

Muscular Tissue

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Muscle

- Muscle—a Latin word for “little mouse”
- Muscle is the primary tissue in the
 - Heart (cardiac muscle tissue)
 - Walls of hollow organs (smooth muscle tissue)
- Skeletal muscle makes up nearly half the body’s mass

Muscle Overview

- The three types of muscle tissue are skeletal, cardiac, and smooth
- These types differ in structure, location, function, and means of activation

Properties of Muscle Tissue

- **Excitability, or irritability**
 - The ability to receive and respond to stimuli
 - Nerve signals excite muscle cells, causing electrical impulses to travel along the sarcolemma
- **Contractility**
 - The ability to shorten forcibly
- **Extensibility**
 - The ability to be stretched or extended
 - Contraction of a skeletal muscle stretches the opposing muscle
 - Smooth muscle is stretched by substances within that hollow organ
 - Food in stomach; urine in urinary bladder
- **Elasticity**
 - Recoils after being stretched
 - The ability to recoil and resume the original resting length



Terminology Specific to Muscle Tissue

- **Myo** and **mys**—prefixes meaning “muscle”
- **Sarco**—prefix meaning “flesh”
 - **Sarcolemma**—plasma membrane of muscle cells
 - **Sarcoplasm**—cytoplasm of muscle cells

Functions of Muscle Tissue

- **Produce movement**
 - **Skeletal muscle** - attached to skeleton
- Moves body by moving the bones
 - **Smooth muscle** - squeezes fluids and other substances through hollow organs
 - **Cardiac muscle** - is responsible for the movement of blood through the body
- **Open and close body passageways**
 - Sphincters function as valves
- Open to allow passage of a substance and contracts to close the passageway
- **Maintain posture and stabilize joints**
 - Enables the body to remain sitting or standing
 - Muscle tone helps stabilize many synovial joints
- **Heat generation**
 - Muscle contractions produce heat and maintains normal body temperature

Types of Muscle Tissue

- **Skeletal muscle tissue**
 - Packaged into **skeletal muscles**
 - Makes up 40% of body weight
 - Cells are striated
 - Skeletal muscle is innervated by voluntary division of the nervous system
- **Cardiac muscle tissue**
 - Occurs only in the walls of the heart
 - Cells are striated
 - Contraction is involuntary
- **Smooth muscle tissue**
 - Occupies the walls of hollow organs
 - Cells lack striations
 - Innervated by involuntary division of the nervous system

Skeletal Muscle

- Each muscle is an organ
 - Consists mostly of **muscle tissue**
 - Skeletal muscle also contains:
- Connective tissue
- Blood vessels
- Nerves

Gross Anatomy of a Skeletal Muscle

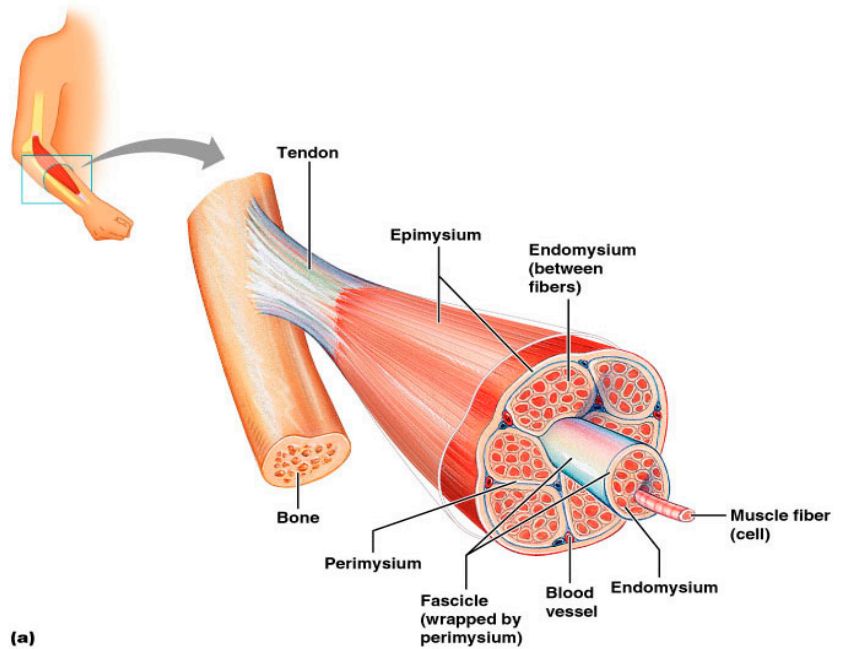
- Connective tissue and **fascicles**
 - Sheaths of connective tissue bind a skeletal muscle and its fibers together
- **Epimysium**—dense regular connective tissue surrounding entire muscle
- **Perimysium**—surrounds each fascicle (group of muscle fibers)
- **Endomysium**—a fine sheath of connective tissue wrapping each muscle cell
- Connective tissue sheaths are continuous with **tendons**
 - When muscle fibers contract, pull is exerted on all layers of connective tissue are tendon
 - Sheaths provide elasticity and carry blood vessels and nerves
- Nerves and blood vessels
 - Each skeletal muscle supplied by branches of
- One nerve
- One artery
- One or more veins
 - Nerves and vessels branch repeatedly
- Smallest branches serve individual muscle fibers

Gross Anatomy of a Skeletal Muscle

- **Muscle attachments**
 - Most skeletal muscles run from one bone to another
 - One bone will move; other bone remains fixed
- **Origin**—less movable attachment
- **Insertion**—more movable attachment
 - Muscles attach to origins and insertions by connective tissue (CT)
- **Fleshy attachments**—CT fibers are short
- **Indirect attachments**—CT forms a tendon or aponeurosis
 - Bone markings present where tendons meet bones
- **Tubercles, trochanters, and crests**

Structure of Skeletal Muscle

- Organ of the muscular system
- Skeletal muscle tissue
- Nervous tissue
- Blood
- Connective tissue
 - Fascia
 - Tendons
 - Aponeurosis



Skeletal Muscle Attachments

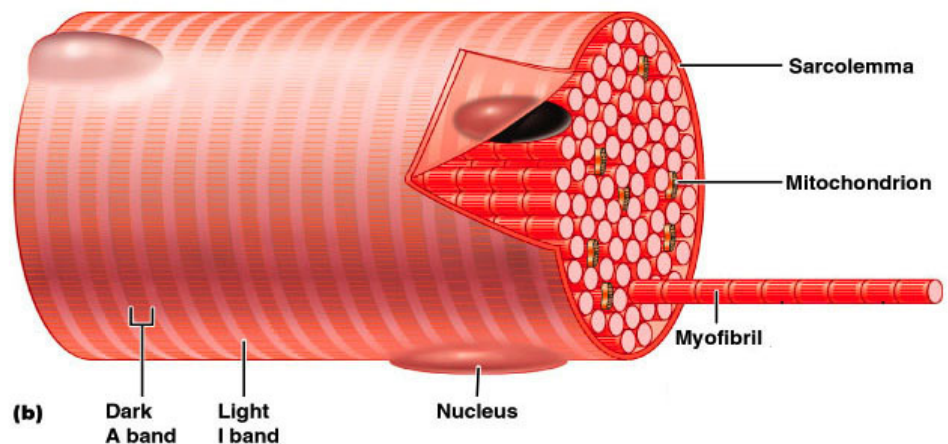
- Most skeletal muscles span joints and are attached to bone in at least two places
- When muscles contract the movable bone, the muscle's insertion moves toward the immovable bone, the muscle's origin

Myofibrils

- Myofibrils are densely packed, rodlike contractile elements
- Hundreds to thousands of myofibrils are in a single muscle fiber
- They make up most of the muscle volume
- The arrangement of myofibrils within a fiber is such that a perfectly aligned repeating series of dark A bands and light I bands is evident

Skeletal Muscle Contraction

- Movement within the myofilaments
- I band (thin)
- A band (thick and thin)
- H zone (thick)
- Z line (or disc)
- M line

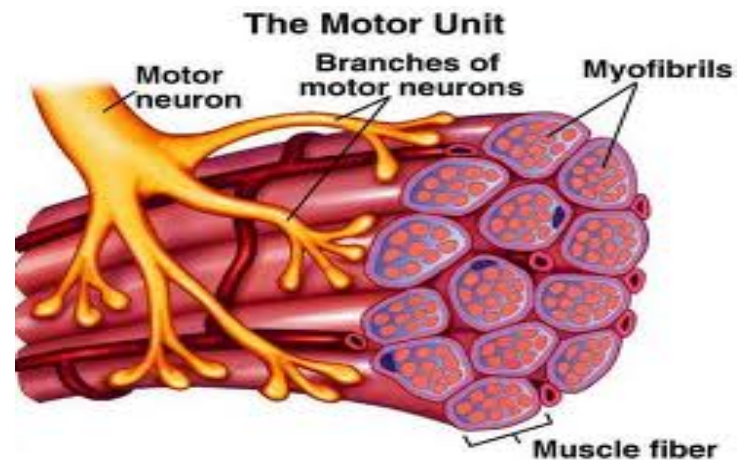


Myofilaments

- Thick myofilaments
 - Composed of myosin protein
 - Form the cross-bridges
- Thin myofilaments
 - Composed of actin protein
 - Associated with troponin and tropomyosin proteins

Neuromuscular Junction

- Also known as NMJ or myoneural junction
- Site where an axon and muscle fiber meet
- Parts
 - Motor neuron
 - Motor end plate
 - Synapse
 - Synaptic cleft
 - Synaptic vesicles
 - Neurotransmitters



Motor Unit

- Single motor neuron
- All muscle fibers controlled by motor neuron
- As few as four fibers
- As many as 1000's of muscle fibers

Skeletal Muscle Physiology

- The brain initiates an impulse for the muscles to contract
- It only takes 2 neurons to tell the skeletal muscle to contract
 - In brain to cord
 - Cord to muscle
- Motor neuron sends an impulse to the muscle cells to contract the motor neuron and the muscle cells that innervate it
- The neuron action potential continues down the neuron to muscle cells (motor unit) and the action potential continues into muscle cells
- As the action potential goes down the muscle cell along the sarcolemma and the T Tubules
- When the action potential passes over the T Tubules, it releases calcium to contract the muscle

Ratchet Theory or Sliding Filament Mechanism

- Denotes the idea of how the myosin cross-bridge pull on the action filament in a ratchet-like manner.
 - A ratchet wrench puts tension on a bolt, then lets go of the tension as you swing it back, then exerts the tension again
- Similarly, a myosin cross-bridge pulls on the actin filament exerting tension, then it relaxes by letting go, exerts tension once again and then relaxes.

Muscle Tone

- Is the constant, slightly contracted state of all muscles, which does not produce active movements
 - Keeps the muscles firm, healthy, and ready to respond to stimulus
- Spinal reflexes account for muscle tone by:
 - Activating one motor unit and then another
 - Responding to activation of stretch receptors in muscles and tendons

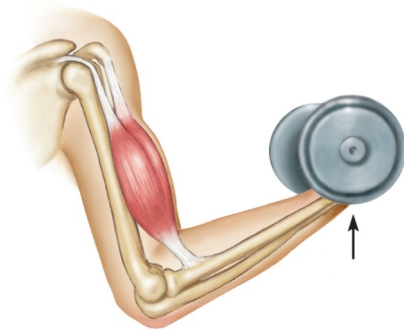
Isotonic Contractions

- In isotonic contractions, the muscle changes in length and moves the load
- The two types of isotonic contractions are concentric and eccentric
 - Concentric contractions – the muscle shortens and does work
 - Eccentric contractions – the muscle contracts as it lengthens

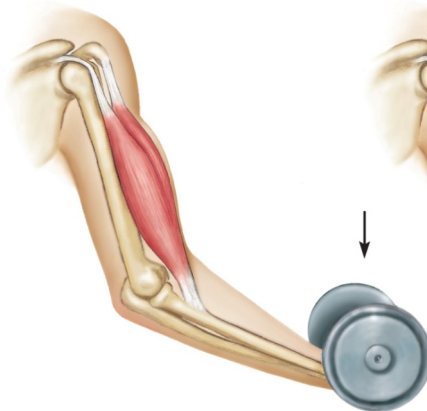
Isometric Contractions

- Tension increases to the muscle's capacity, but the muscle neither shortens nor lengthens

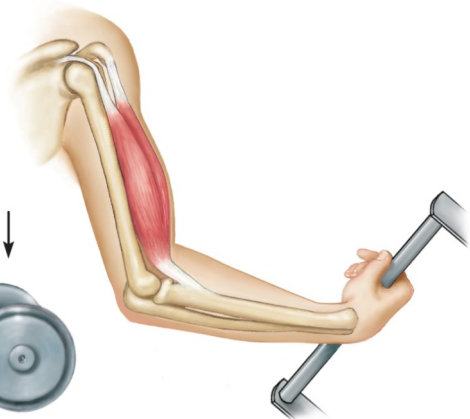
Concentric



Eccentric



Isometric



Muscle Metabolism: Energy for Contraction

- ATP is the only source used directly for contractile activity
- As soon as available stores of ATP are hydrolyzed (4-6 seconds), they are regenerated by:
 - The interaction of ADP with creatine phosphate (CP)
 - Anaerobic glycolysis
 - Aerobic respiration

Muscle Fatigue

- Muscle fatigue – the muscle is in a state of physiological inability to contract
- Muscle fatigue occurs when:
 - ATP production fails to keep pace with ATP use
 - The deficit of ATP causes contractures
 - Lactic acid accumulates in the muscle

Recruitment of Motor Units

- Recruitment - increase in the number of motor units activated
- Whole muscle composed of many motor units
- More precise movements are produced with fewer muscle fibers within a motor unit
- As intensity of stimulation increases, recruitment of motor units continues until all motor units are activated

Sustained Contractions

- Smaller motor units (smaller diameter axons) - recruited first
- Larger motor units (larger diameter axons) - recruited later
- Produce smooth movements
- Muscle tone – continuous state of partial contraction

Fast Twitch and Slow Twitch Muscle Fibers

- Slow-twitch fibers
 - Always oxidative
 - Resistant to fatigue
 - Red fibers
 - Most myoglobin
 - Good blood supply
- Fast-twitch fibers
 - White fibers
 - Poorer blood supply
 - Susceptible to fatigue

Fast Twitch and Slow Twitch Muscle Fibers

- Fast-twitch fatigue-resistant fibers
 - Intermediate fibers
 - Oxidative
 - Pink to red in color
 - Resistant to fatigue

Force of Muscle Contraction

- The force of contraction is affected by
 - The number of muscle fibers contracting – the more motor fibers in a muscle, the stronger the contraction
 - The relative size of the muscle – the bulkier the muscle, the greater its strength
 - Degree of muscle stretch – muscles contract strongest when muscle fibers are 80-120% of their normal resting length

Skeletal Muscle – The Big Picture

- A skeletal muscle attaches to two bones and crosses the joints between the bones
- The big picture is that when the muscles contract, it shortens its center
- The contraction creates a pulling force on the bony attachments
- If the pulling force is strong enough, one or both of the bones that attaches to the muscle will be pulled toward the center of the muscle
- Because bones are located within body parts, movements of a bone results in movement of a body part

Interactions of Skeletal Muscles

- Skeletal muscles work together or in opposition
- Muscles only pull (never push)
- As muscles shorten, the insertion generally moves toward the origin
- Whatever a muscle (or group of muscles) does, another muscle (or group) “undoes”

Developmental Aspects: Male and Female

- There is a biological basis for greater strength in men than in women
- Women’s skeletal muscle makes up 36% of their body mass
- Men’s skeletal muscle makes up 42% of their body mass

Developmental Aspects: Age Related

- With age, connective tissue increases and muscle fibers decrease
- Muscles become stringier and less elastic
- By age 80, 50% of muscle mass is lost (sarcopenia)
- Regular exercise reverses sarcopenia
- Aging of the cardiovascular system affects every organ in the body

