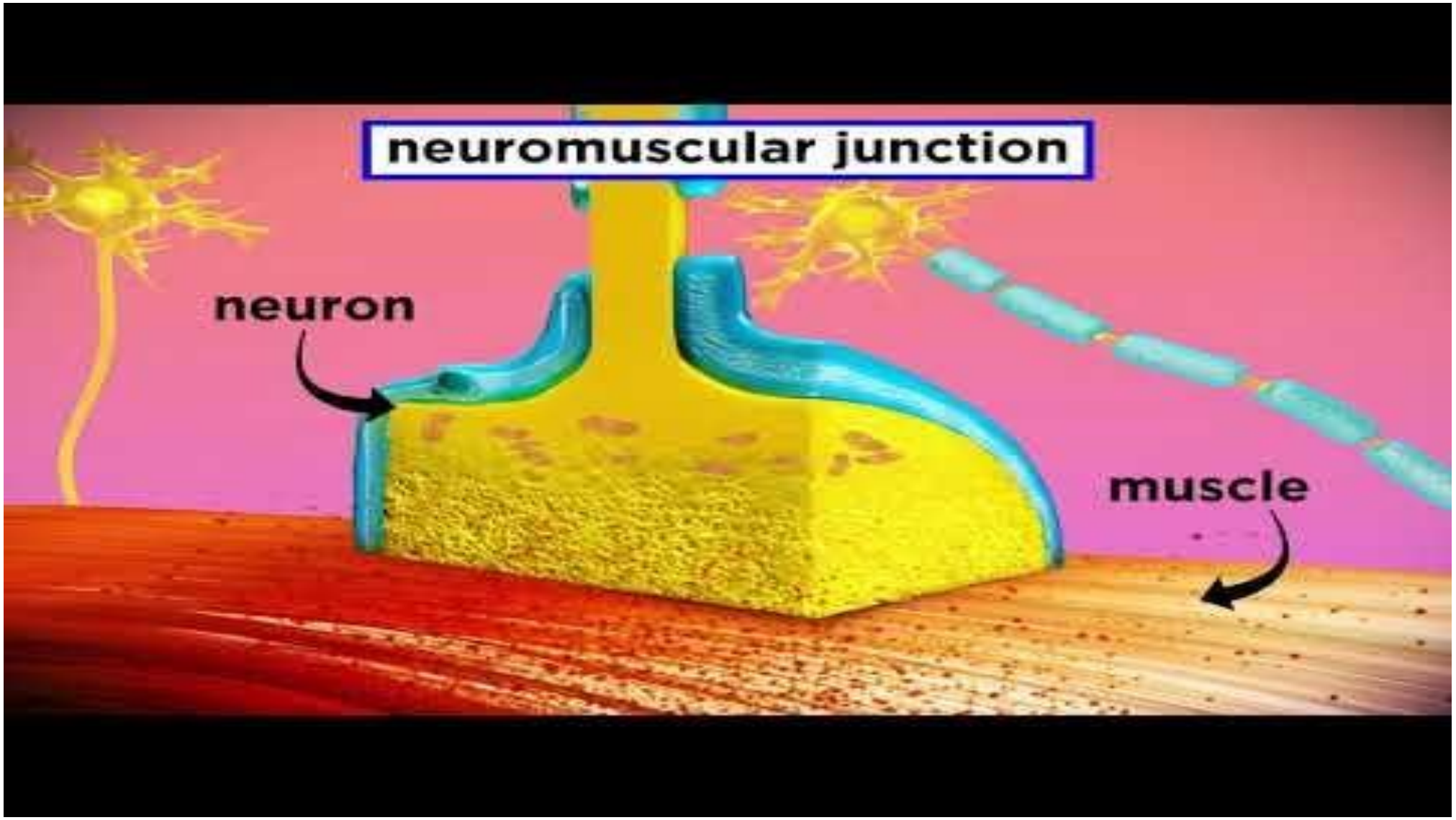
# Structure

## Myofibrils

- Built from three groups of proteins
  - Contractile proteins
    - Generate force during contraction
  - Regulatory proteins
    - Help switch the contraction process on and off
  - Structural proteins
    - Keep the thick and thin filaments in proper alignment and link the myofibrils to the sarcolemma and extracellular matrix

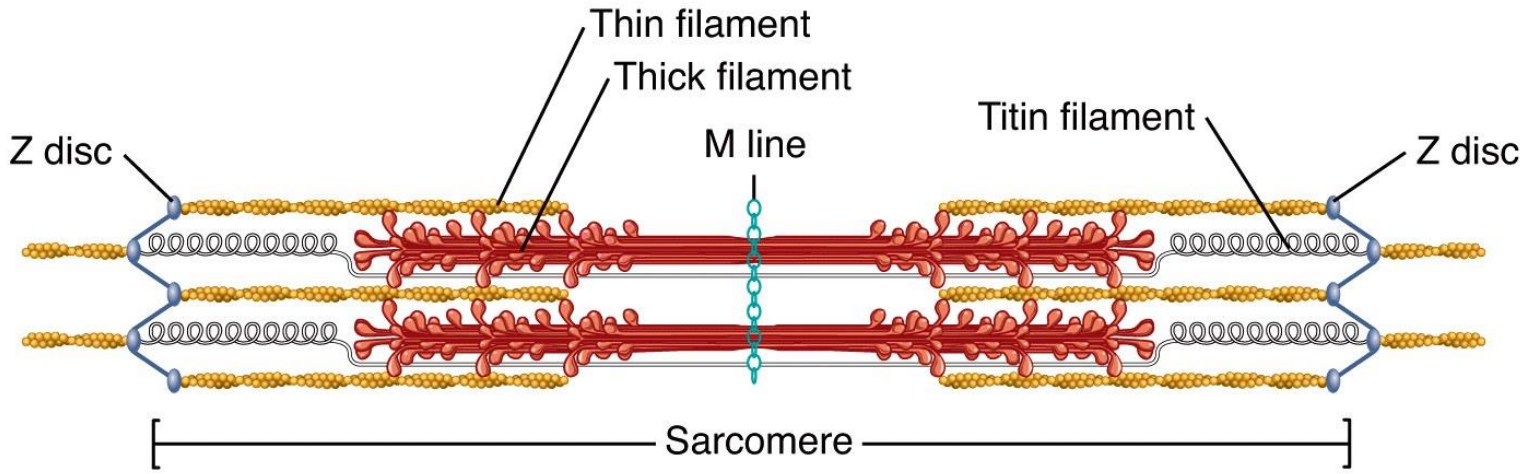


# Sarcomeres, Action Potential, and the Neuromuscular Junction



# Muscle Proteins

- The thin filaments are comprised mostly of the structural protein actin, and the thick filaments are comprised mostly of the structural protein myosin
- However, in both types of filaments, there are also other structural and regulatory proteins



# Muscle Proteins

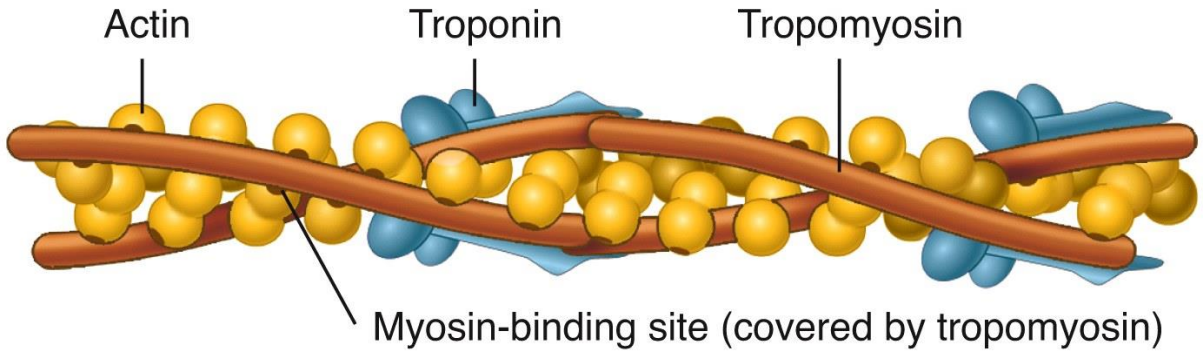
- In the thin filaments actin proteins are strung together like a bead of pearls

- In the thick filaments myosin proteins look like golf clubs bound together

# Muscle Proteins

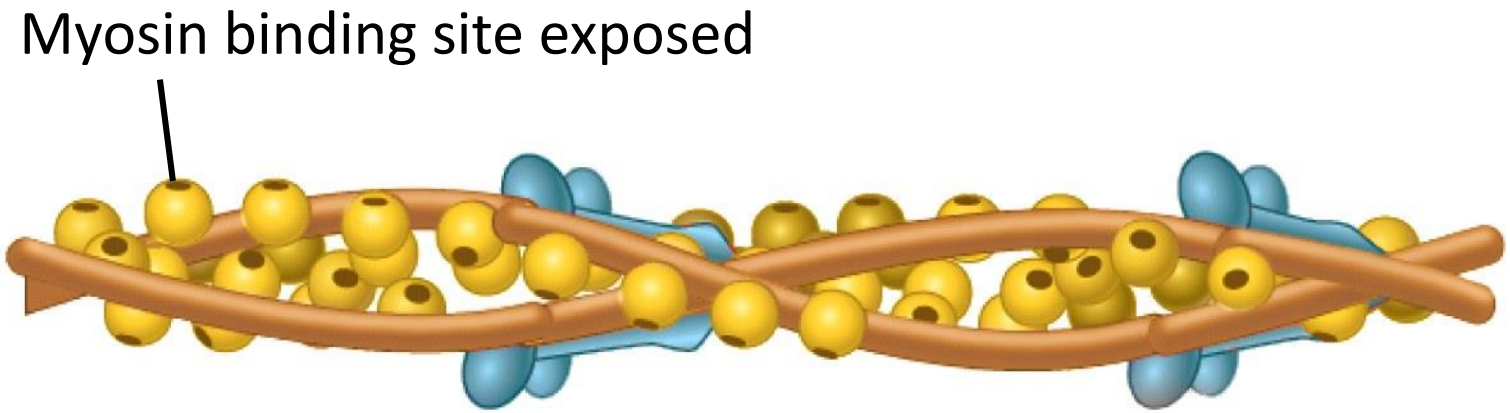
- The myosin binding sites on the actin proteins are readily visible.


- The regulatory proteins troponin and tropomyosin have cover the myosin binding



# Muscle Proteins

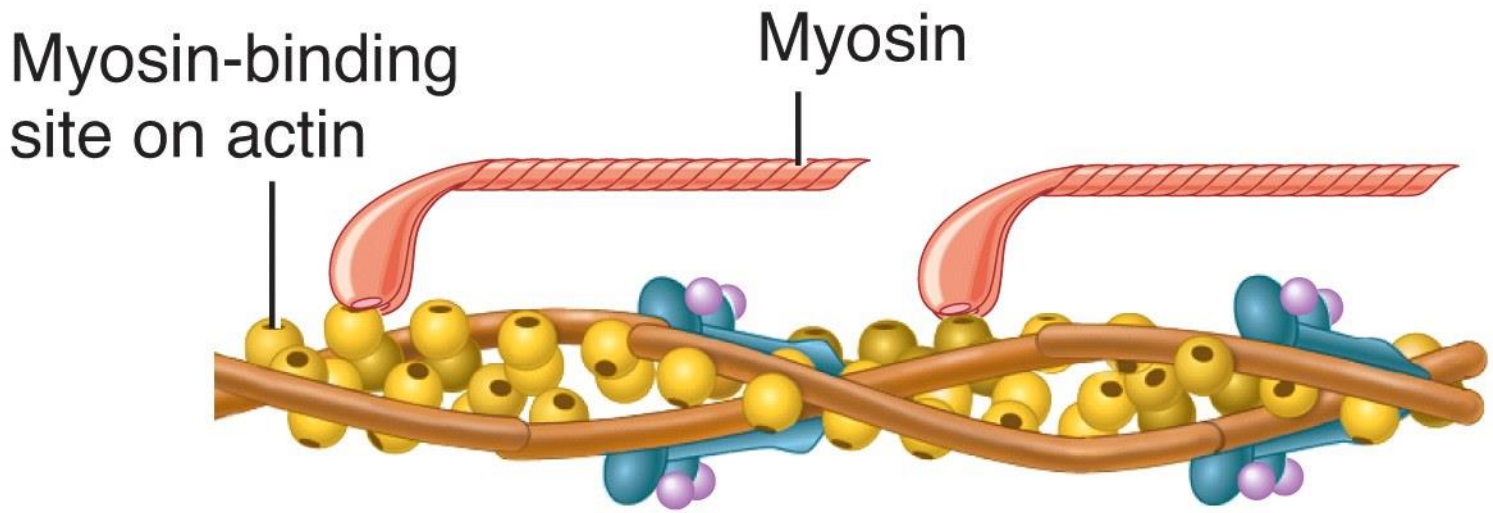
- The troponin-tropomyosin complex has slid down into the “gutters” of the actin molecule unblocking the myosin binding site




- The troponin-tropomyosin complex can slide back and forth depending on the presence of $Ca^{2+}$

# Muscle Proteins

- $Ca^{2+}$ binds to troponin which changes the shape of the troponin-tropomyosin complex and uncovers the myosin binding sites on actin

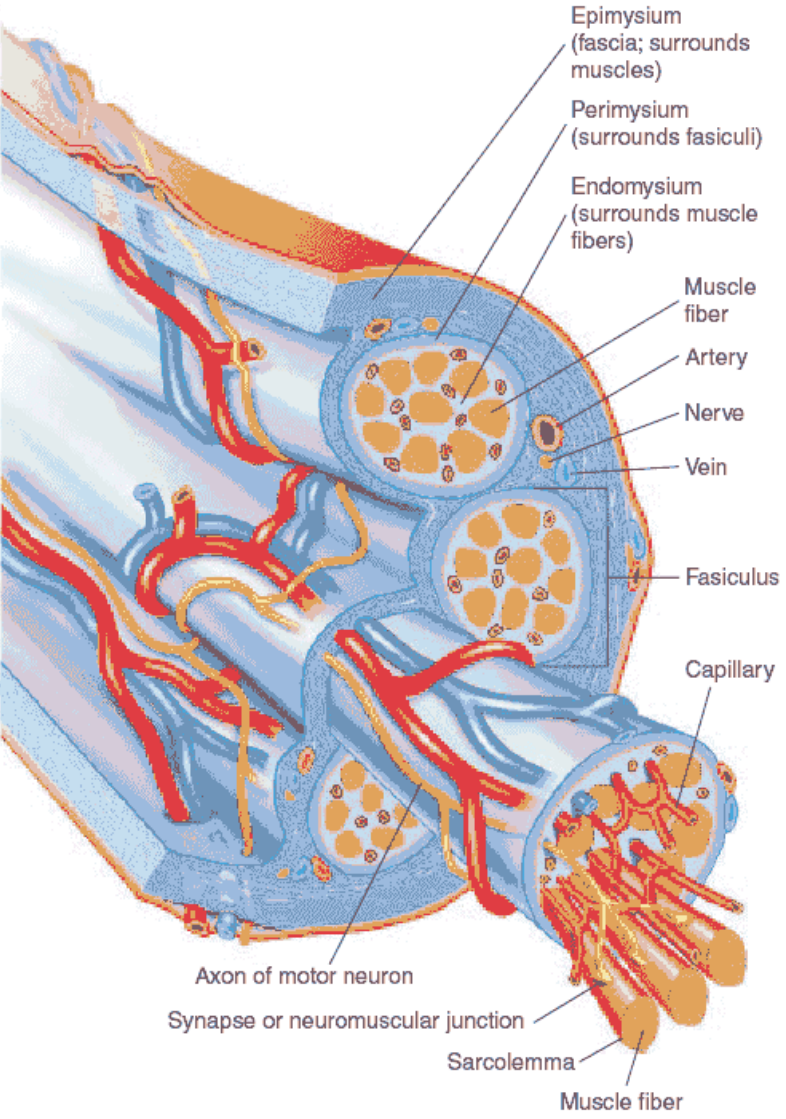


# Muscle Proteins

- Besides contractile and regulatory proteins, muscle contains about a dozen structural proteins which contribute to the alignment, stability, elasticity and extensibility of myofibrils
  - Titan is the third most plentiful protein in muscle, after actin and myosin - it extends from the Z disc and accounts for much of the elasticity of myofibrils
  - Dystrophin is discussed later as it relates to the disease of muscular dystrophy

MEDAVIE HealthEd ÉduSanté

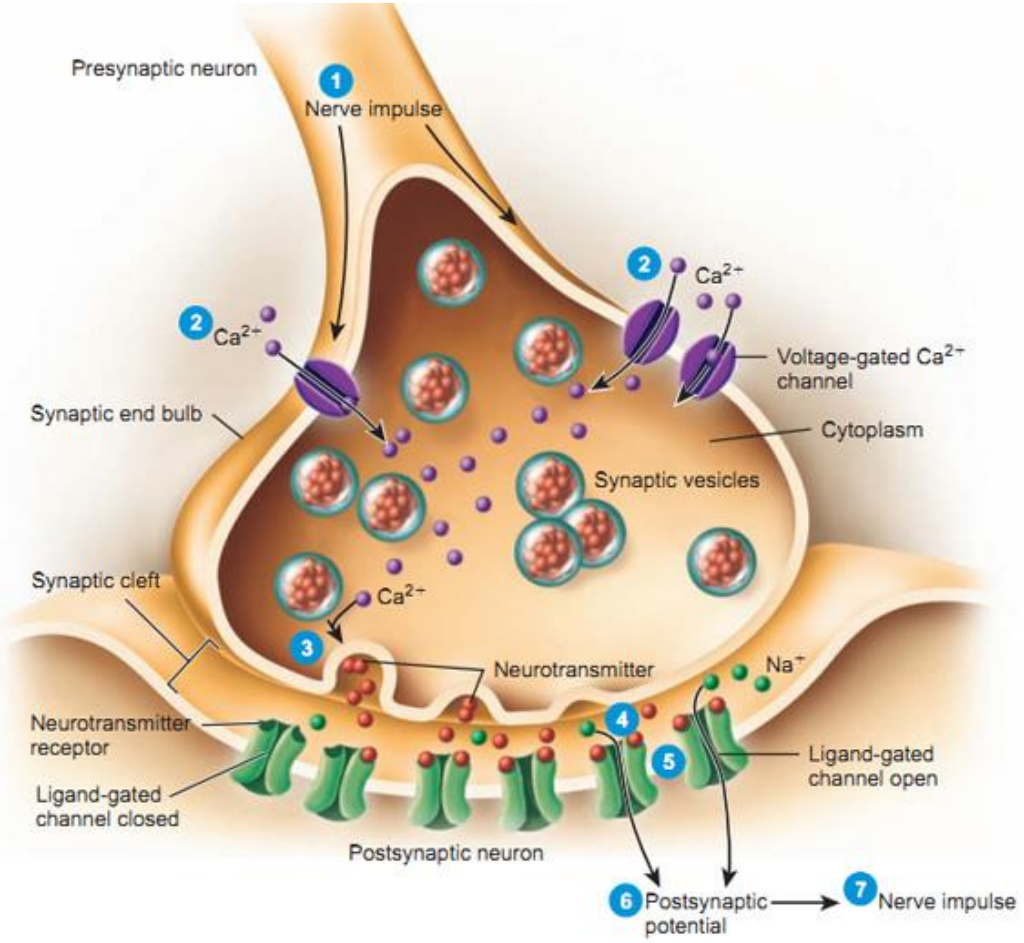
# Nerve and Blood Supply




- Have an abundant supply
- Before a muscle can contract it needs a stimulus
- This requires ATP
- Blood supply deliver $O_2$ and nutrients to produce this and remove the waste products
- One artery and one vein accompany each nerve

# Contraction

- Stimulated by specialized nerve cells called motor neurons
- The motor neuron and muscle(s) is called a motor unit
- Where the axon of the neuron meets the muscle is called the **neuromuscular junction**
- Between the two is a small depression in the muscle membrane called the synaptic cleft



# Contraction

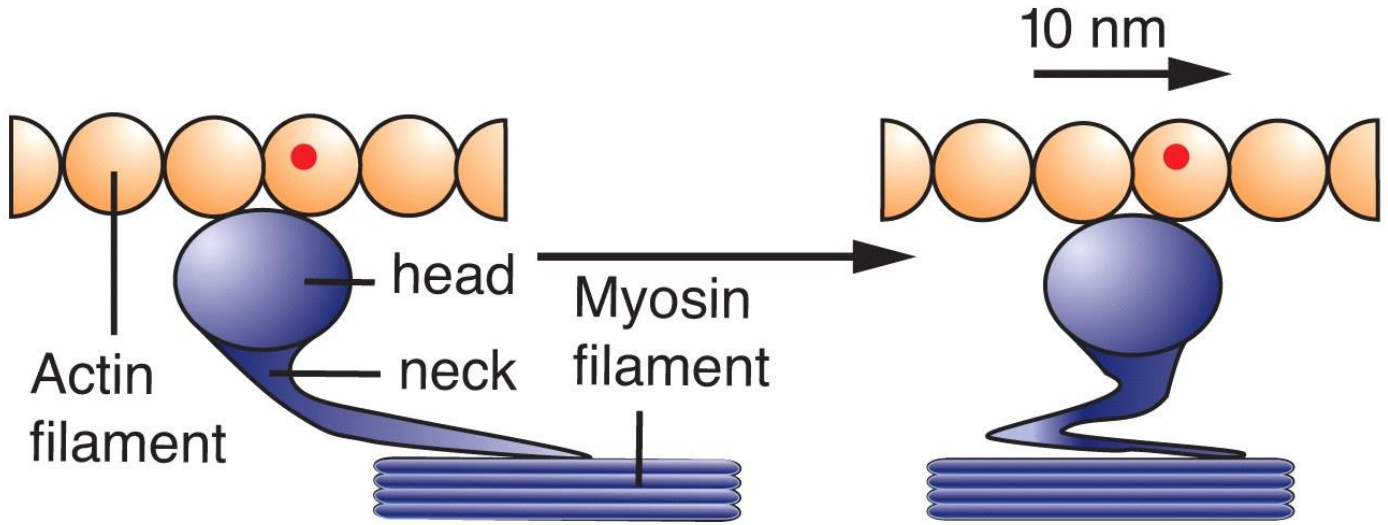
- ACh is contained within the synaptic vesicles of the axon
- Receptors for ACh are in the sarcolemma
- The combination results in a stimulus for contraction (an impulse) which travels along the sarcolemma into the T-tubules where a physiological change occurs causing a contraction
- The enzyme acetylcholinesterase deactivates the ACh at the synaptic cleft

# Sarcomere Contraction

- In a relaxed muscle fiber myosin receptor sites on the actin are inactive
- Heads on the myosin are also inactive and are bound to ATP
- $Ca^{2+}$ is stored in the sarcoplasmic reticulum and has a low concentration in the sarcoplasm
- An impulse into the T-tubule cause release of $Ca^{2+}$ from the SR into the sarcoplasm
- This rapid influx changes configuration of troponin on the actin fibers which exposes receptor sites

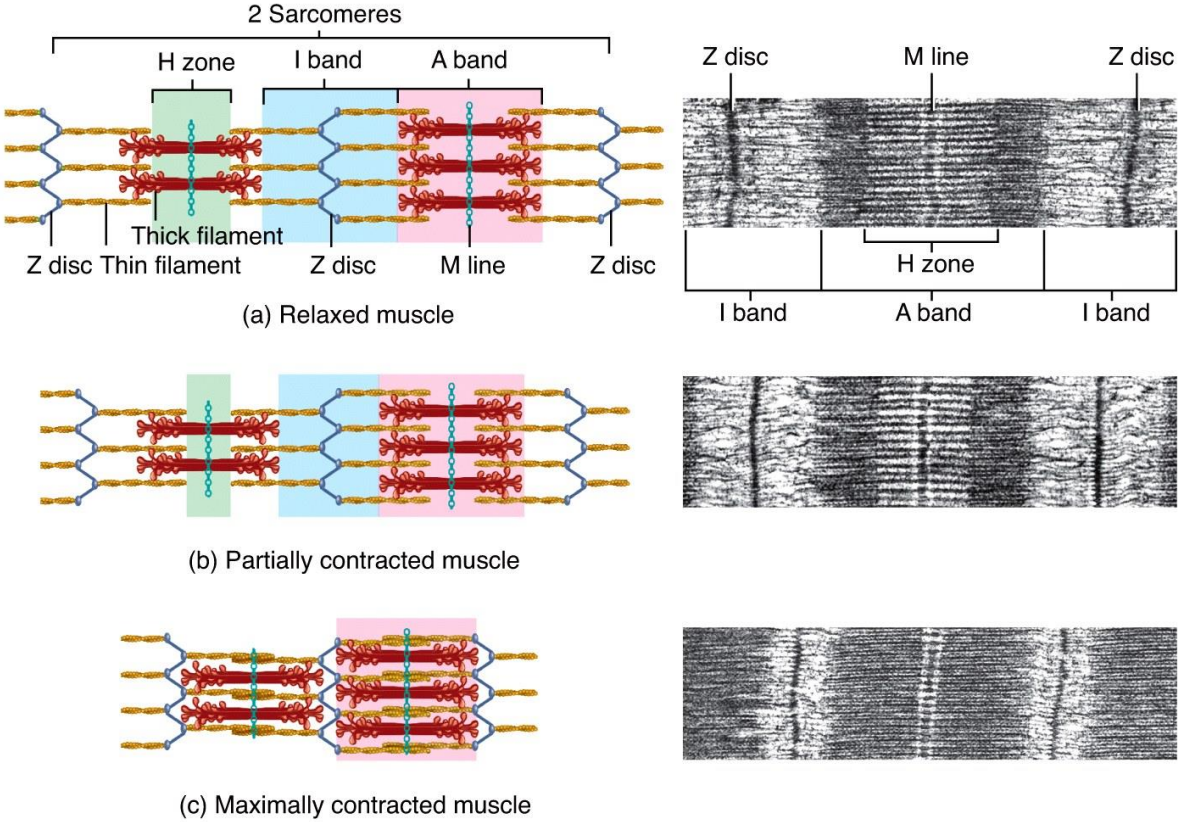
# The Sliding-Filament Mechanism

- With exposure of the myosin binding sites on actin (the thin filaments)—in the presence of $Ca^{2+}$ and ATP—the thick and thin filaments "slide" on one another and the sarcomere is shortened



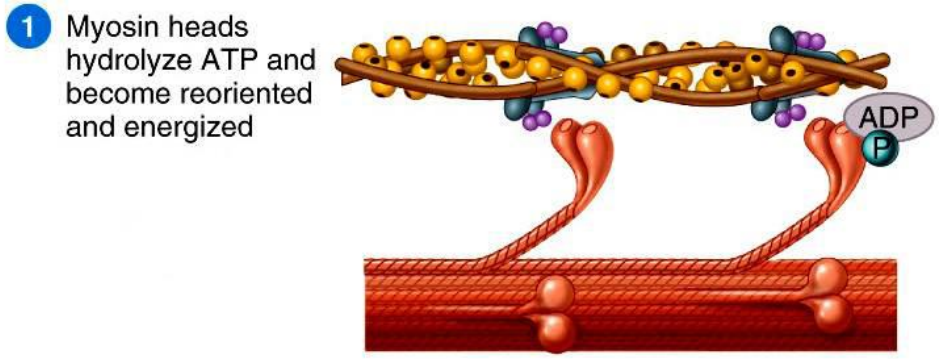
# The Sliding-Filament Mechanism

- The “sliding” of actin on myosin (thick filaments on thin filaments) can be broken down into a 4 step process

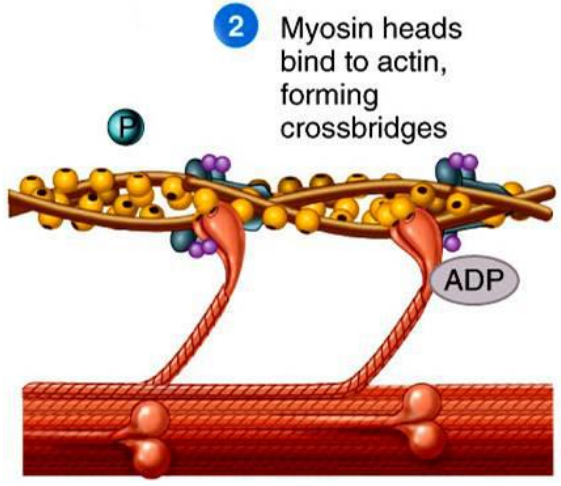


# The Sliding-Filament Mechanism

- Step 1: ATP hydrolysis

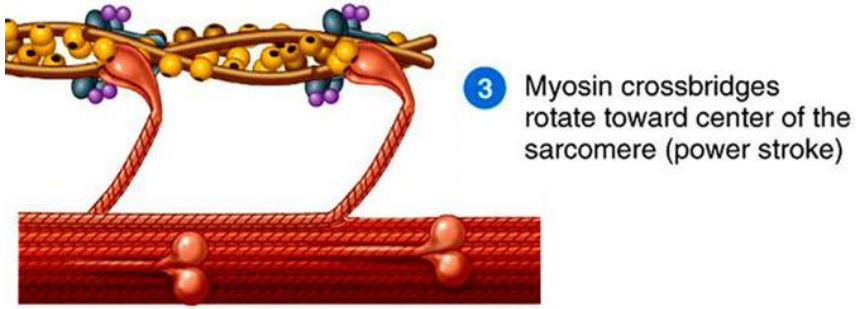



- Step 2: Attachment

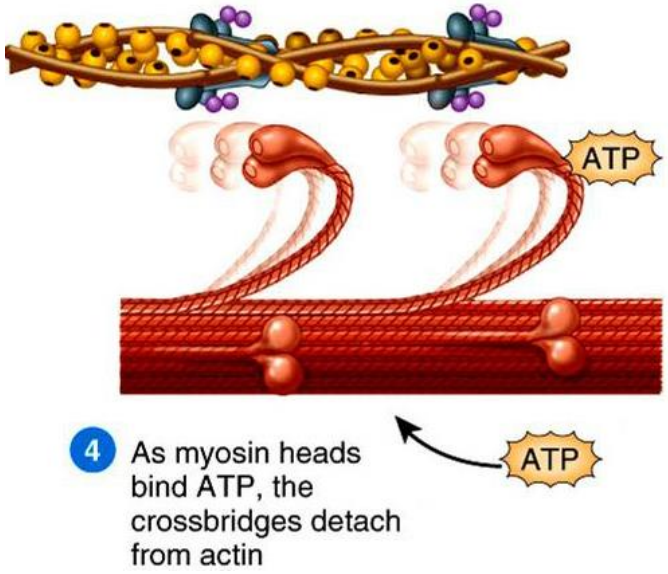


# The Sliding-Filament Mechanism

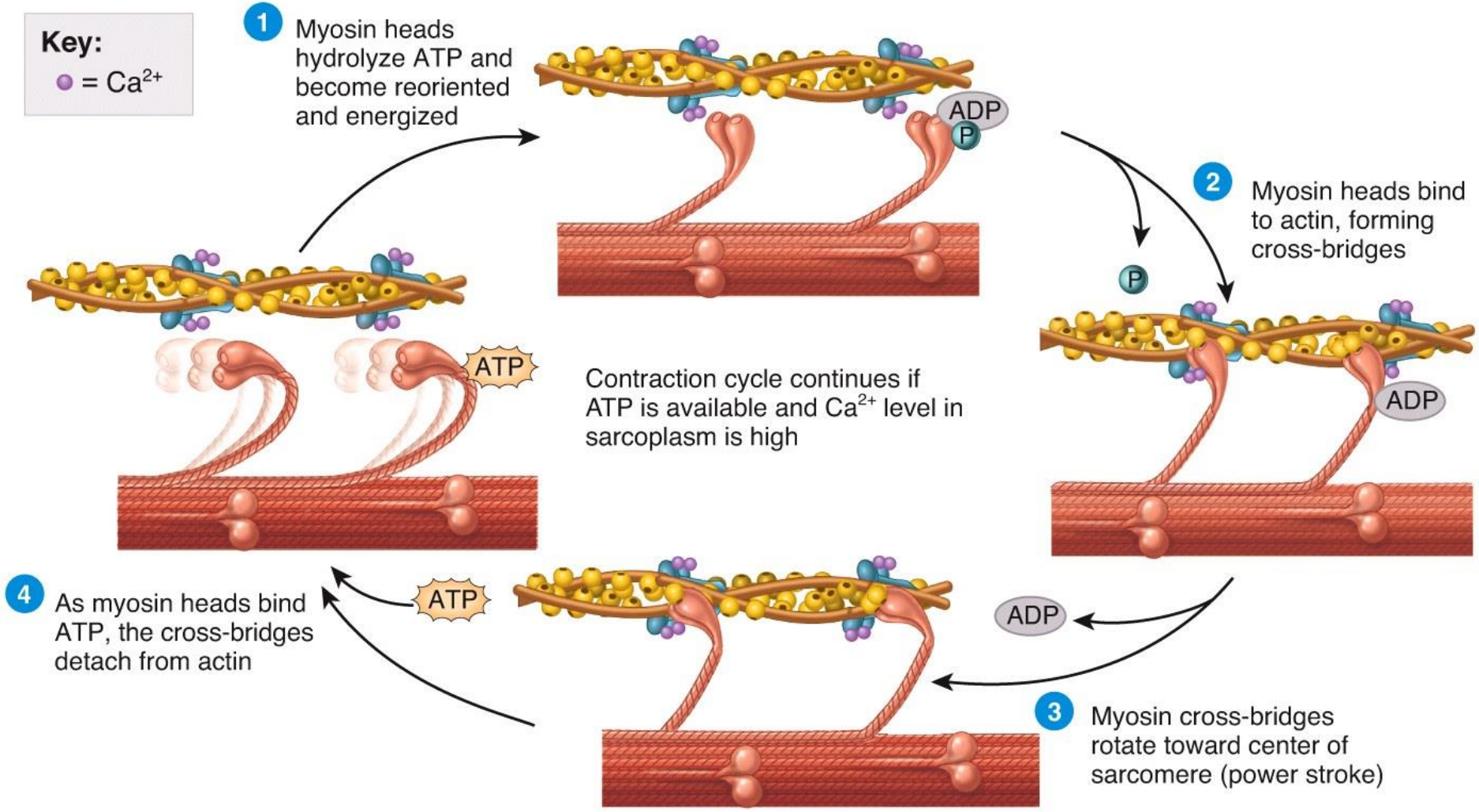
- Step 3:  Power Stroke




- Step 4:  Detachment

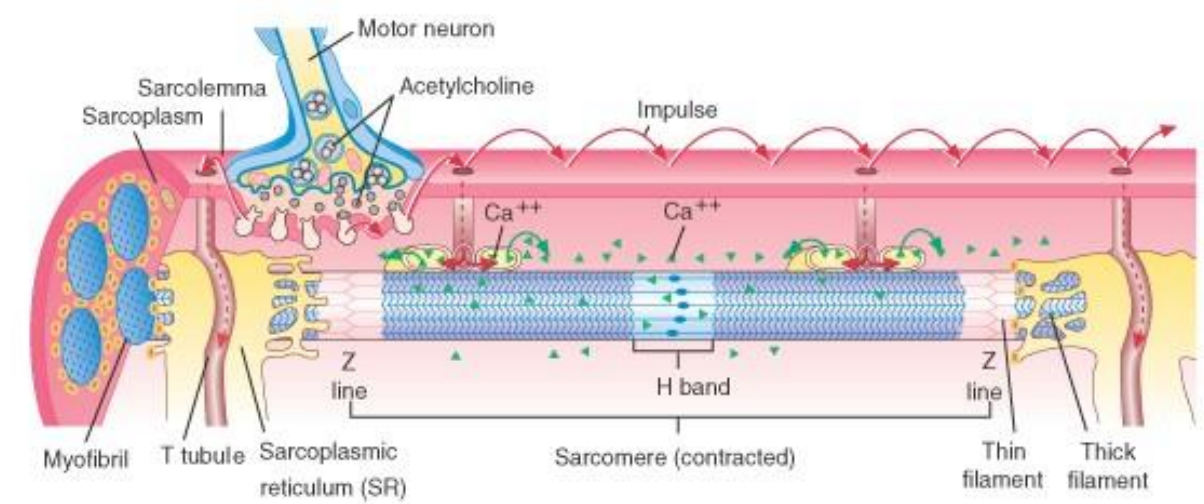


# The Sliding-Filament Mechanism



# Sarcomere Contraction

- As a result of the sliding filament mechanism the Z lines are pulled closer together shortening the sarcomere
- This does not shorten the myofilament
- New ATP on myosin reverse the reaction



# Sarcomere Contraction

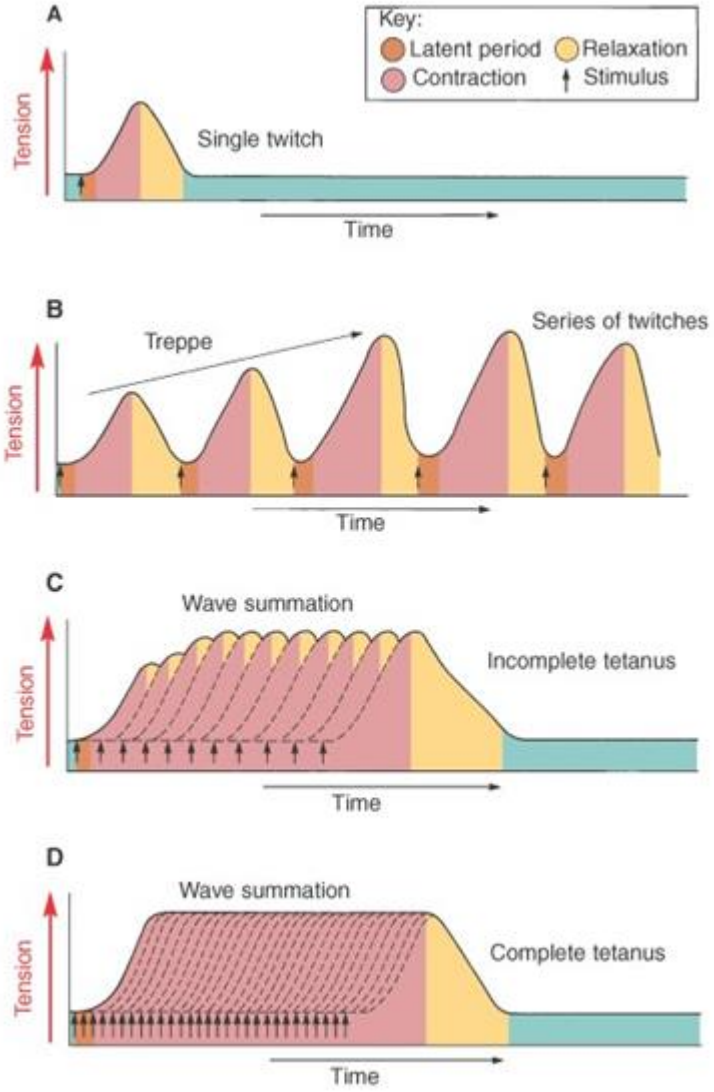
- When the stimulation ceases, $Ca^{2+}$ is actively transported into the SR
- This causes the receptor sites to close and ceasing the contraction
- Follows the all-or-none principle:
  - A sufficient stimulus is need to cause a contraction (threshold stimulus)
  - A greater stimulus will not produce greater contraction
  - Not enough will elicit no response (sub-threshold stimulus)

# Whole Muscle Contraction

- **Does not** follow the All-or-none principle
- Varies due to work load
- Increase contraction is achieved by motor unit summation and wave summation
- A single stimulus causes a twitch (lab setting)

- 3 stages of contraction
  - Lag phase
  - Contraction
  - Relaxation

# Whole Muscle Contraction

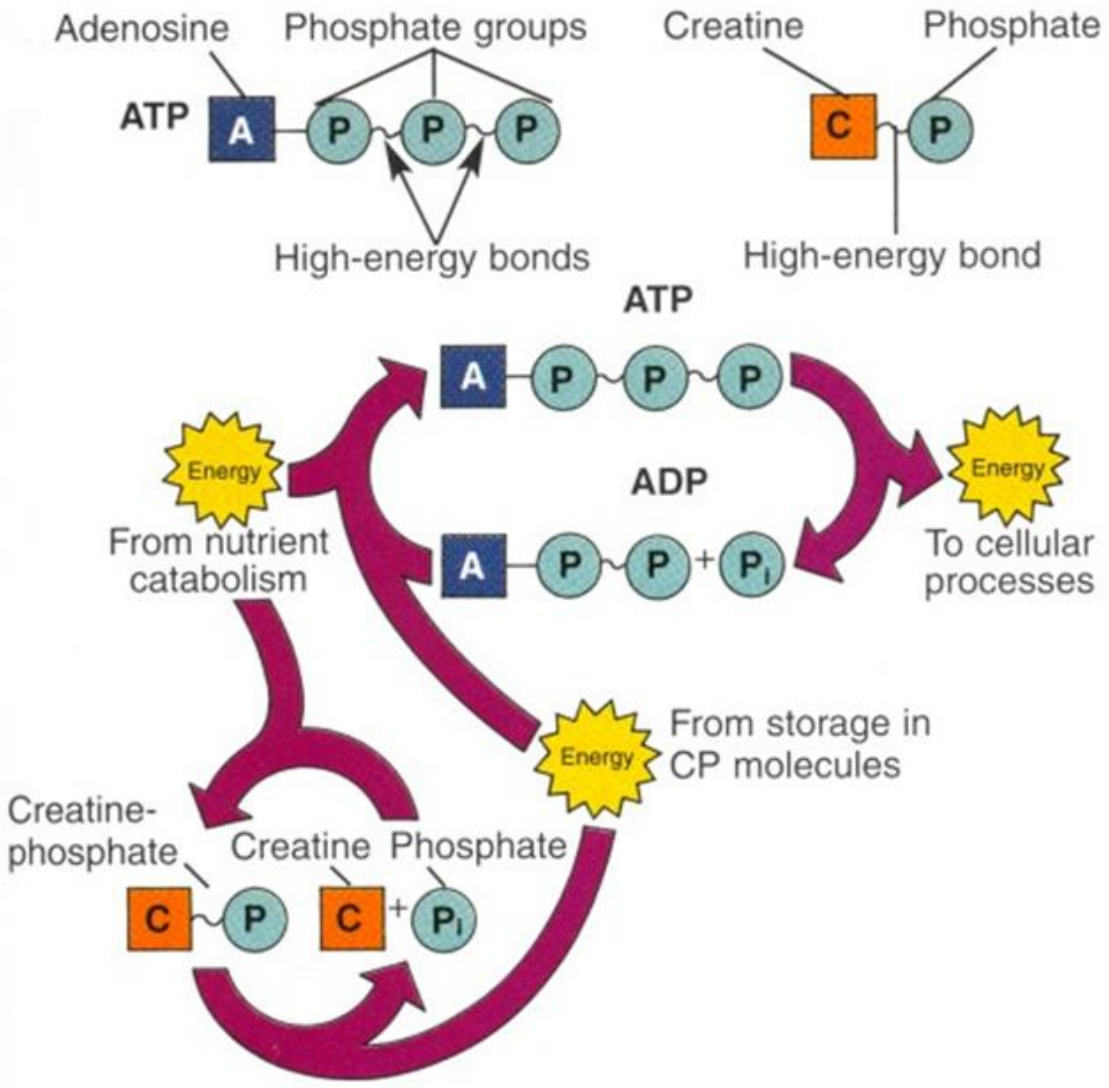



- A stimulus given during relaxation phase will cause stronger contraction, and continues to build to form a smooth contraction called tetany (multiple wave summation)
- Treppe (staircase) shows an increase in force with a stimulus of same intensity

MEDAVIE HealthEd ÉduSanté

# Whole Muscle Contraction

# Energy Sources




- Initial Source
  - ATP for the cross-bridge and active transport
  - Last only 6 seconds
- Second Source
  - Creatine Phosphate is used to instantaneously give its energy to ADP to synthesis ATP
  - If ATP is in excess it will convert to Creatine phosphate to store for later use
  - Lasts only 10 seconds

# Energy Sources

- Third Stage
  - Muscles use fatty acids and glucose for energy
  - Fatty acids found  in blood
  - Glucose is a derivative of the glycogen found in the muscle
  - If oxygen available then the fats and glucose are broken down with aerobic metabolism (20 times more production)
- Fatty Acids or glucose + $O_2$ → $CO_2$ + $H_20$ + ATP
  - If oxygen is not available then glucose is the primary source of energy (anaerobic metabolism – happens at a faster rate)
- Glucose → lactic acid + ATP

# Energy Sources

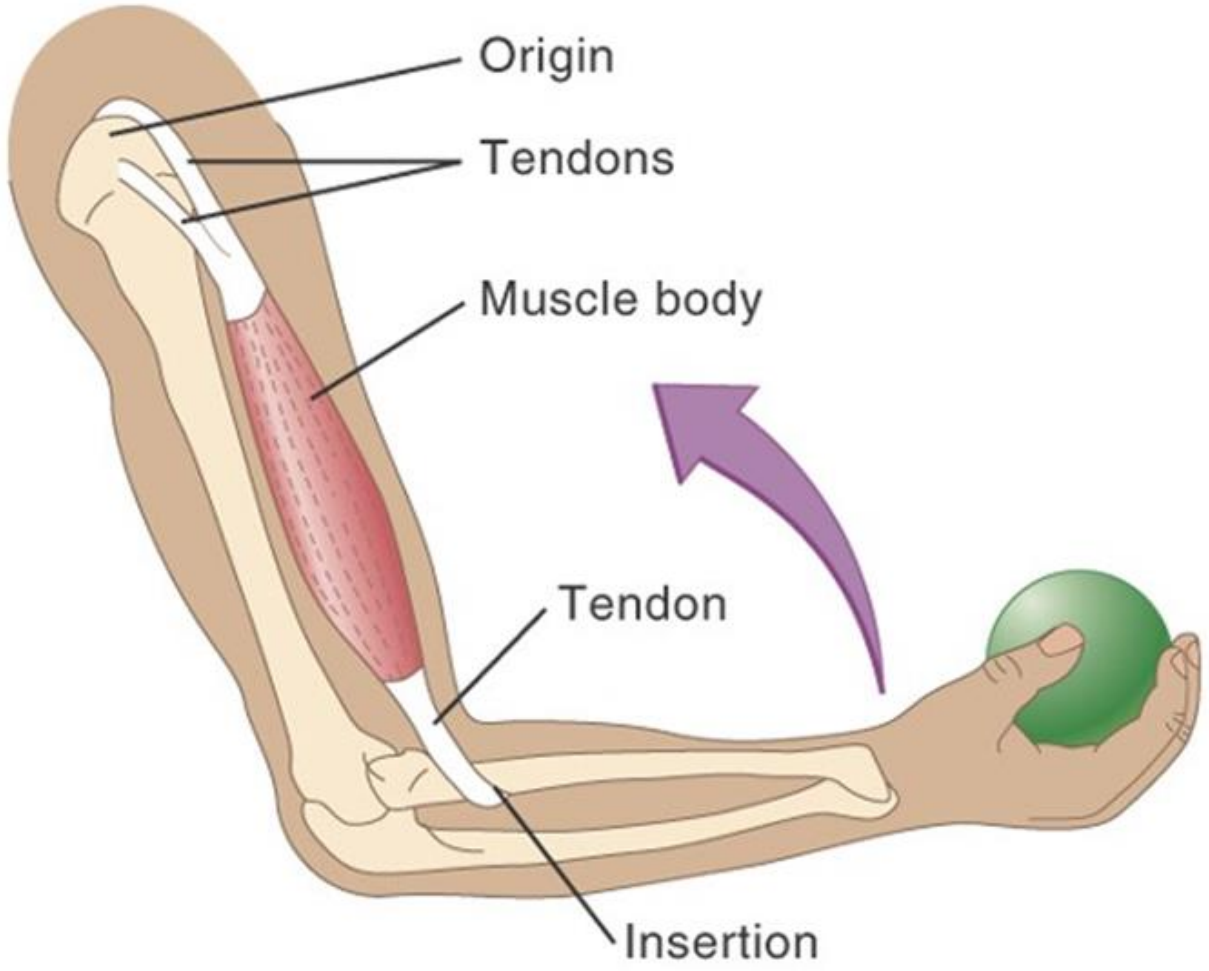
- Oxygen storage
  - Red fibers have myoglobin which has iron to bind with $O_2$
  - White Fibers do not contain myoglobin
- Lactic Acid
  - Excessive lactic acid is send to the liver when $O_2$ is available and converted and stored as glycogen
- Oxygen Debt
  - After strenuous exercise using anaerobic metabolism, ATP and creatine phosphate have to be replaced, this requires $O_2$
  - Is the additional $O_2$ needed to do this after exercise

# Muscle Attachments

- Some may attach to the bone by the epimysium to form a direct attachment
- Most have an extension of the epi, peri and endomysium to form a tendon or a flat sheet-like aponeurosis.  This is an indirect attachment
- Muscles typically span a joint
- The attachment that remains relatively fixed is the origin, the other end is the insertion

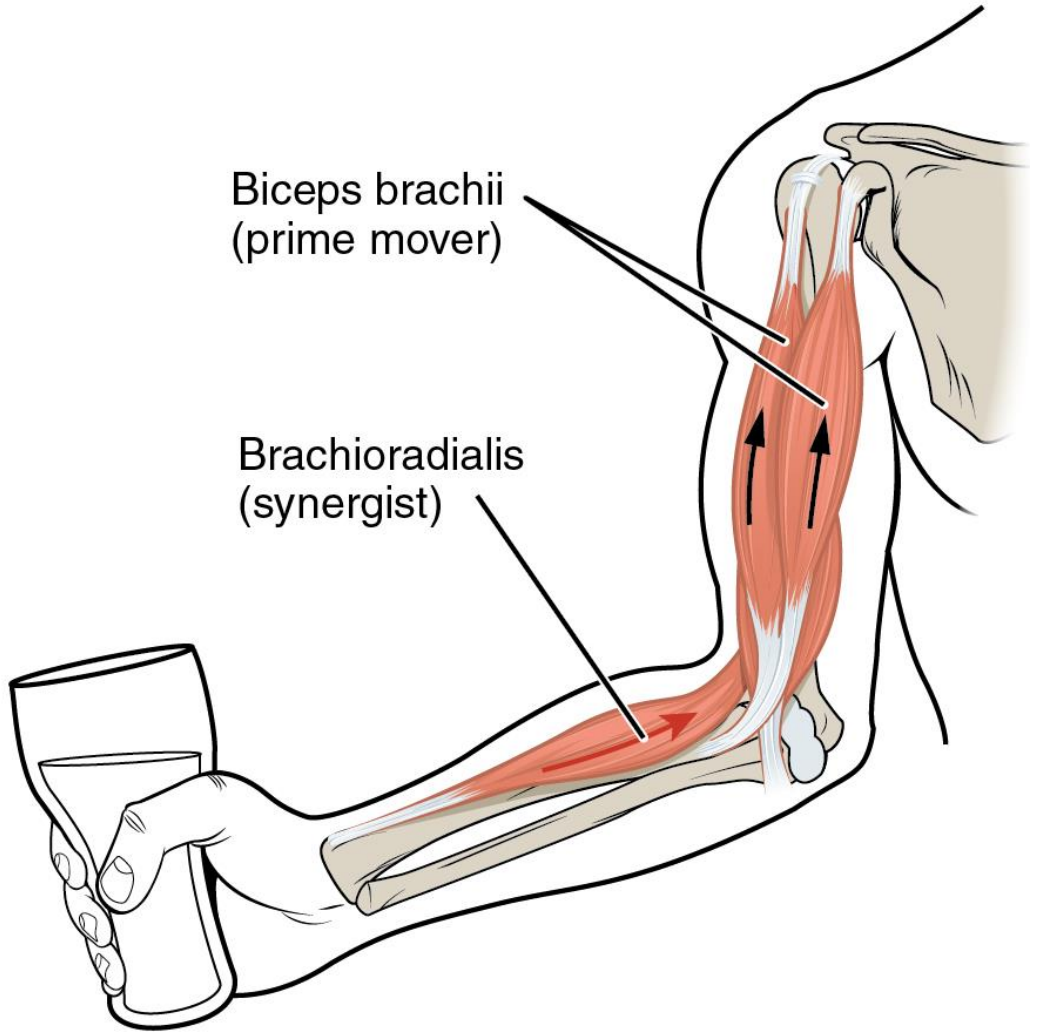
# Muscle Movements

- Origin
  - Attachment that remains relatively fixed
- Insertion
  - Moves in relation to the origin with a contraction



# Muscle Movements

- Muscles will work in groups to produce a movement
- Prime Mover
  - Muscle has the primary role in the motion
- Synergist
  - Assist prime mover
- Antagonists
  - Muscles that oppose a particular movement



# Naming Muscle

- Size
  - Vastus (huge), maximus (large)
- Shape
  - Deltoid (triangle), teres (round)
- Direction of fibers
  - oblique (diagonal)
- Location
  - Pectoralis (chest)

# Naming Muscle

- # of origins
  - Biceps (2), triceps (3)
- Origin and Insertion
  - sternocleidomastoideous
- Action
  - Abductor, flexor