



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

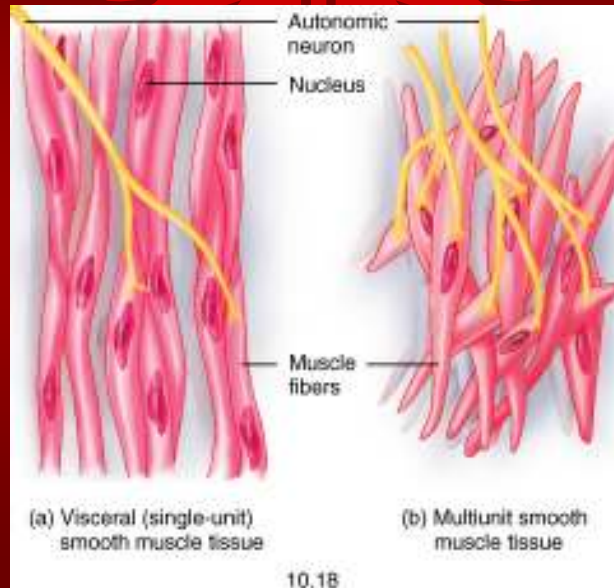
Cardiac Muscle

- 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

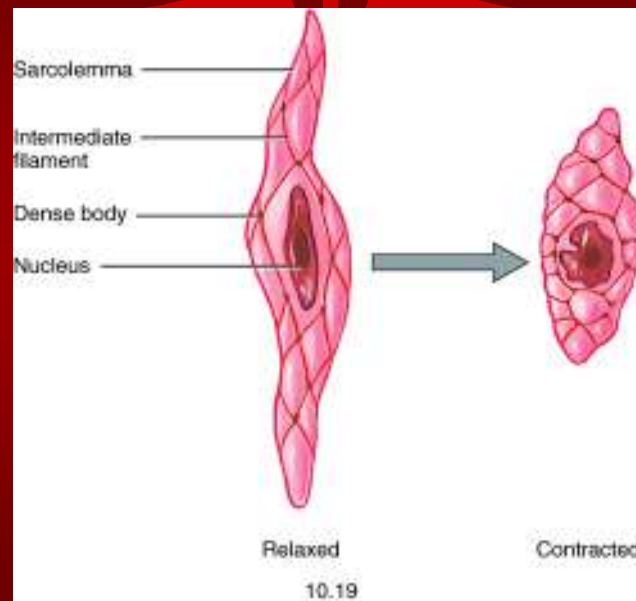
Smooth (Visceral) Muscle

- 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

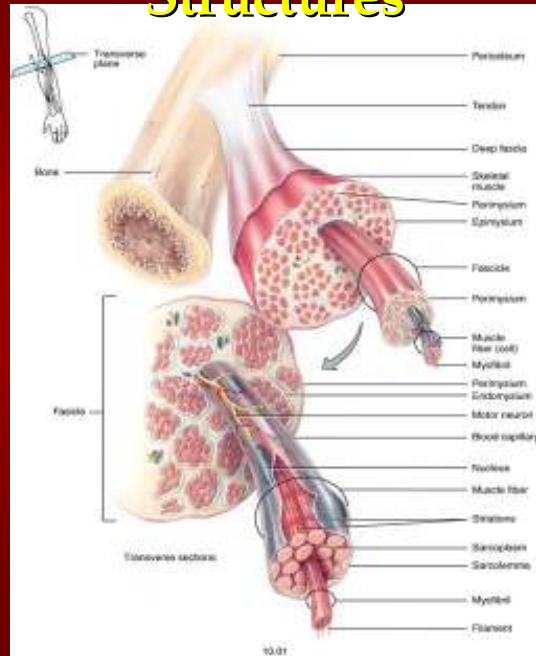
Smooth (Visceral) Muscle



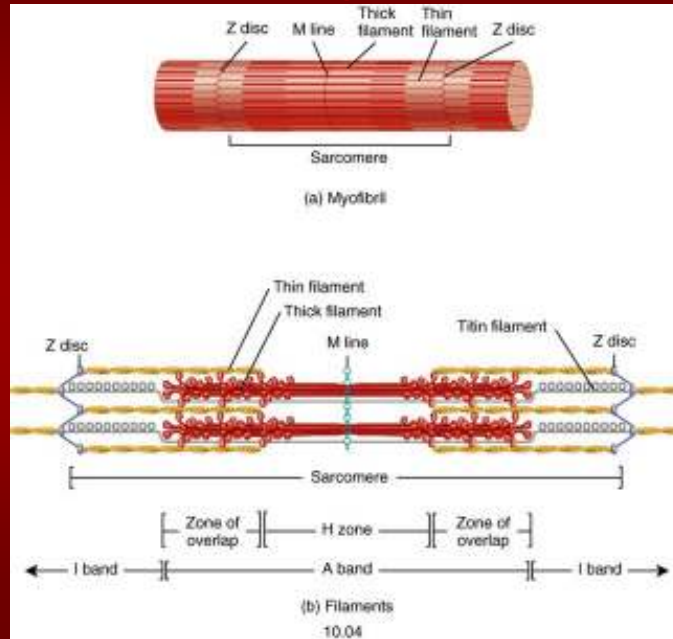
Smooth (Visceral) Muscle



Skeletal Muscle Tissue Structures



Sarcomere

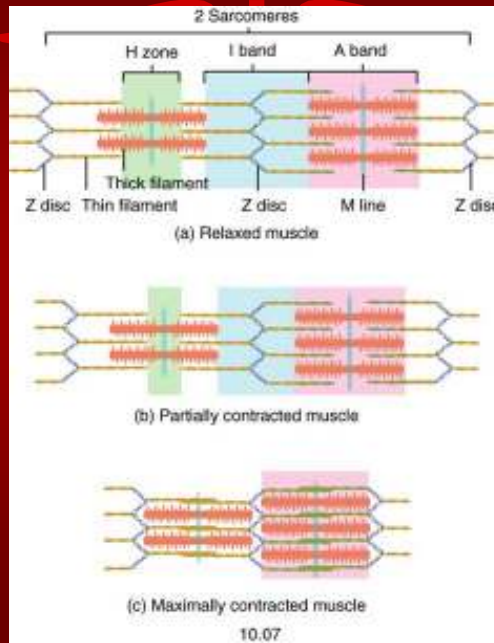


Muscle Tissue Histology



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

Regions of a Sarcomere



Myosin



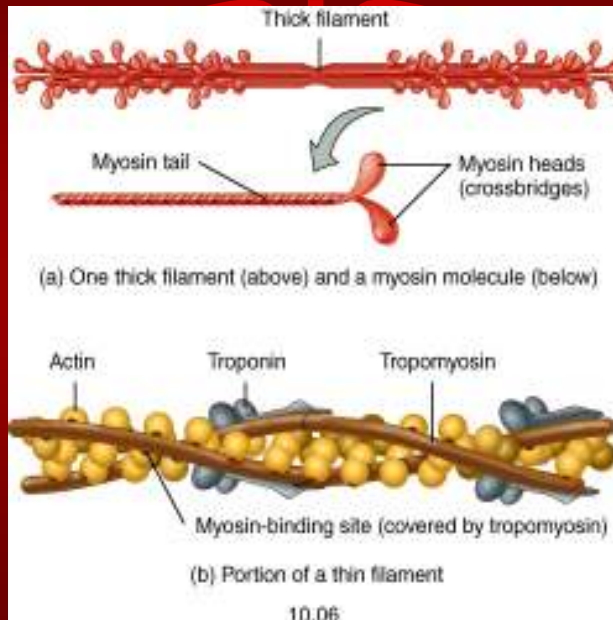
- Thick myofilaments
- Occupy the A Band of the sarcomere
- Overlap free ends of the actin myofilament
- Shaped like a golf club
 - Long, thick protein molecule (tail)
 - Globular head at the ends

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





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.

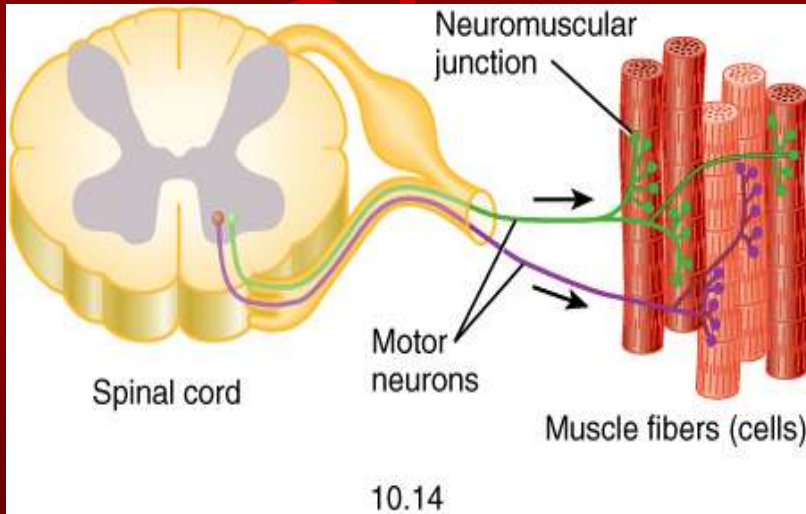
Sliding Filament Theory of Muscular Contraction

- 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

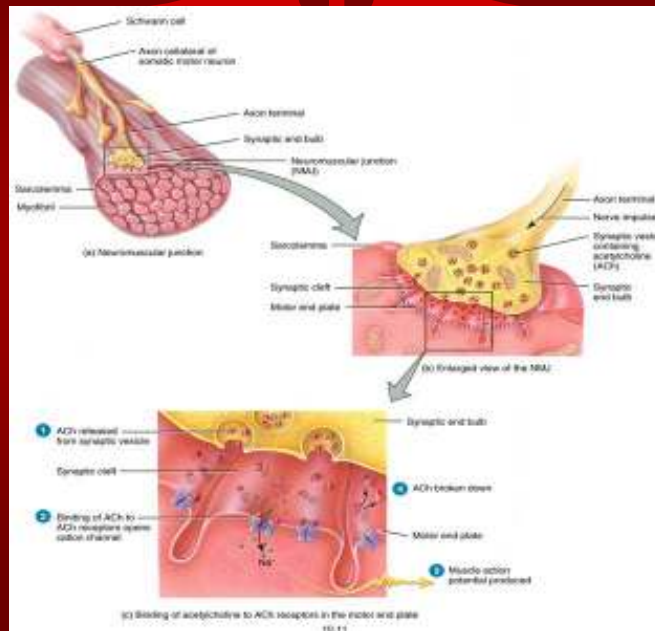
Muscle Nerve Interaction

- 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



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

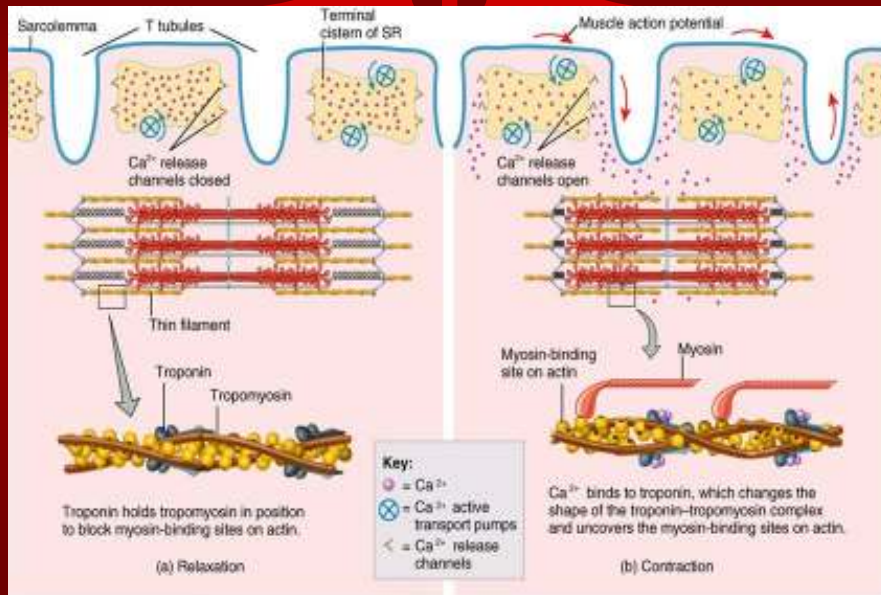
- An action potential travels down the motor neuron. When it arrives at the synaptic knob, the membrane of the nerve at the synaptic cleft is depolarized, thereby increasing the Ca^{++} permeability of the membrane.
- Ca^{++} diffuses from outside of the synaptic knob to inside the synaptic knob.

- 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

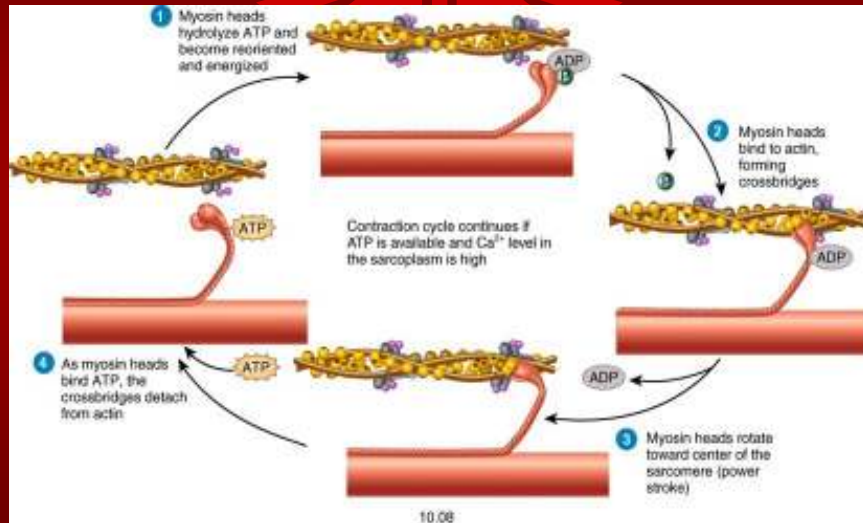


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- When troponin changes shape, it physically moves the other regulatory protein, tropomyosin, out of the way exposing the active sites on the actin myofilament.
- Since the heads or cross-bridges of myosin have a very strong affinity for the active 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.

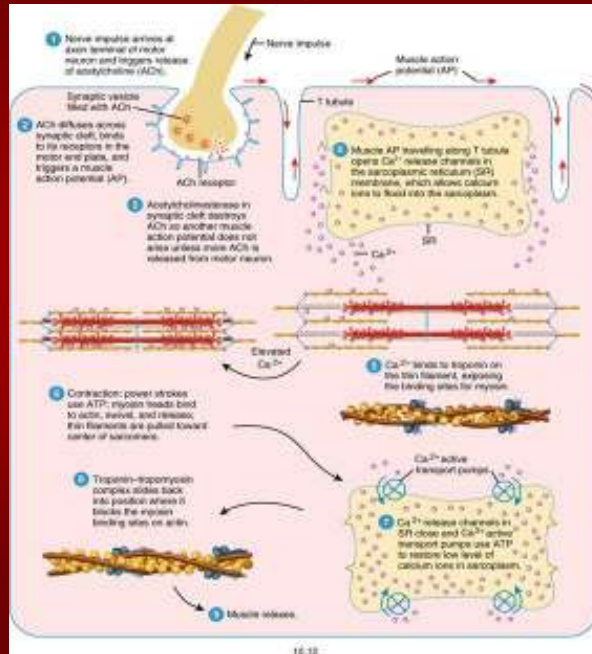
- The energy released by the splitting of ATP is used to produce movement of the cross-bridges, sliding the actin and myosin filaments past one another which causes the sarcomere to shorten and the muscle to contract and produce force.
- The myosin cross-bridge has a low affinity for ADP but a very high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

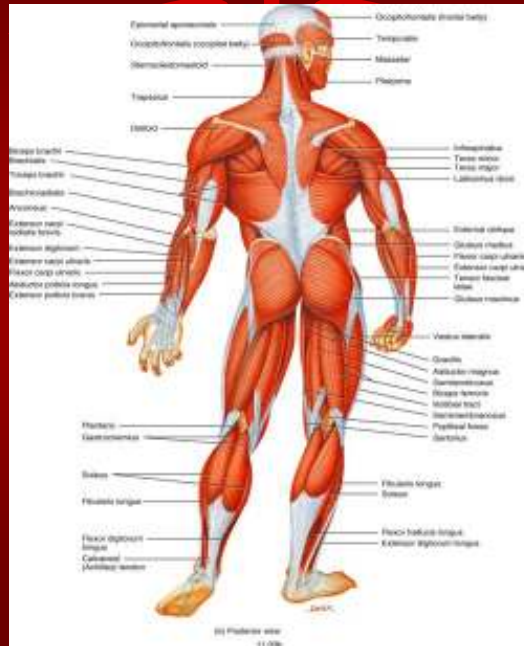
Anterior Skeletal Muscles



Selected Superficial Skeletal Muscles (Posterior View)

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

Posterior Skeletal Muscles





Muscle Diseases and Disorders

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

