**Muscular Tissue**

**Dr. Gary Mumaugh**

**Muscle Overview**

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

**Functional Characteristics of Muscle Tissue**

* Excitability, or irritability – the ability to receive and respond to stimuli
* Contractility – the ability to shorten forcibly
* Extensibility – the ability to be stretched or extended
* Elasticity – the ability to recoil and resume the original resting length

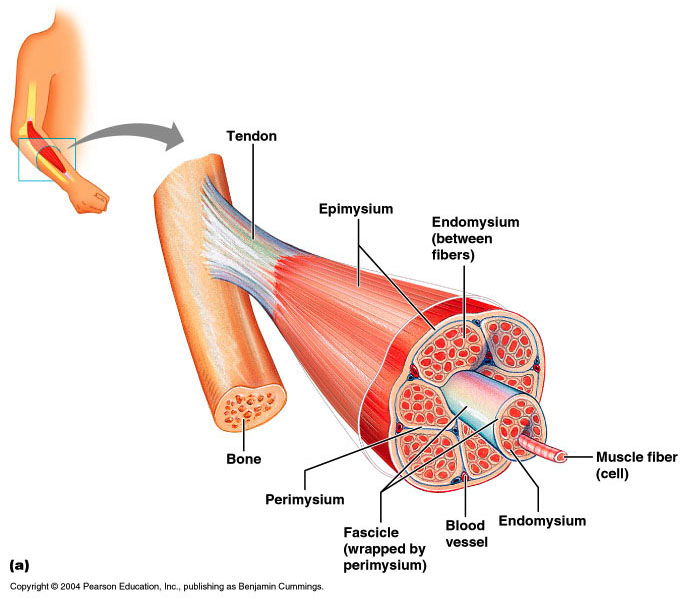
**Muscle Function**

* Skeletal muscles are responsible for all movement
* Cardiac muscle is responsible for the movement of blood through the body
* Smooth muscle helps maintain blood pressure, and squeezes or propels substances (i.e., food, feces) through organs
* Muscles also maintain posture, stabilize joints, and generate heat

**Three Types of Muscle**

* Skeletal
  + Voluntary or somatic
  + Usually attaches to bones
  + Striated
* Cardiac
  + Involuntary or autonomic
  + Walls of Heart
  + Striated
* Smooth
  + Involuntary or autonomic
  + Walls of viscera, blood vessels and skin
  + Not striated

**Structure of Skeletal Muscle**

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

**Muscle Coverings**

* Epimysium
* Perimysium
* Endomysium
* Muscle organ
* Fascicles
* Muscle cells or fibers
* Myofibrils
* Thick and thin myofilaments
  + Actin and myosin proteins
  + Titin is an elastic myofilament

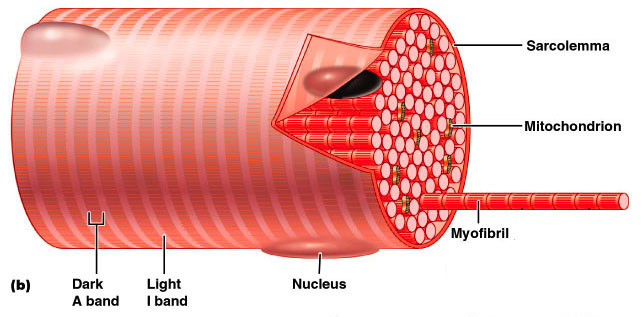
**Skeletal Muscle Attachments**

* 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

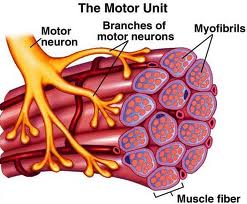
**Skeletal Muscle Contraction**

* 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 sarcolema 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

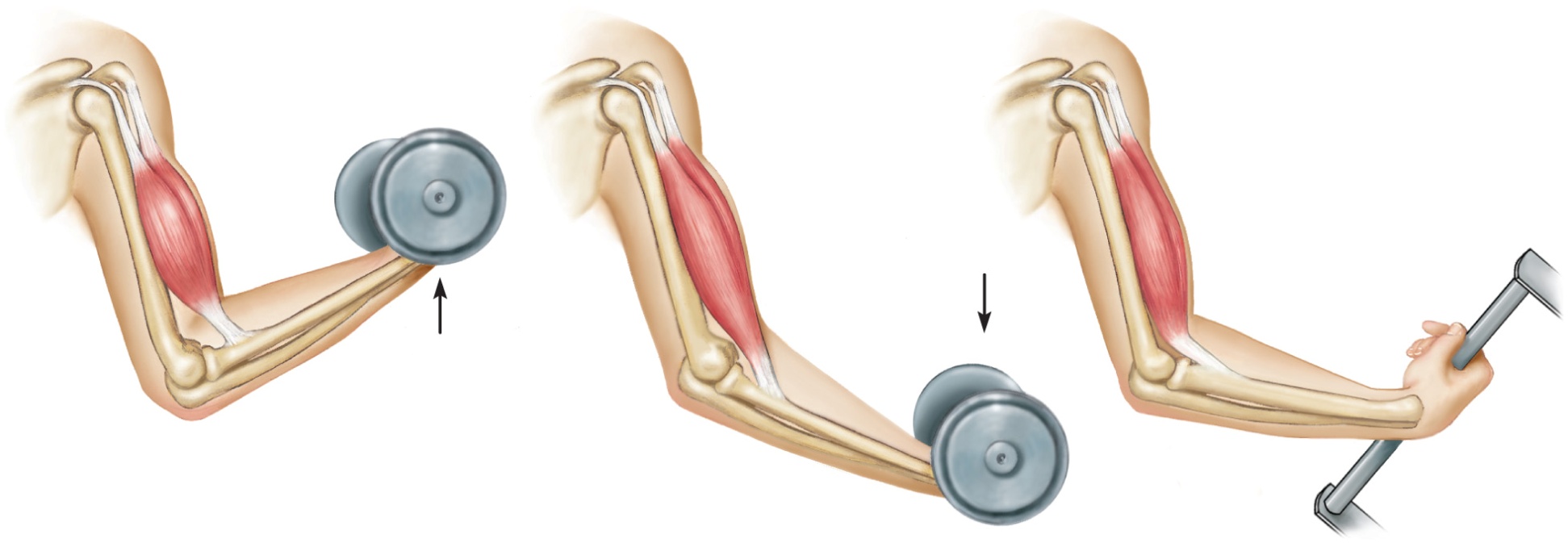
**Isotonic Contractions**

* 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 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 it’s center
* The contraction creates a pulling force on the boney 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”

**Naming Skeletal Muscles**

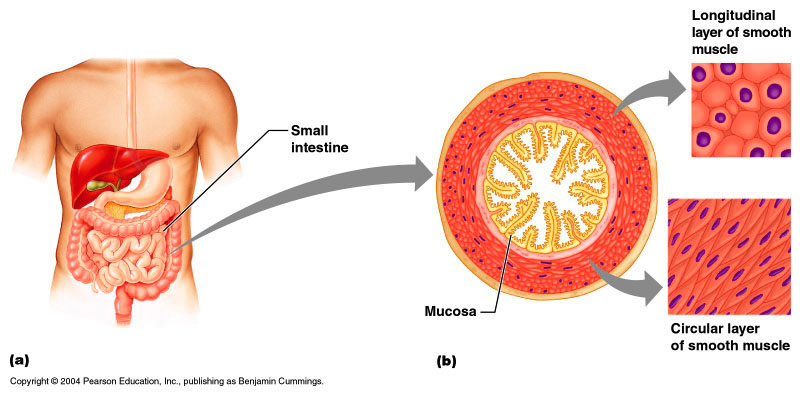
* Number of origins – e.g., biceps (two origins) and triceps (three origins)
* Location of attachments – named according to point of origin or insertion
* Action – e.g., flexor or extensor, as in the names of muscles that flex or extend, respectively
* Location of muscle – bone or body region associated with the muscle
* Shape of muscle – e.g., the deltoid muscle (deltoid = triangle)
* Relative size – e.g., maximus (largest), minimus (smallest), longus (long)
* Direction of fibers – e.g., rectus (fibers run straight), transversus, and oblique (fibers run at angles to an imaginary defined axis)

**Smooth Muscle**

* Found in walls of hollow organs (except the heart)
* Have essentially the same contractile mechanisms as skeletal muscle

**Peristalsis**

* When the longitudinal layer contracts, the organ dilates and contracts
* When the circular layer contracts, the organ elongates
* Peristalsis – alternating contractions and relaxations of smooth muscles that mix and squeeze substances through the lumen of hollow organs

****

**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