



The Muscular System

Functions of Muscle Tissue

- Movement Facilitation
- Thermogenesis
- Postural Support
- Regulation of Organ Volume
- Protects Internal Organs
- Pumps Blood (*HEART*)

Characteristics of Muscle Tissue

- Contractility – able to shorten.
- Extensibility (Flexibility) – able to lengthen.
- Elasticity – able to return to original shape.
- Excitability (Irritability) – able to respond to a stimulus.

Skeletal Muscle

- Attached to bones
- Striated appearance under a microscope
- Voluntary control (conscious control)
- Multinucleated
- Myofilaments - contractile elements of each muscle fiber

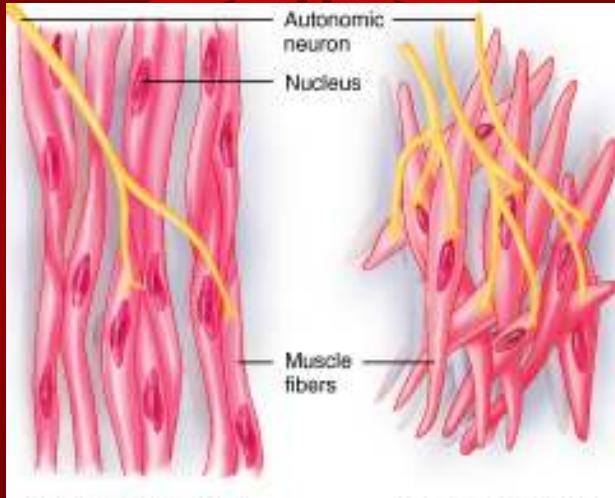
Cardiac Muscle

- Forms the bulk of heart wall (Myocardium)
- Striated
- Involuntary (typically)
- Fibers are quadrangular and branching
- Cardiac fibers typically have a centrally located nucleus
- Sarcolemmas connected by intercalated discs
 - Strengthens cardiac muscle tissue
 - Propagates an action potential from cell to cell through specialized structures on the intercalated discs called gap junctions

Smooth (Visceral) Muscle

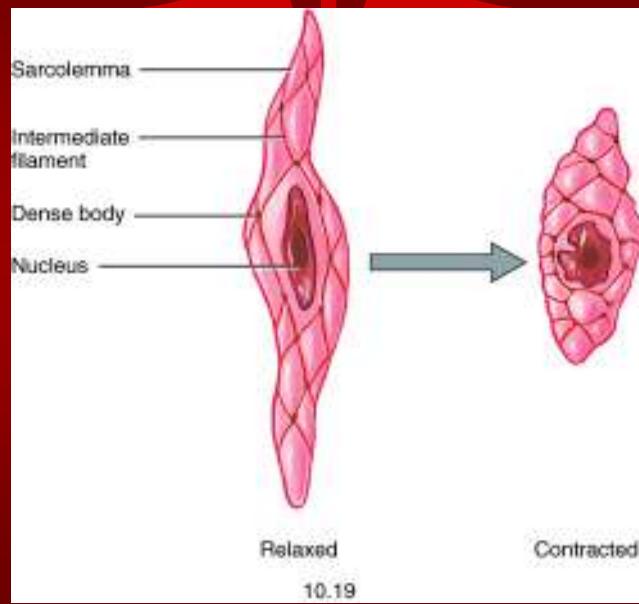
- Located in walls of hollow internal surfaces such as:
 - blood vessels - stomach
 - urinary bladder - intestines
- Non-striated in appearance
- Involuntary (typically)
- Can be stretched to great lengths
- Allows for tremendous size variability

Smooth (Visceral) Muscle



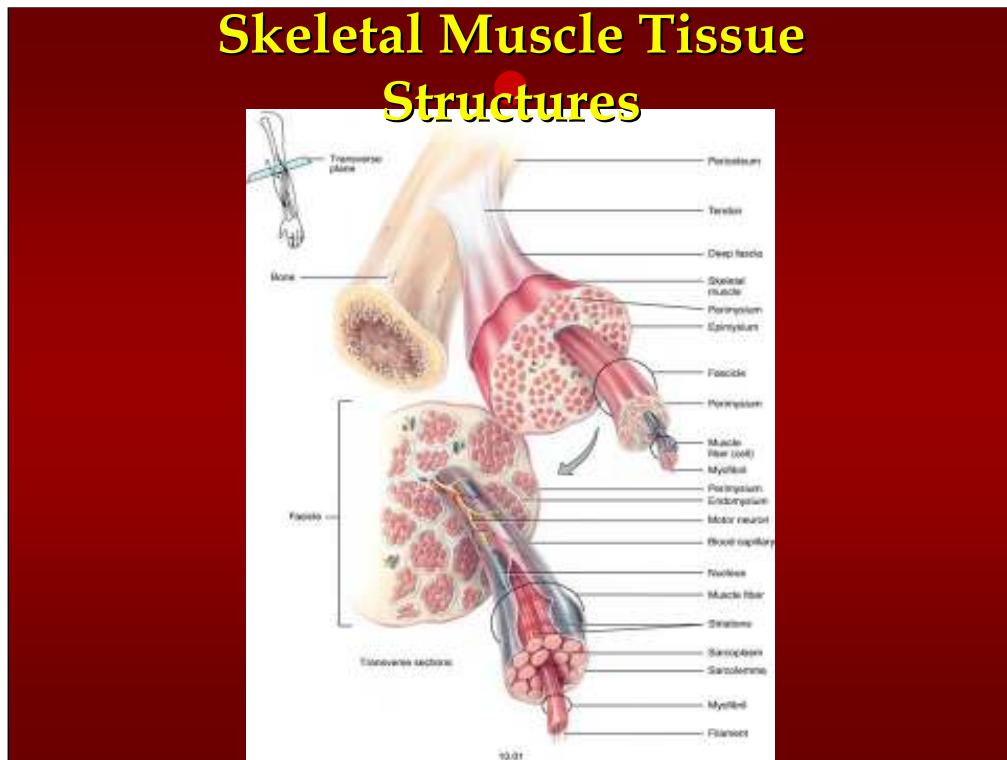
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Smooth (Visceral) Muscle

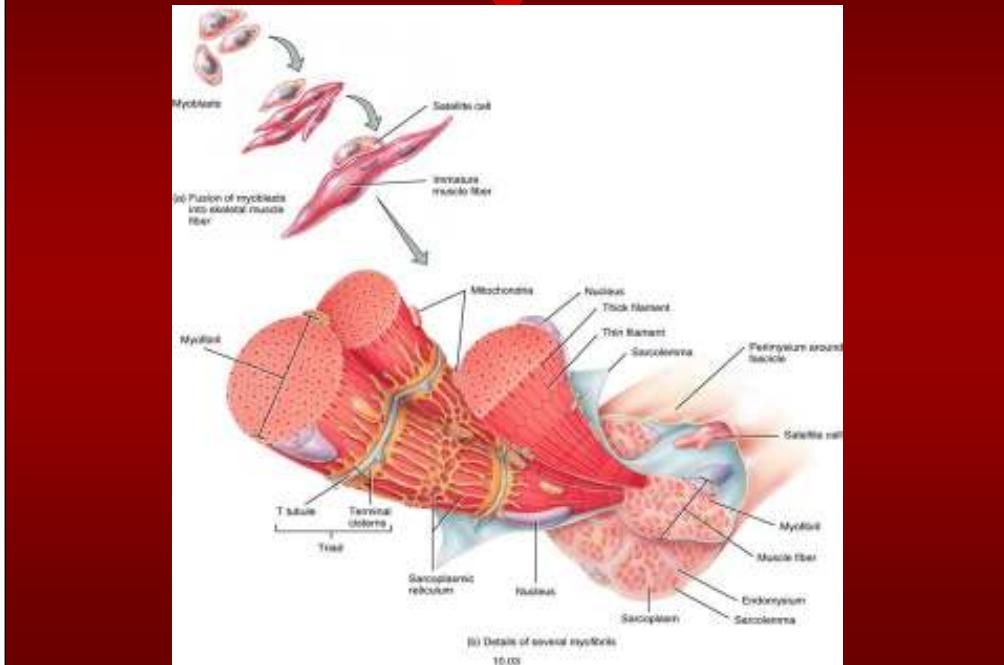


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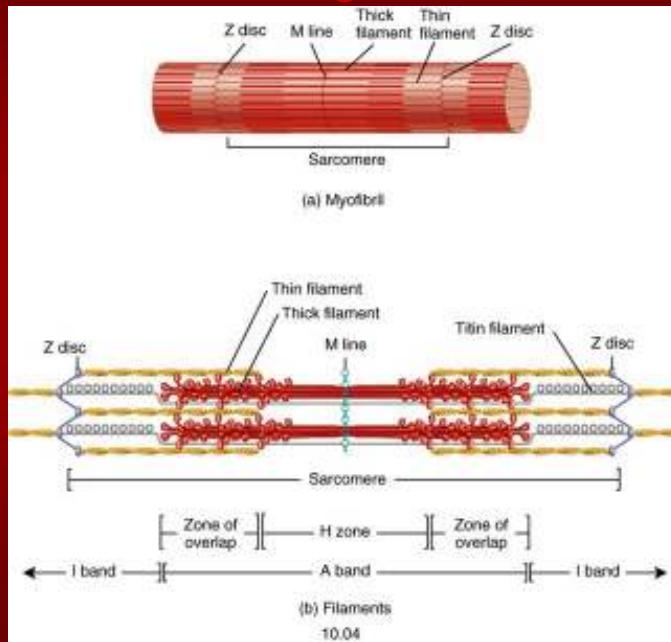
Skeletal Muscle Tissue Structures



Muscle Tissue Structures



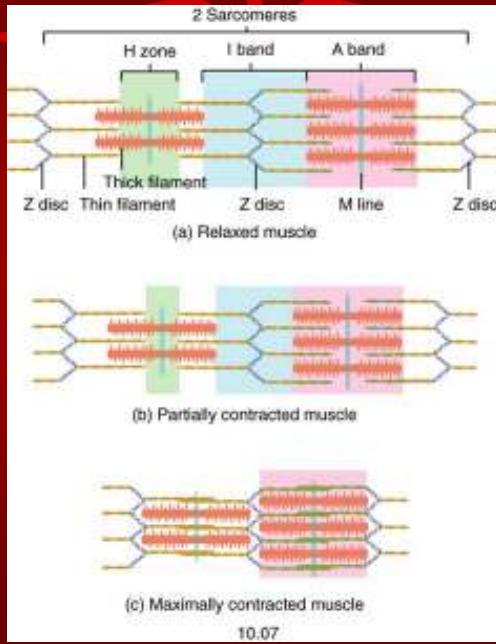
Sarcomere



Muscle Tissue Histology

- Myofilaments - structural components of myofibrils
 - Myosin - thick myofilaments
 - Actin - thin myofilaments

Regions of a Sarcomere



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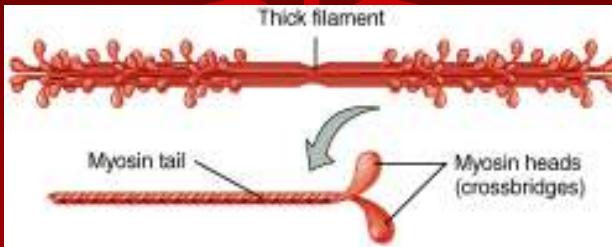
Myosin

- Thick myofilaments
- Occupy the A Band of the sarcomere
- Overlap free ends of the actin myofilament
- Shaped like a golf club
 - Long, thick protein molecule (tail)
 - Globular head at the ends

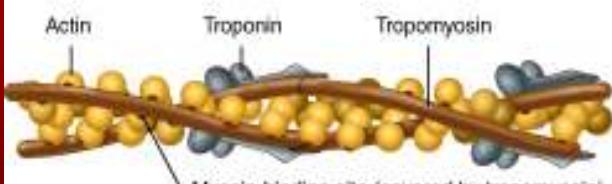
Actin

- Thin myofilaments
- Anchored to the Z Line
- Two stranded protein molecule intertwined around each other
- Associated with two regulatory proteins
 - Tropomyosin - long stranded protein molecule that follows the contour of actin
 - Troponin - protein located at regular interval along the tropomyosin that covers the active sites on actin. Has three subunits

Myofilaments



(a) One thick filament (above) and a myosin molecule (below)



(b) Portion of a thin filament

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Muscle Action Potential

An electrical impulse that originates at the motor end plate, travels along the length of the sarcolemma, down a transverse tubule, and causes the muscle to contract.

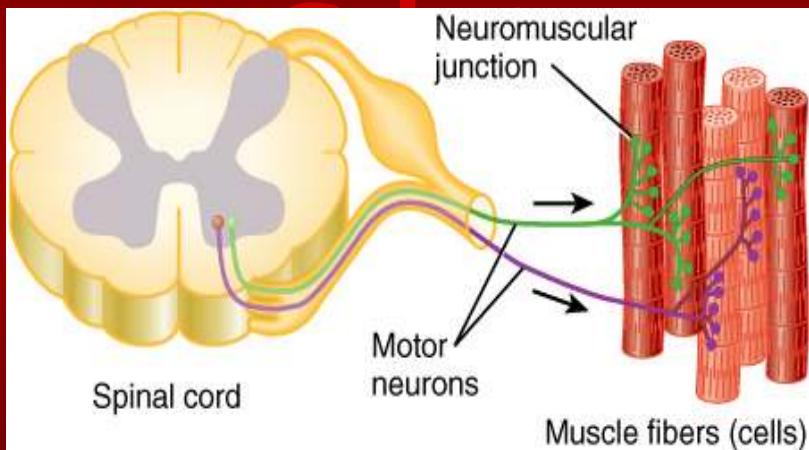
Sliding Filament Theory of Muscular Contraction

- Due to an action potential, the actin and myosin myofilaments slide past one another shortening the sarcomere
- No change in length of myofilaments
- H Zone narrows or disappears
- I Band narrows or may disappear
- A Band remains the same length

Muscle Nerve Interaction

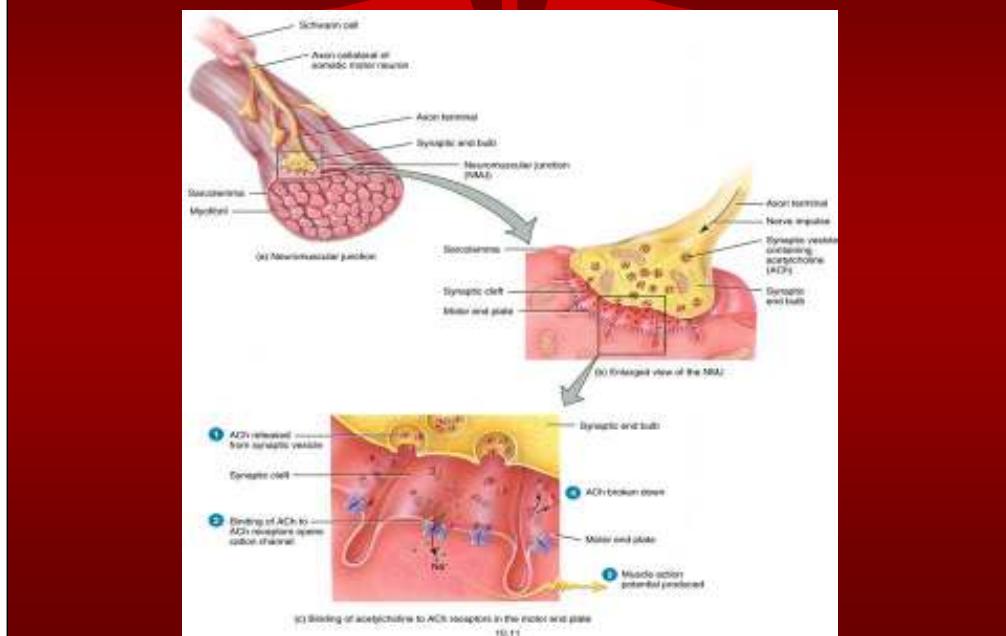
- Neuron - nerve cell
- Axon - long, threadlike process that transmits impulse away from cell body (may be up to 1 meter in length)
- Motor Unit - motor neuron and all the muscle fibers it innervates
- Neuromuscular Junction - junction between axon terminal and muscle fiber

Neuromuscular Junction

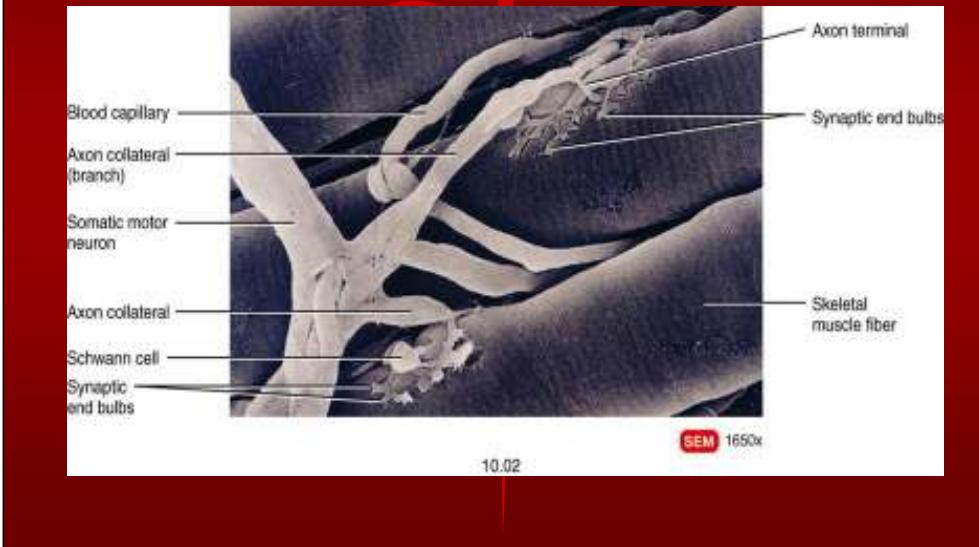


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Neuromuscular Junction



Neuromuscular Junction



Muscle Nerve Interaction

- Motor End Plate - location on the muscle fiber at the end of an axon terminal
- Synaptic End Bulb - distal end of axon terminal
- Synaptic Vesicles - membrane enclosed sacs within the synaptic end bulbs that store neurotransmitters

Muscle Nerve Interaction

- Synaptic Cleft - space between axon terminal and motor end plate
- Subneural Clefts - folds in sarcolemma along the synaptic gutter
- Acetylcholine (Ach) - neurotransmitter released from synaptic vesicles that initiates an action potential in a muscle

Muscle Response to Nervous Stimuli

- All or None Principle
 - Once a threshold stimulus is applied to a motor unit the muscle fibers innervated by that motor unit will contract to their fullest potential
- Threshold Stimulus - the weakest stimulus from a neuron that will initiate a muscular contraction

Events Leading to Muscular Contraction

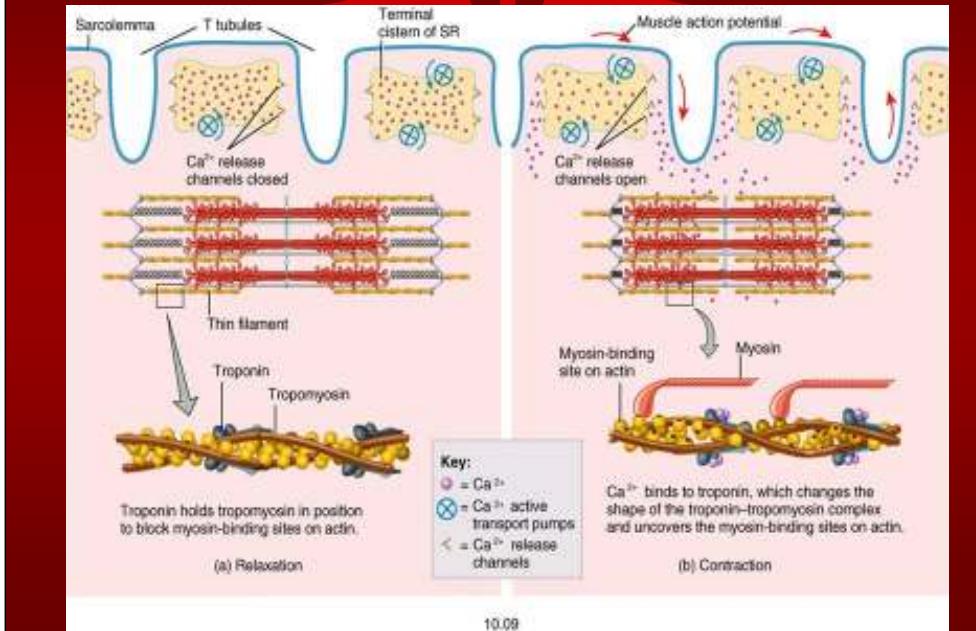
- An action potential travels down the motor neuron. When it arrives at the synaptic knob, the membrane of the nerve at the synaptic cleft is depolarized, thereby increasing the Ca^{++} permeability of the membrane.
- Ca^{++} diffuses from outside of the synaptic knob to inside the synaptic knob.

- The influx of Ca^{++} into the nerve causes the release of Ach.
- Ach is ejected into the synaptic cleft, diffuses across the cleft, and depolarizes the muscle membrane.
- This increases the permeability of the muscle membrane to Na^+ .
- Na^+ rushes into the muscle cell, depolarizing the membrane as it travels away from the motor end plate thus initiating an action potential.

- Ach is quickly broken down in the cleft by Ach-ase so that each action potential arriving from the nerve initiates only one action potential within the muscle.
- The action potential spreads across the muscle membrane and down the T-tubules deep into the muscle cell.
- The action potential of the T-tubules depolarizes the membrane of the nearby sarcoplasmic reticulum which results in the release of Ca^{++} into the sarcoplasm.

- Ca^{++} is very quickly removed out of the sarcoplasm by the sarcoplasmic reticulum so the effects of one action potential are very short lived and produce a very small contraction.
- Many action potentials are necessary to produce enough force to produce a strong or prolonged muscle contraction.
- The Ca^{++} released from the sarcoplasmic reticulum binds with troponin and cause troponin to change shape.

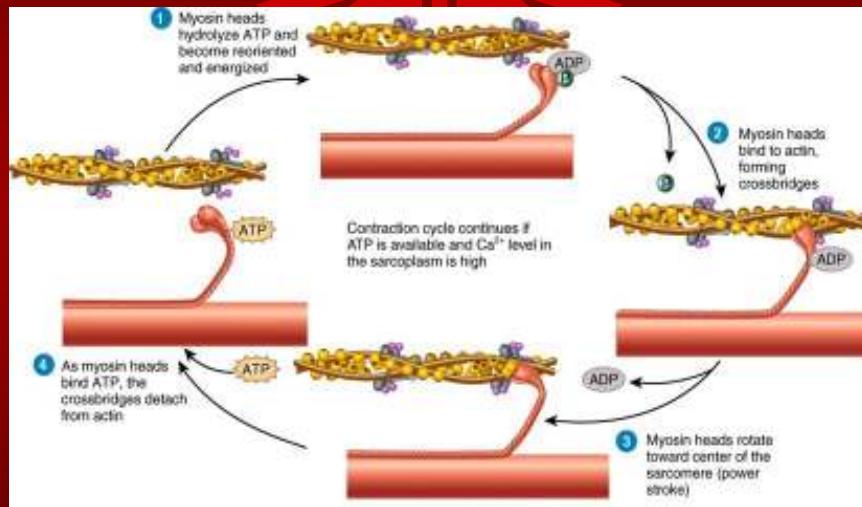
Muscle Contraction Events



- When troponin changes shape, it physically moves the other regulatory protein, tropomyosin, out of the way exposing the active sites on the actin myofilament.
- Since the heads or cross-bridges of myosin have a very strong affinity for the active sites on actin, they make contact immediately after the active sites have been exposed.
- The acto-myosin complex has ATPase activity and ATP is split into ADP + P and energy is released.

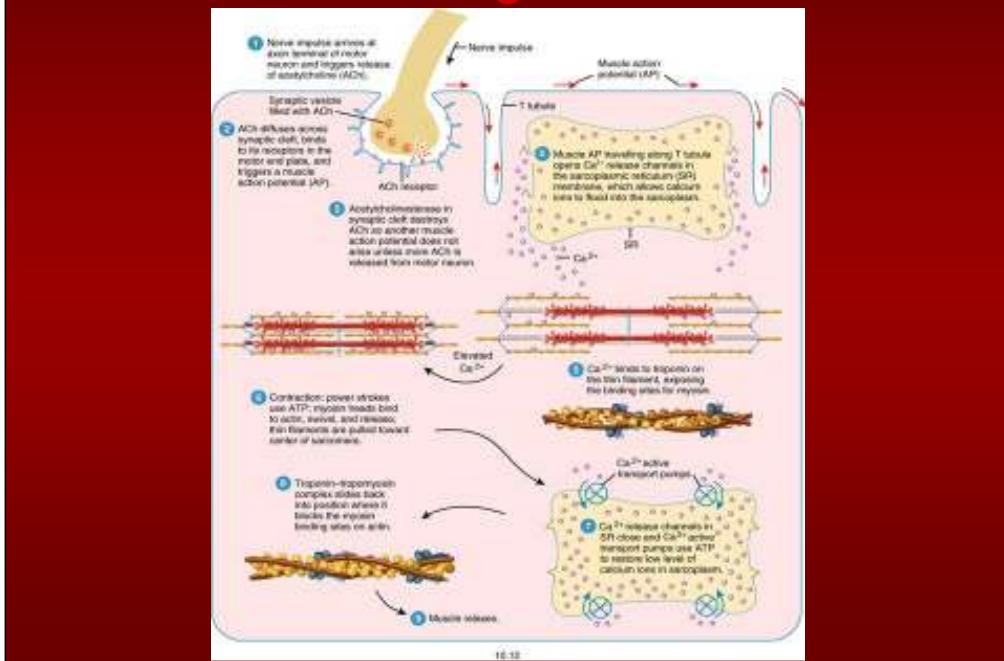
- The energy released by the splitting of ATP is used to produce movement of the cross-bridges, sliding the actin and myosin filaments past one another which causes the sarcomere to shorten and the muscle to contract and produce force.
- The myosin cross-bridge has a low affinity for ADP but a very high affinity for ATP.
- It discards the ADP and becomes recharged with a new ATP.

Muscle Contraction Events



- The myosin then releases its hold on the active sites on actin, swivels back to its original position, and is ready to respond to another action potential.
- When another action potential comes along the entire process is repeated.
- It takes many action potentials to produce enough shortening of the sarcomeres to generate enough force to produce movement of a body segment.

Muscle Contraction Events



Muscle Origin and Insertion

- Origin
 - Body segment with most mass
 - Usually more proximally located
 - Usually larger surface area of attachment
- Insertion
 - Body segment with least mass
 - Usually more distally located
 - Usually smaller surface area of attachment
- Gaster (Belly)
 - Fleshy portion of the muscle between the tendons of the origin and insertion

Roles of Skeletal Muscles

- Agonist (Prime Mover)
 - Muscle responsible for the majority of force
- Antagonist
 - Performs the opposite movement
- Synergist
 - Muscle that assists the agonist
 - provides additional force
 - redirects the force of the agonist
- Fixator (Stabilizer)
 - Stabilizes a body segment so the prime mover can act more effectively

Selected Superficial Skeletal Muscles (Anterior View)

- Pectoralis major
- Deltoid
- Biceps brachii
- Sternocleidomastoid
- Diaphragm
- Quadriceps
 - rectus femoris
 - vastus medialis
 - vastus lateralis

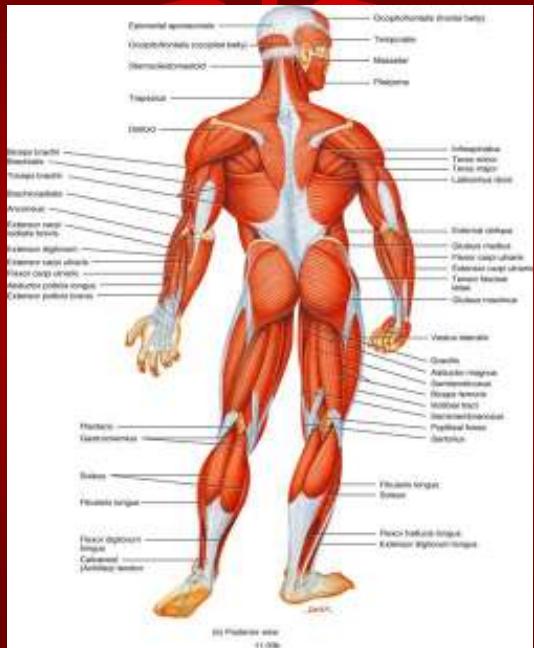
Anterior Skeletal Muscles



Selected Superficial Skeletal Muscles (Posterior View)

- Trapezius
- Triceps brachii
- Gastrocnemius
- Latissimus dorsi
- Hamstring Group
 - semimembranosus
 - biceps femoris
 - semitendinosus
- Gluteus maximus

Posterior Skeletal Muscles





Myalgia (Fibromyalgia)

- Painful disorders of muscles, tendons, and surrounding soft tissue

Muscular Dystrophies

- Muscle destroying diseases characterized by the degeneration of individual muscle fibers
- Leads to progressive atrophy of skeletal muscles
- Due to a genetic defect

Shin Splints

- Pain in the lower leg
- Tendonitis of the tibialis posterior muscle
- Inflammation of the periosteum
- Stress fracture of the tibia
- Exaggerated enlargement of muscles within the epimysium
- Pulling away of the periosteum from the underlying bone
- Treatment:
 - RICE
 - strengthen tibialis anterior muscle

Sprains

- the forcible wrenching or twisting of a joint with partial or complete rupture or injury to joint attachments without dislocation
- 1st Degree Sprain = stretching of ligaments
- 2nd Degree Sprain = partial tearing of ligaments
- 3rd Degree Sprain = complete tear of ligaments

Strains

- pulling or overstretching a muscle
- soft tissue (Muscle) injury

