MEDAVIE HealthEd ÉduSanté

Muscular System

Advanced Care Paramedicine

Module: 08

Section: 01b

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

Functions

- Movement
- Posture
- Joint stability
- Heat Production

Types

- Smooth
  - Involuntary
  - Found in the walls of organs
  - Ex: Intestinal tract
- Skeletal
  - Voluntary
- Cardiac
  - Found only in cardiac muscle

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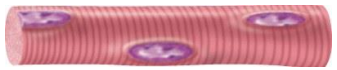
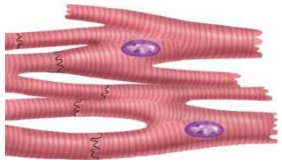
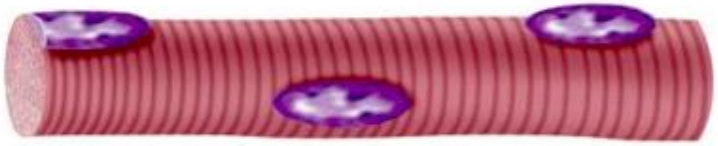
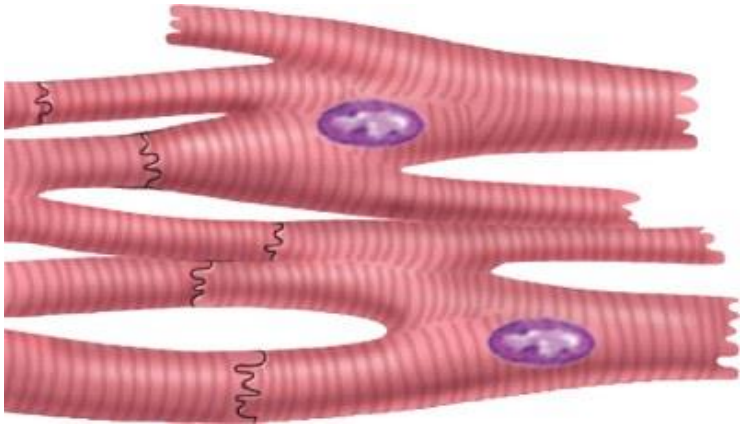
Three Types of Muscular Tissue

	Location	Function	Appearance	Control
Skeletal 	skeleton	movement, heat, posture	**striated**, multi-nucleated (eccentric), fibers parallel	**voluntary**
Cardiac 	heart	pump blood continuously	**striated**, one central nucleus	**involuntary**
Visceral (smooth muscle) 	G.I. tract, uterus, eye, blood vessels	Peristalsis, blood pressure, pupil size, erects hairs	**no striations**, one central nucleus	**involuntary**

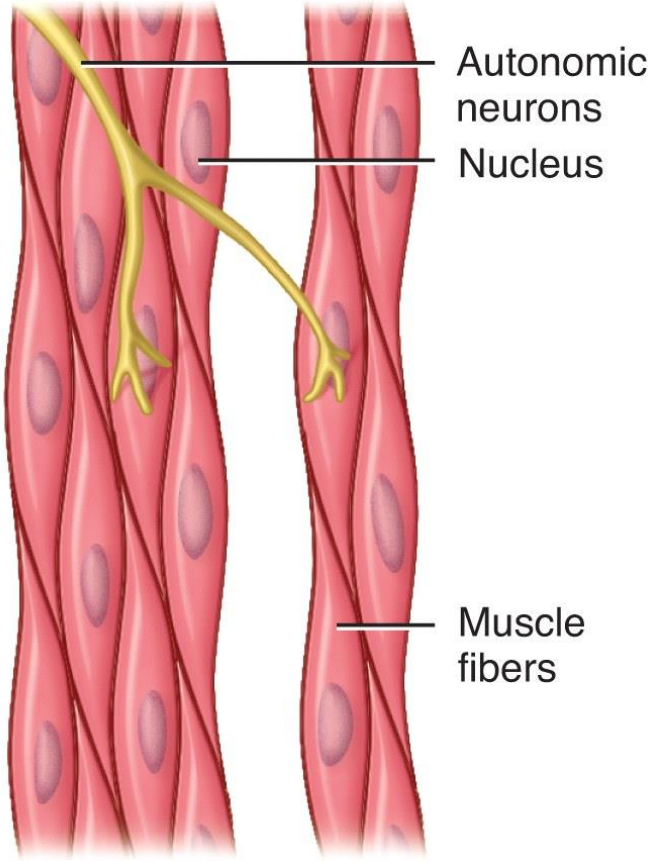
Types of Muscular Tissue



(a) Skeletal muscle



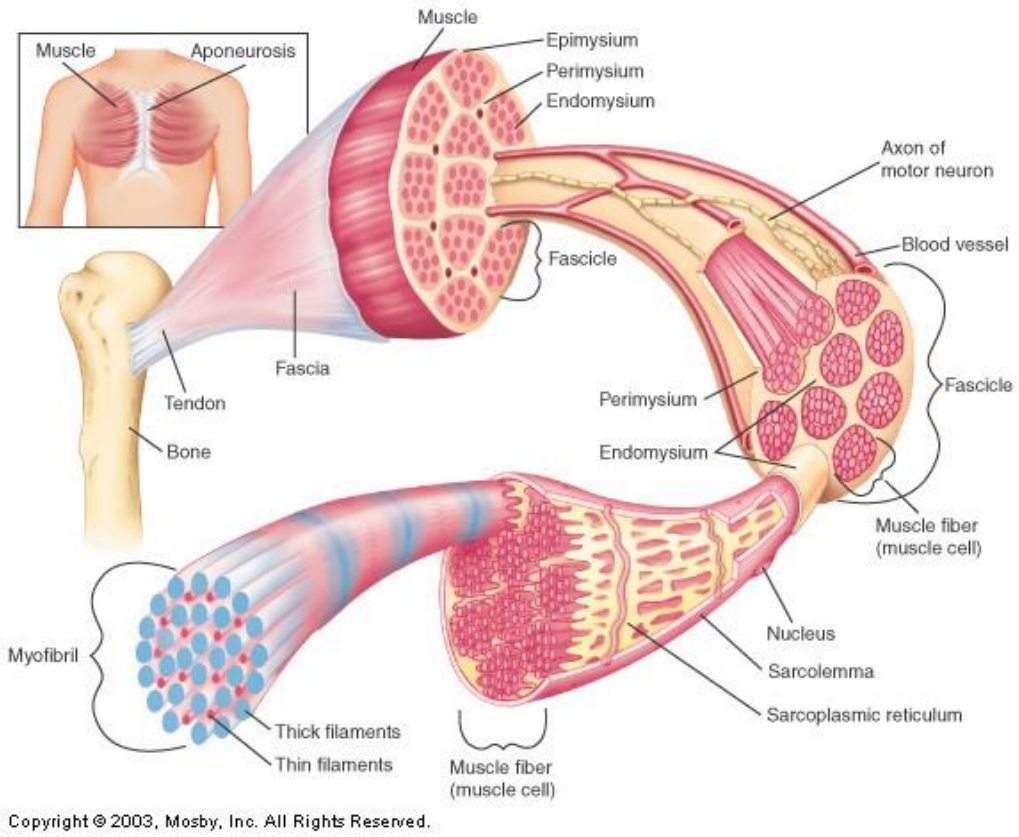
(b) Cardiac muscle



(c) Visceral smooth muscle

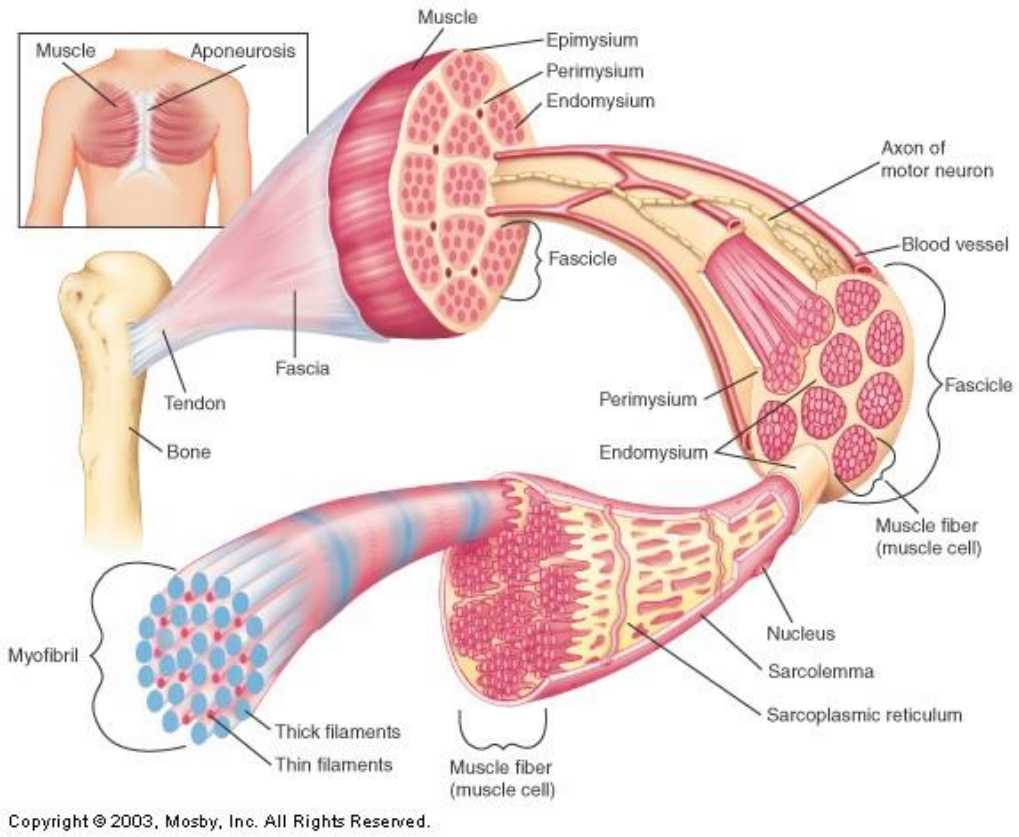
Structure

- Fascia
  - surrounds and separates each muscle
- Epimysium
  - Surrounds each muscle
  - a protective sheath
  - divides the muscle into compartments

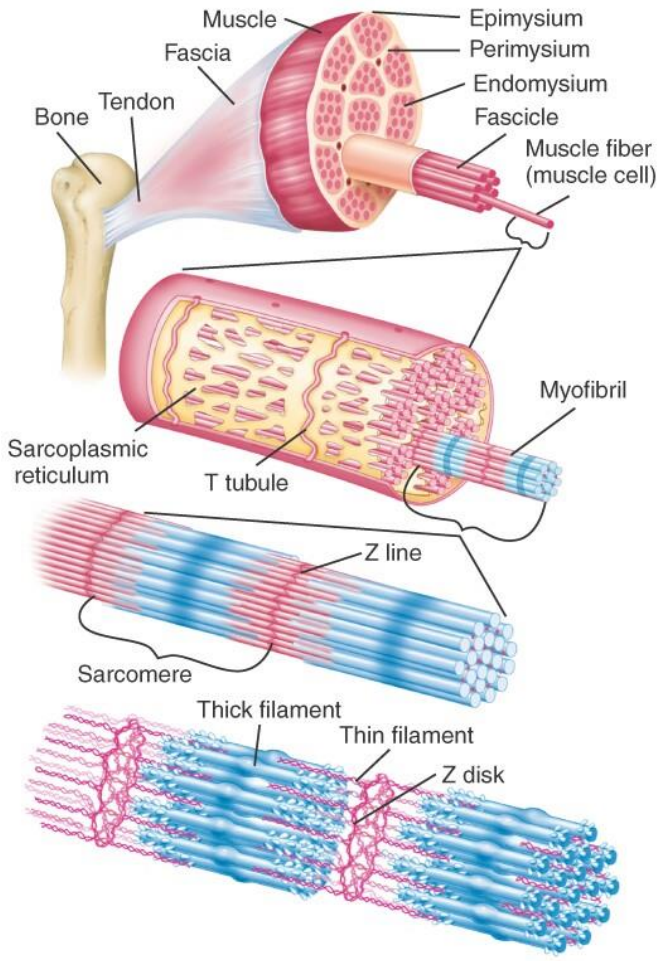


Structure

- Fasiculus
  - 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



Structure



Muscle Fibers

- Each fiber is a cylindrical cell
- The cell membrane is called the sarcolemma
- The cytoplasm is the sarcoplasm
- A special Endoplasmic Reticulum in the sarcoplasm is called the sarcoplasmic reticulum
- The sarcolemma has multiple nuclei and mitochondria (for energy production)
- Inward extensions of the sacrolemma are called T-tubules

Muscle Proteins

- Myofibrils are 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

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

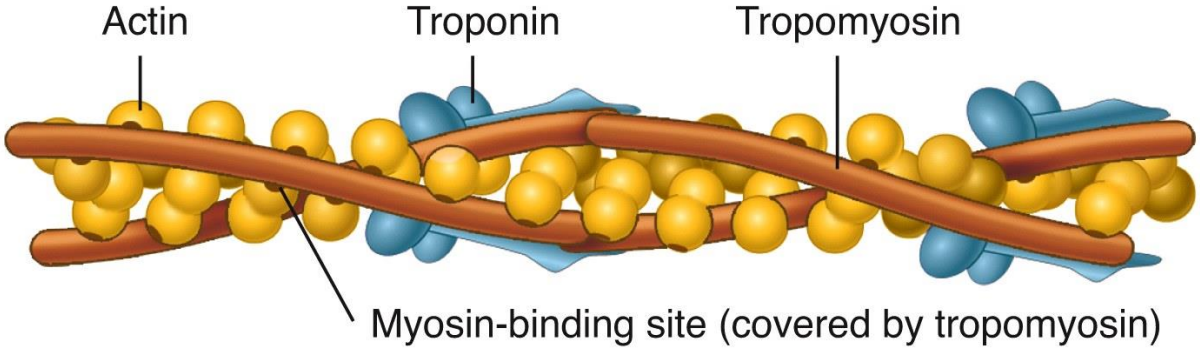
- In the thin filaments actin proteins are strung together like a bead of pearls

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

Muscle Proteins

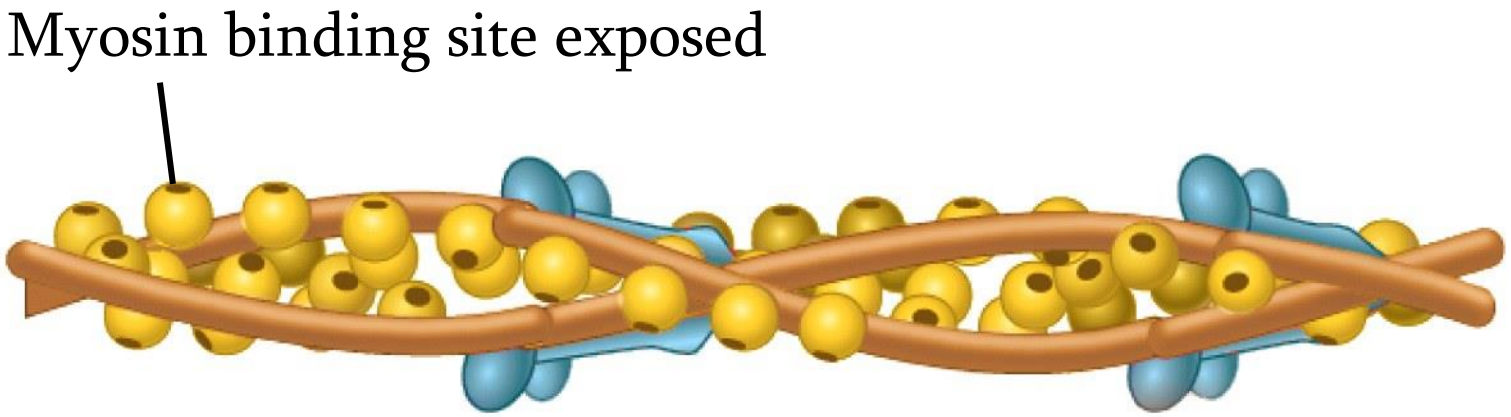
- The myosin binding sites on the actin proteins are readily visible.

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



Muscle Proteins

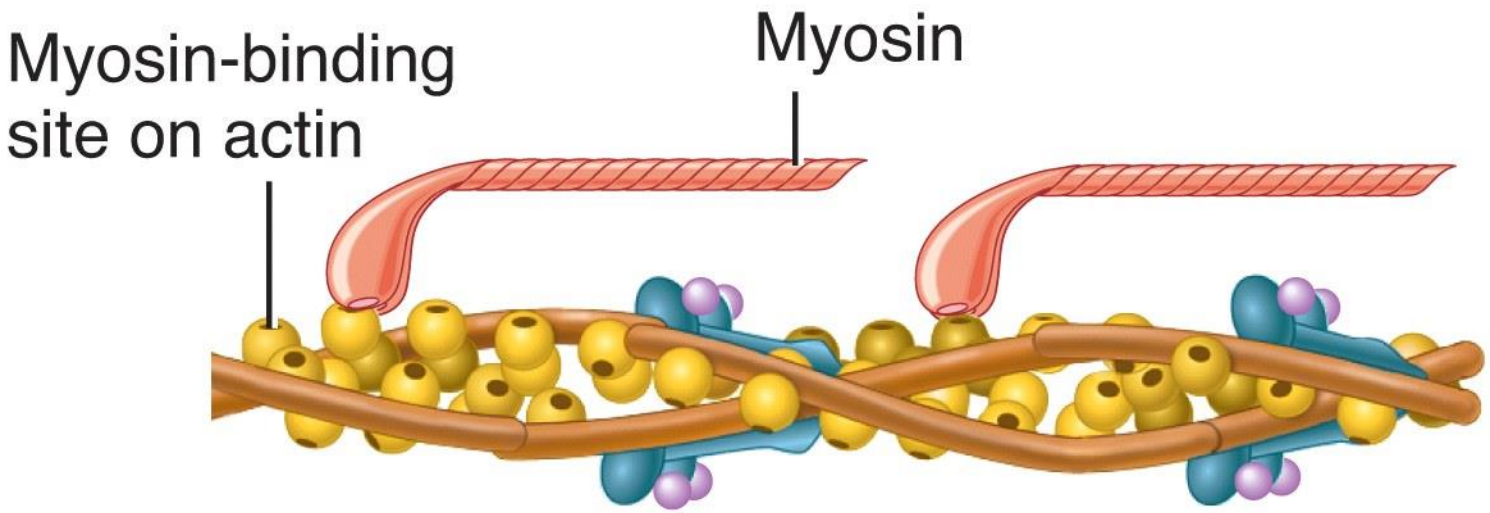
- The troponin-tropomyosin complex has slid down into the “gutters” of the actin molecule unblocking the myosin binding site



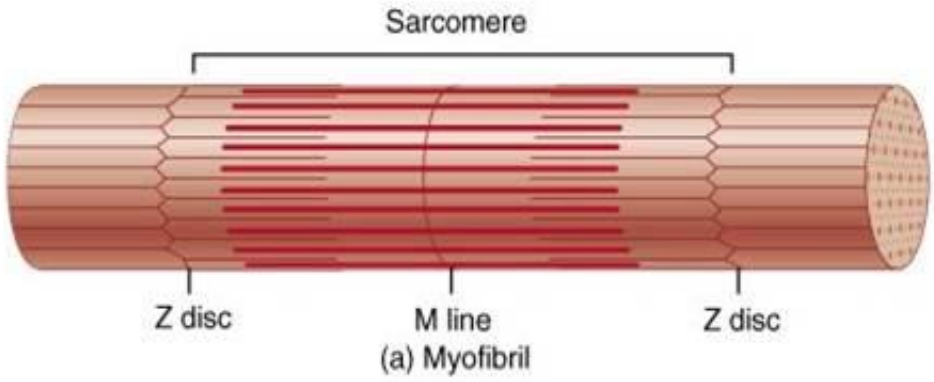
- The troponin-tropomyosin complex can slide back and forth depending on the presence of Ca^{2+}

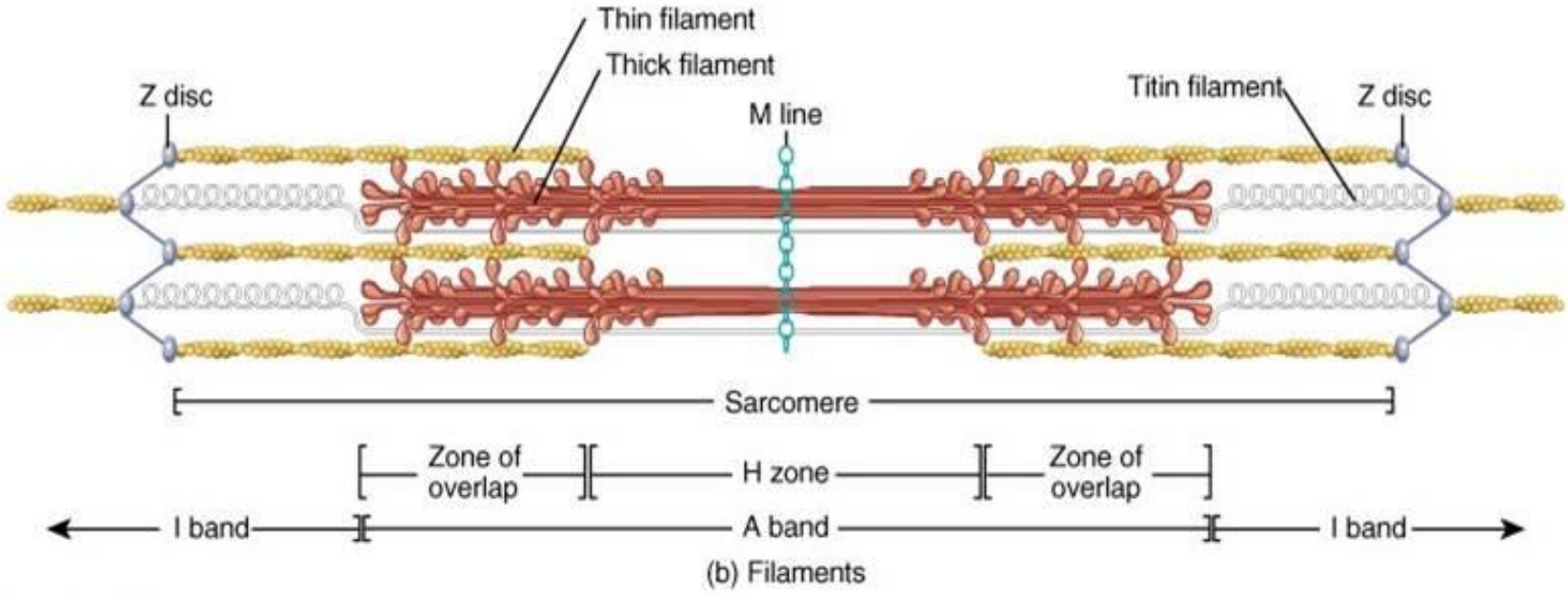
Muscle Proteins

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



Structure


Sarcomere
Z disc
M line
Z disc
(a) Myofibril


Thin filament
Thick filament
Z disc
M line
Titin filament
Z disc
Sarcomere
Zone of overlap
H zone
Zone of overlap
I band
A band
I band
(b) Filaments

Muscle Proteins

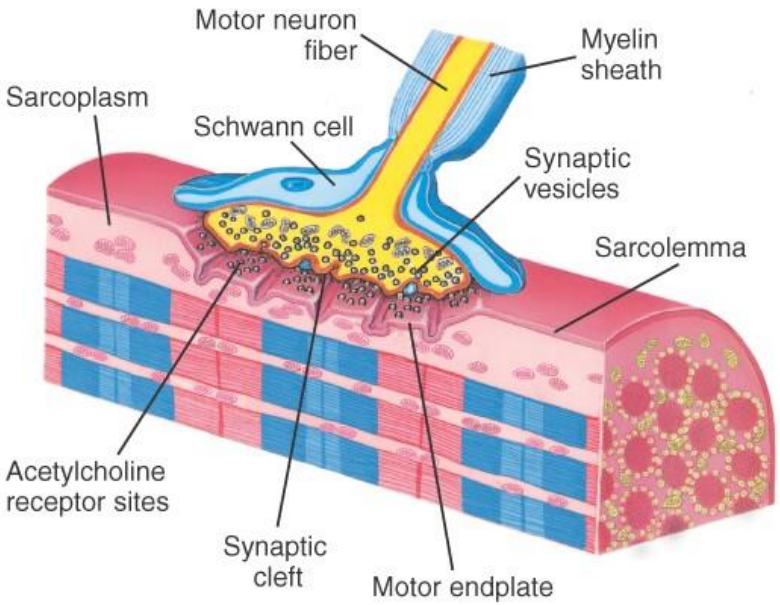
- Besides contractile and regulatory proteins, muscle contains about a dozen structural proteins which contribute to the alignment, stability, elasticity, and extensibility of myofibrils
  - Titan is the third most plentiful protein in muscle, after actin and myosin - it extends from the Z disc and accounts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

Nerve & 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

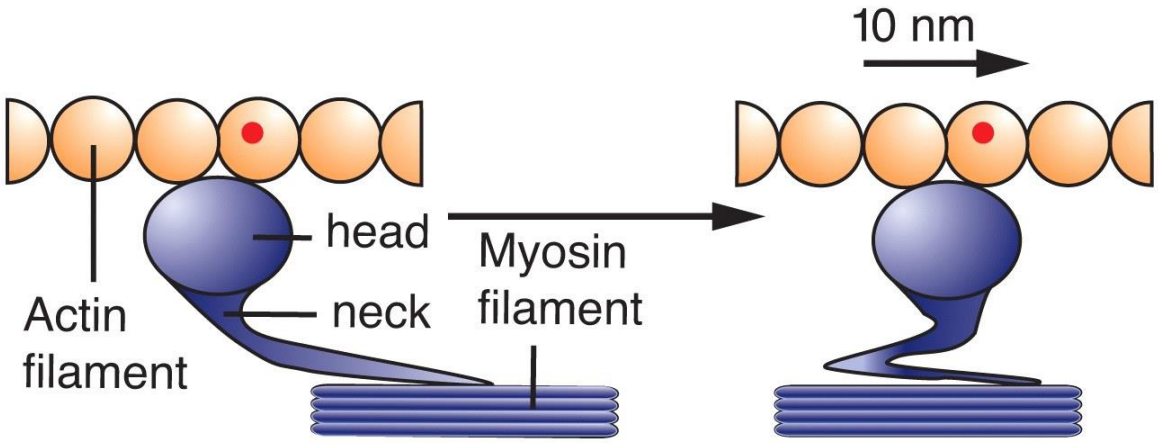
- ACh is contained within the synaptic vesicles of the axon
- Receptors for ACh are in the sacrolemma
- The combination results in a stimulus for contraction (an impulse) which travels along the sacrolemma into the T-tubules where a physiological change occurs causing a contraction
- The enzyme **acetylcholinesterase** 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 is stored in the sarcoplasmic reticulum and has a low concentration in the sarcoplasm
- An impulse into the T-tubule cause release of Ca from the SR into the sarcoplasm
- This rapid influx changes configuration of troponin on the actin fibers which exposes receptor sites

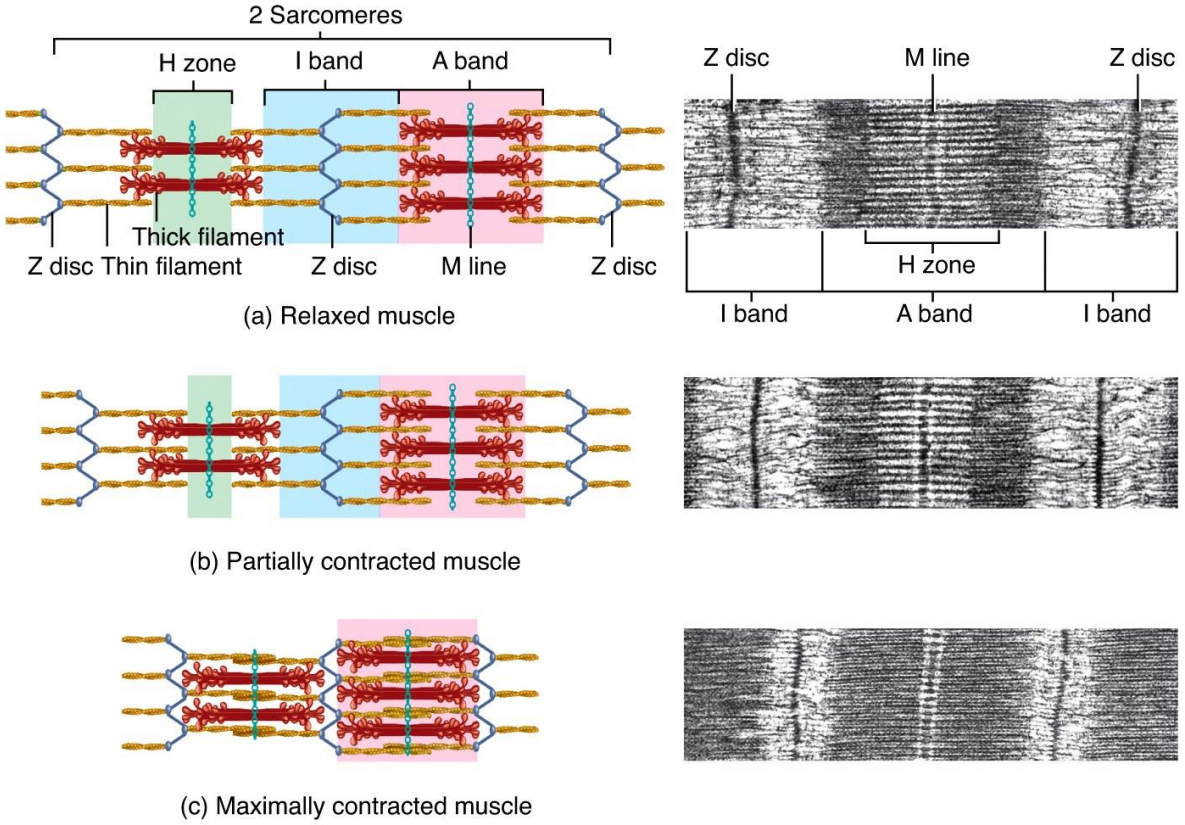
The Sliding-Filament Mechanism

- 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



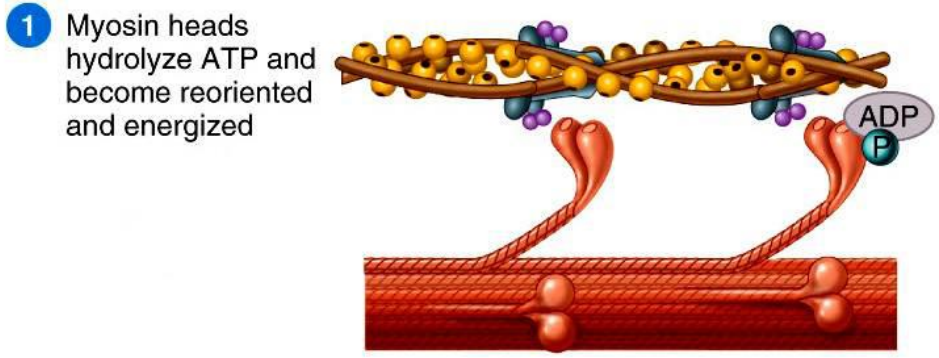
The Sliding-Filament Mechanism

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

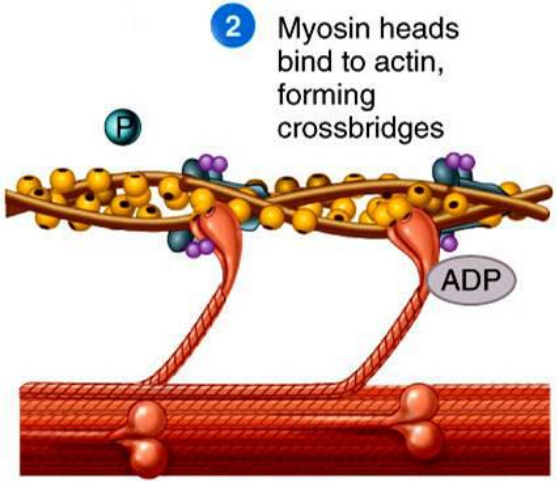


The Sliding-Filament Mechanism

- Step 1: ATP hydrolysis

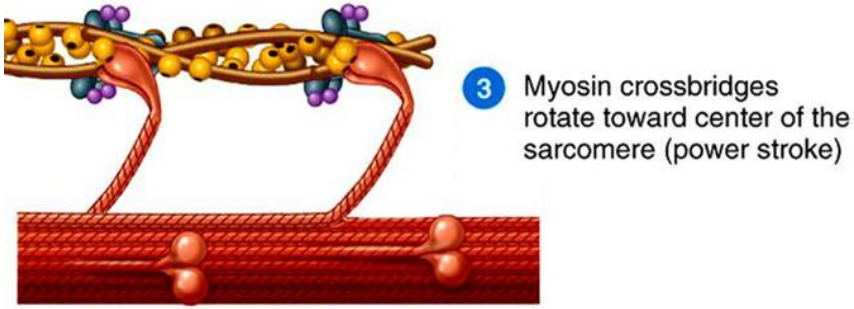


- Step 2: Attachment

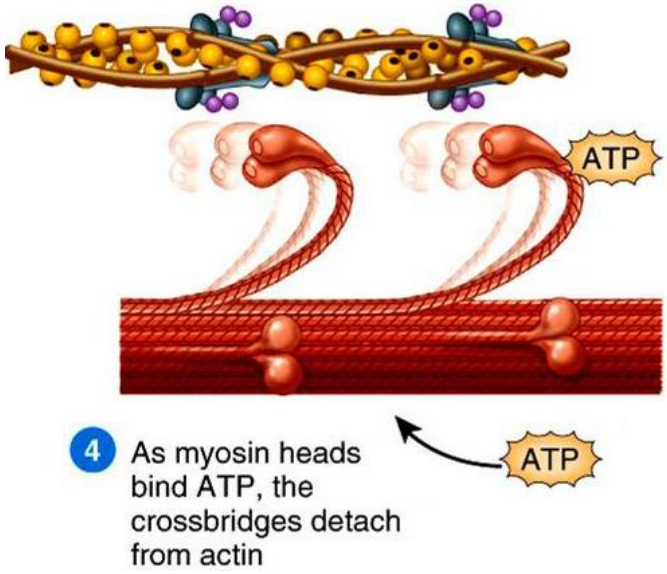


The Sliding-Filament Mechanism

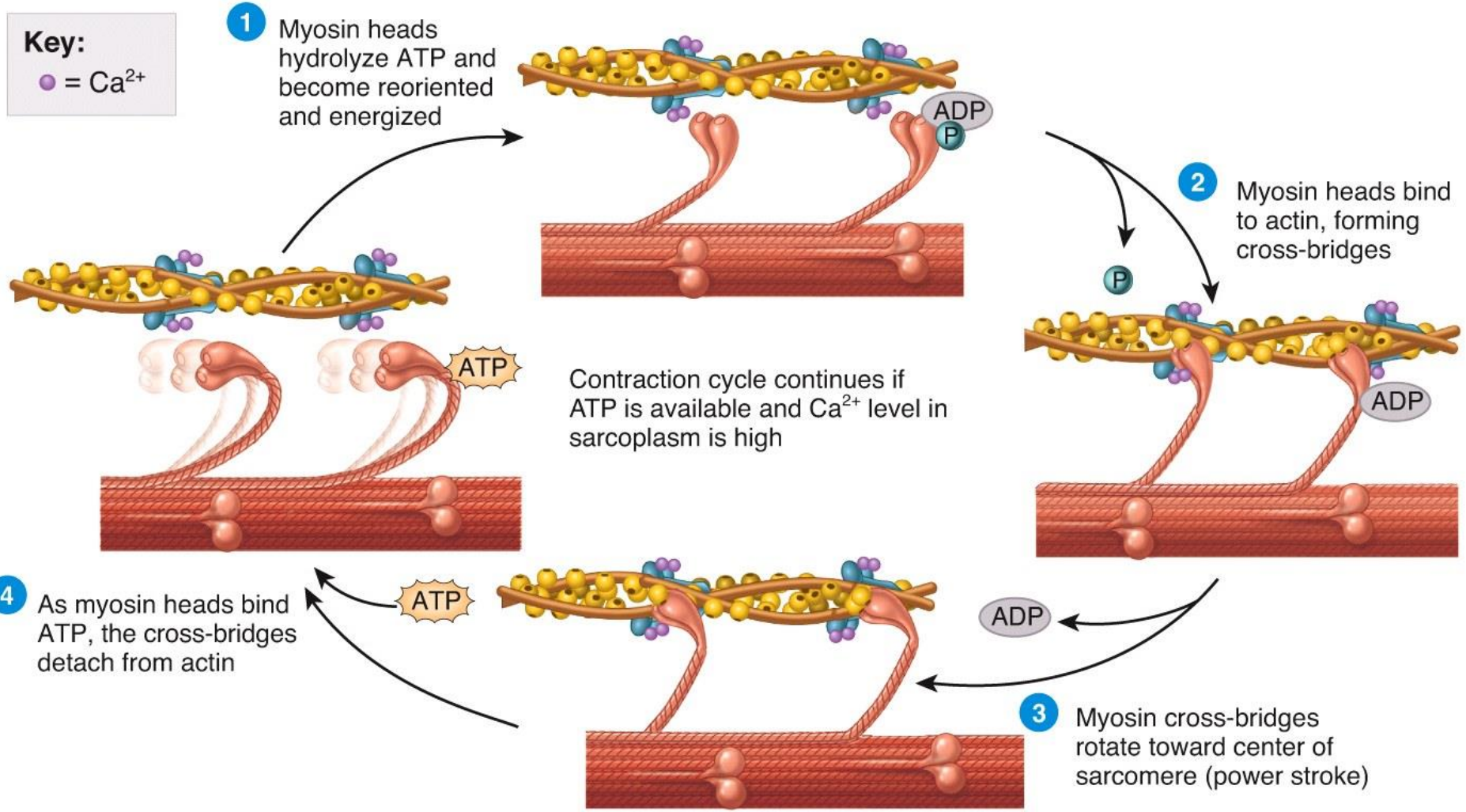
- Step 3: Power Stroke



- Step 4: Detachment

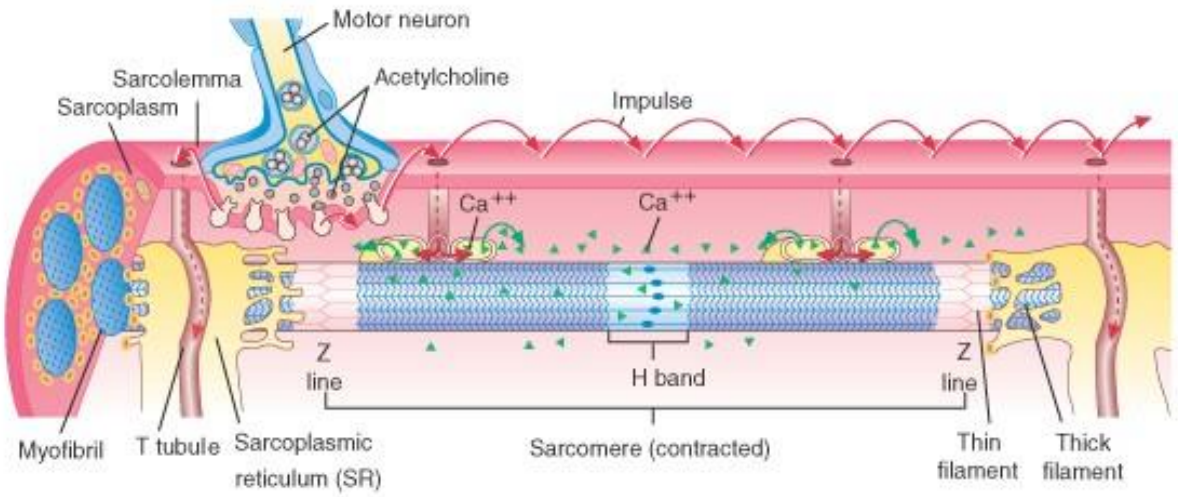


The Sliding-Filament Mechanism



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



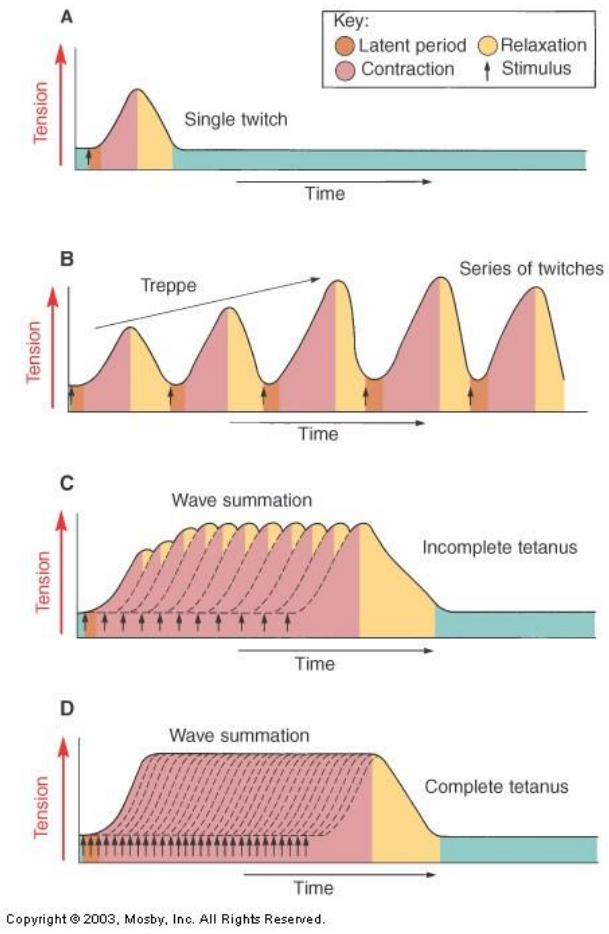
Sacromere Contraction

- 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, which is basically:
  - 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 All-or-none
- 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

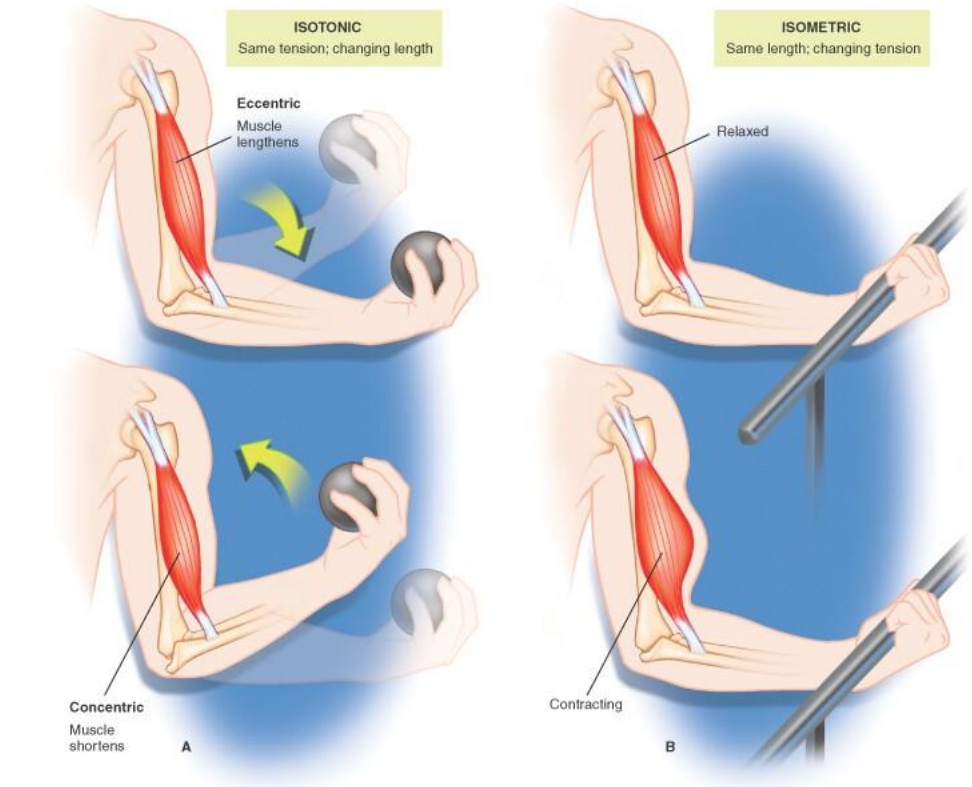
Whole Muscle Contraction



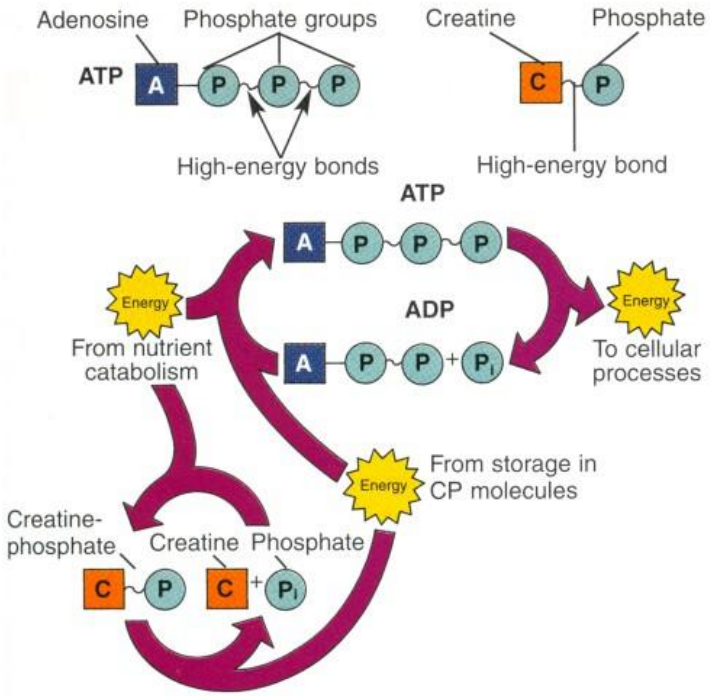
- A stimulus given during relaxation phase will cause stronger contraction, and continues to build to form a smooth contraction called tetany (multiple wave summation)
- Treppe (staircase) shows an increase in force with a stimulus of same intensity

Whole Muscle Contraction

- Muscle tone is the continued state of partial contractions of the muscles (needed for posture and temp)
- If movement occurs it is an isotonic contraction
- If there is no movement then it is isometric



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)**

$$\text{Fatty Acids or glucose} + O_2 \rightarrow CO_2 + H_20 + \text{ATP}$$

  - If oxygen is not available then glucose is the primary source of energy (**anaerobic metabolism – happens at a faster rate)**

$$\text{Glucose} \rightarrow \text{lactic acid} + \text{ATP}$$

Energy Sources

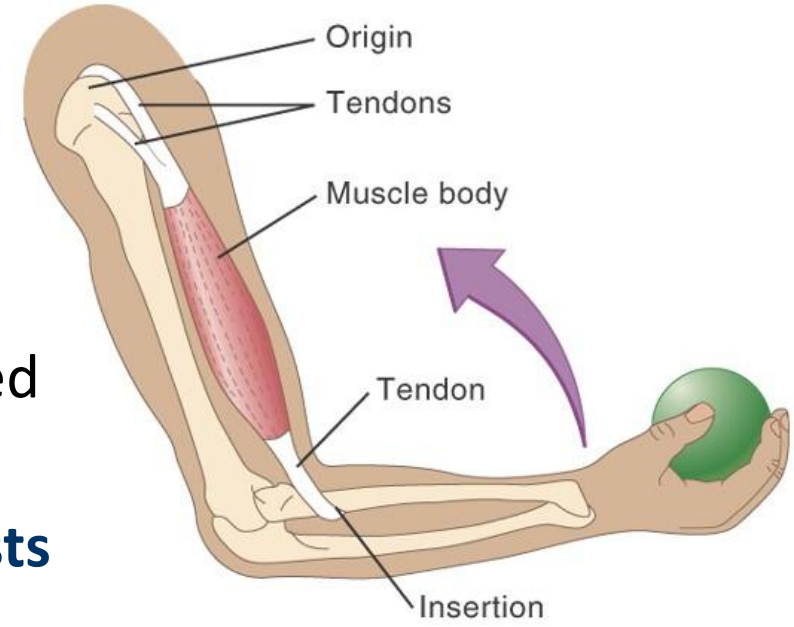
- Oxygen storage
  - Red fibers have myoglobin which has iron to bind with O_2
  - White Fibers do not contain myoglobin
- Lactic Acid
  - Excessive lactic acid is send to the liver when O_2 is available and converted and stored as glycogen
- Oxygen Debt
  - After strenuous exercise using anaerobic metabolism, 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 apaneurosis. 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

- The insertion moves in relation to the origin with a contraction
- Muscles will work in groups to produce a movement
- If a one muscle has the primary role in the motion then it is called the **prime mover**
- Ones that assist are the **synergists**
- **Antagonists** are 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