

Joints and Muscles

When 2 bones meet = **articulation**. Articulations form **joints**.

Joints classified based on **range of motion** possible at joint:

Types of Joints

1) no motion = **synarthroses** (syn=union/association)

a) sutures-different types

1) sagittal-parietal bones have finger-like projections that lock them together = **interdigitate**

2) squamosal- squamos of temporal lays on top of parietal

3) vomer with maxilla- vomer lays on top of maxilla

b) **syndesmoses**-connected by dense, fibrous connective tissue

1) ex:distal articulation between tibia and fibula-bones locked together with tissue

2) sternal angle

c) another ex of synarthroses- gomphoses-deep sockets of teeth

2) partial motion = **amphiarthroses**

a) **symphysis**-bones connected by thin disk of fibrocartilage

1) pubic symphysis-fibrocartilage acts as shock absorber to allow vibrations to dissipate in hip

2) mandibular symphysis

b) **synchondrosis**-bones separated by hyaline cartilage

1) costal cartilage-connects ribs to sternum, provides protection and *flexibility*

2) epiphyseal plates in children-gives *flexibility*

3) freely moveable = **diarthroses**

A) at synovial joints

B) 5 characteristics

1) Joints are enclosed in a capsule = **synovial capsule**

2) Capsule is lined by smooth connective tissue. Lined with membrane = **synovial membrane**. Fluid = **synovial fluid**. Function: lubricant to reduce friction

3) Ends of bones covered with hyaline cartilage = **articular cartilage**

4) Joint may be reinforced with ligaments to hold bones in position.

5) Fibrocartilage pads may be present.

a) meniscus of knee = pad of fibrocartilage

b) joints b/t vertebrae-intervertebral discs = fibrocartilage pads

C) 6 types of diarthroses

1) **gliding joints**

a) flat or slightly curved articular surface on 1 bone that matches up with flat or slightly curved articular surface on another bone. Bones glide past 1 another.

b) range of sliding motion is limited by:

1) bony projections (ex: bumps by wrists)

2) intercarpal and intertarsal ligaments

c) nonaxial motion-does not occur around an axis or along a plane

d) 3 ex of gliding joints:

1) intercarpal joints of wrists

2) intertarsal joints of ankles

3) sterno-clavicular joint-joint b/t sternum and clavicle

2) **hinge/ ginglymus joints**

a) rounded bone fits into concave surface of another bone

b) allows extension and flexion

c) allow uniaxial motion

d) 3 ex:

1) elbow- humeral-ulnar joint

2) knee- femoral-tibial joint

3) interphalangeal joints

3) **pivot joints**

a) rounded or conical surface of 1 bone fits into shallow depression of another bone

b) provides **uniaxial rotation**

c) ex:

1) flipping hands over (radioulnar joint)

2) head pivots about Dens (atlanto-axial joint)

3) between capitulum of humerus and fovea of radius

4) **ellipsoidal/ condyloid joints**

a) oval condyle of one bone fits into depression of another bone

b) allows **biaxial motion**

c) allows flexion, extension, abduction, adduction, and circumduction

d) ex is metacarpal/ phalangeal articulations of knuckles (can move fingers up and down or side to side-2 way motion)

5) **saddle joints**

a) saddle-shaped convex fits into concave portion of another bone

b) allows **biaxial motion**

c) allows flexion, extension, abduction, adduction, and circumduction

d) ex is carpometacarpal joint between trapezium of carpus and metacarpal of thumb

6) **ball and socket joints**

a) ball-like surface of one bone fits into cuplike depression of another bone

b) **polyaxial**-allow movement around 3 axes plus all directions in between

c) allow flexion, extension, abduction, adduction, circumduction, and rotation

d) ex

1) shoulder-head of humerus fits into glenoid fossa of scapula

2) hip-head of femur fits into acetabulum of coxal bone

(Shoulder easier to dislocate b/c glenoid fossa is not deep, so not protected by upper shelf of bone. Hip is in deep socket of acetabulum, so it's protected by upper shelf of bone.)

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Body Motions

- 1) **flexion**-decrease angle between 2 bones
- 2) **extension**-increase angle between 2 bones
 - a) ex-moving arms, fingers, or wrists toward you (flexion) or away from you (extension)
 - b) hyperextension-extending too far
- 3) **abduction**-movement away from midline
- 4) **adduction**-movement toward midline
- 5) **rotation**-movement of bone around its longitudinal axis
 - a) ex-forearm and head
- 6) **circumduction**-includes flexion, extension, abduction, and adduction. Proximal end of appendage remains stationary while the distal end inscribes a circle (looks more like a cone)
 - a) 2 ex
 - 1) keep shoulder stationary while use hand to draw circle
 - 2) keep metacarpals stationary and draw circle with phalanges

2 Hand Motions (7-8)

- 7) **pronation**-moving palmar surface anterior to posterior from SAP (turning palm down)
- 8) **supination**-moving palmar surface from posterior to anterior from SAP (turning palm up)

4 Foot Motions (9-12)

- 9) **inversion**-move sole of foot medially (lean on outside side of foot, so bottom points sideways toward midline)
- 10) **eversion**-move sole of foot laterally (lean on inside of foot, so bottom points sideways away from midline)
- 11) **plantar flexion**- point toes downward (stand on toes)
- 12) **dorsiflexion**-point toes up (rock back on heels)
- 13) **opposition**-can touch thumb to all other fingers. Thumb is opposable so can grab things.
- 14) **reposition**-returning back to SAP
 - a) ex-can open hand again once thumb touches other fingers.

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6 Mandibular motions (15-20)

- 15) **protraction**-moving structure anteriorly (forward)
 - a) ex-moving mandible forward
- 16) **retraction**-moving structure posteriorly-back into position
- 17) **elevation**-raise a structure
 - a) ex-shoulder/scapula and mandible
- 18) **depression**-lower a structure
 - a) ex-shoulder and mandible
- 19) **excursion**- moving lower jaw laterally-moving mandible away from midline-to side
- 20) **reposition**-moving back into position
 - a) ex-moving lower jaw medially

Hand Diagram

- 1) **condyloid/ ellipsoidal joint**- between scaphoid and radius
 - a) Motions possible: flexion, extension, abduction, adduction, circumduction
 - b) No axial rotation (can't rotate wrist about axis)
- 2) **gliding joints**- intercarpal joints- limited by ligaments or bony processes
 - a) Motions possible-only sliding
 - b) No angular or rotary movements
- 3) **saddle joint**- specific for thumb-reciprocal concaval-convex arrangement between trapezium and metacarpal one
 - a) Motions possible: flexion, extension, abduction, adduction, and circumduction
 - b) No axial rotation (can't spin thumb)
- 4) **condyloid joints**- metacarpal-phalangeal articulations
 - a) Motions possible: flexion, extension, abduction, adduction, circumduction
 - b) No axial rotation
- 5) **hinge joint = ginglymus-like joint**- between metacarpal 1 and proximal phalange 1 of thumb
 - a) Motions possible: flexion and extension
 - b) No axial rotation
- 6) **hinge joints**- interphalangeal joints
 - a) Motions possible: flexion and extension
 - b) No axial rotation
- 7) **midcarpal joint**- landmark-denotes 2 rows.

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8) **ball and socket-like joint**- lunate fits into depression on capitate, provides flexibility to wrist

9) **pivot joint**- between radius and ulna

a) Motion possible: uniaxial rotation

Muscle Review from Histology Test

Type of muscle	location	shape	striated or no	vol or no	cause of contraction	multi-nucleated or no	special stuff
skeletal	on skeleton	cylindrical	striated	vol	motor neurons	multi	t-tubules myoglobin
visceral smooth	digestive organs and uterus	spindle	no	invol	stretching peristalsis oxytocin	mono	no t-tubules or myoglobin
multi-unit smooth	iris, airway, blood vessels	spindle	no	invol	motor neurons ADH, angiotensin seratonin norepinephrine	mono	no t-tubules or myoglobin
cardiac	heart	interbranched cylinders	striated	invol	intrinsic rhythm norepinephrine ACH	mono	interbranching intercalated disks t-tubules myoglobin

Muscle info:

A. Skeletal

1. Red b/c of **myoglobin**-pigmented protein
 - a. function of myoglobin-oxygen attaches to it
 - b. impt b/c now always have oxygen in blood even b/f exercising
2. **T-tubules**=transverse tubules
 - a. infolding of cell membrane-cut across membrane- increases surface area
3. In wrapping=membrane so cells don't touch

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B. Cardiac

1. Has **intercalated disks**

- a. thickening of cell mem where one cell ends and next starts
- b. special gap junctions

2. Cells touch each other. Smooth cells also touch each other.

C. Muscle tissue characteristics

1. Excitable
2. Extendable
3. Contractile
4. Conductive

Types of Muscles

1) **prime mover**- muscle principally involved in action

2) **synergists**- muscles that assist prime movers by reducing undesired actions or unnecessary movement

3) **antagonists**- muscles that oppose or reverse the action of a prime mover

Ex: a) **biceps brachii** (muscle of arm)- prime mover in flexing forearm. **Brachialis**- muscle lateral to it- is a synergist- helps biceps brachii flex forearm. **Triceps brachii**- extends the forearm, so it is antagonistic to both the biceps brachii and brachialis. All muscles are found as antagonist pairs. b) **quadriceps femoris**- extension, **hamstrings**-flexion. Antagonistic.

4) **fixator muscles**- stabilize joint and immobilize origin of prime mover. Locking joints into position gives us mechanical advantage. Ex- to pick up heavy object, fixator muscles lock back into position and stabilize shoulders.

4 Muscle Characteristics

1) **origin**- point of muscle attachment to skeleton. Attaches via tendons (sheet = aponeuroses)

2) **insertion**- a) distal end of a muscle that is usually attached to a bone, but could be a muscle, skin, or eyeball.

b) Insertion moves when muscle contracts. Ex- biceps brachii originates on humerus and inserts on ulna

3) **action**- what happens to skeleton when muscle contracts (ex- shoulder abducts, scapula is elevated...)

4) **innervation**- name of branch of spinal or cranial nerve that stimulates/supplies the muscle. (Ex- trapezius and sternocleidomastoid are stimulated by CN XI)

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Gross Arrangement of Muscles (structures visible with naked eye)

1) **periosteum**

- A) surrounds bone- origin of muscle
- B) 2 layers
 - 1) **osteogenic**- closer to bone
 - 2) **fibrous**- outer layer- where muscle attaches via tendons

2) **tendons**

- A) attach muscle to skeleton
- B) made of dense regular connective tissue made of *collagen*
- C) easier to rip muscle than tendons

3) **epimysium**

- A) outer covering of muscle to protect it
- B) insulates adjacent muscles from each other, so don't all contract when one muscle contracts b/c muscular contraction = electrical activity

4) **nerves and arteries**

- A) found between muscles
- B) some go into muscles for arteriole supply and venous drainage

5) **fascicles**

- A) tubes running the length of muscles
- B) can see them as circles when transect a muscle =cut a muscle

6) **perimysium**

- A) membrane that surrounds fascicles
- B) functions:
 - 1) separates 1 fascicle from another
 - 2) binds muscle cells together

7) **muscle cells**

- A) smallest level of muscle
- B) make up fascicles

8) **endomysium**

- A) membrane that surrounds individual muscle cells
- B) insulates muscle cells from each other, so contraction of 1 doesn't cause all to contract
- C) 2 main purposes
 - 1) allows for fine control b/c can cause just a few cells to contract
 - 2) therefore, allows for conservation of ATP
- D) only found in skeletal muscles cells- smooth cells do not have this wrapping

(Quick summary- muscle cells wrapped with endomysium make up fascicles wrapped with perimysium which make up muscles wrapped in epimysium which insulates muscles from each other.)

9) **collateral branches**

- A) several end terminals of the same nerve cell
- B) spinal nerves plunge into muscles to stimulate them

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10) **motor unit**

- A) motor nerve + however many muscle fibers it stimulates to contract
- B) proprioception determines how much energy to expend- conserves ATP
 - 1) golgi-tendon organs make you aware of heaviness to match effort
 - 2) number of fascicles for each motion is adjusted based on proprioception
- C) 2 types
 - 1) **small motor unit**
 - a) small ratio of motor neuron to muscle fibers like 1:3
 - b) gives fine control
 - c) characteristic of eye muscles and hand muscles
 - 2) **large motor unit**
 - a) large ratio of motor neurons to muscle fibers like 1:100
 - b) gives gross motor control
 - c) ex- bands of arrector spinae muscles that run along vertebral column to straighten back

Muscle Responses (extracorporeal muscle responses b/c described using extracorporeal experiment-done on body part outside body)

Background- Gastrocnemius removed from frog. Placed on apparatus. Tied to bracket. Connected to **electrical stimulator** so can use electrical current (measured in mV) to cause muscle to contract. Stimuli is measure in seconds (to the nearest tenth). **Kymograph**- entire system used to measure physical contraction of a muscle (not electrical). Connect stimulator to **chart recorder** = running strip of paper. 2 pens: top = **event marker**. Stimulus will make a little blip. Bottom = **muscle response**.

- 1) **subthreshold stimulus**- no response b/c too little voltage to cause muscle to contract
- 2) **threshold stimulus**- minimal stimulus required to cause a reaction
- 3) **“All or none response”**- muscle will either contract or not. (Force goes up when muscle contracts and down during relaxation. 1 contract + 1 relax = single twitch)
- 4) **treppe**- muscle responds more vigorously as same stimulus is applied over time using same time interval and allowing muscle to relax completely in between stimuli. (complete relaxation = back to baseline)
- 5) **wave summation**- muscle contracts more and more, stimulating more fascicles to contract as same stimulus is applied over shorter time intervals, not allowing muscle to relax completely in between stimuli
- 6) **tetanus**- constant state of contraction, muscles locked in position b/c all fascicles are now contracting. Results in rigidity. Can't go on forever b/c metabolic wastes building up.
- 7) **waste products of muscles**
 - A) CO₂ and non-protein nitrogens: urea, uric acid, ammonia, creatine, creatinine
 - B) result from metabolism
 - C) NPN's are non-volatile = can't form gases, so can't breathe them out
 - D) get rid of them through kidney (urine), sweat, and fecal material (uric acid)

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8) **acidosis**- too much acid

A) caused by:

1) buildup of CO_2 leads to pH going down



2) Since O_2 is being used up, anaerobic respiration takes place leading to the buildup of lactic acid which helps lower the pH.

B) interferes with enzyme function

9) **fatigue**

A) inability of muscle to contract

B) causes:

1) interruption of blood supply- pinch off blood vessel

2) lack of ACH

3) increase of lactic acid

4) diminished ATP (low glucose)

10) **tonus/muscle tone**

A) state of partial contraction

B) muscles always like this-to hold head up, keep back straight...

11) **atrophy**

A) the wasting away of a muscle

B) happens when **lose innervation** to a muscle (or when just don't use muscles like astronauts) (ex- polio can affect motor neurons)

12) **hypertrophy**

A) increase in size of muscles

B) caused by exercise b/c develop tone

C) ex- spleen hypertrophies due to mononucleosis; heart can hypertrophy

3 Steps to Get ATP/ Glucose Breakdown

1) **glycolysis**

A) anaerobic

B) glucose + 2 ATP → 4 ATP + pyruvic acid

C) location: cytoplasm

2) **Kreb's cycle**

A) anaerobic (but shuts off when no oxygen)

B) yields 2 ATP and waste product = CO_2

C) location: mitochondria

3) **electron transport system**

A) aerobic

B) yields 32 ATP

C) location: mitochondria

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What happens when there's no oxygen because muscles are contracting continuously (tetanus)?

- 1) Under **high oxygen conditions**, oxygen breaks down peruvic acid, as part of aerobic respiration, which allows glycolysis to continue. Produces CO_2 as a waste product which we breathe out of the body. An important byproduct of aerobic respiration is heat.
- 2) However, under **low oxygen conditions**, peruvic acid cannot undergo aerobic respiration (steps 2 and 3) and builds up, causing glycolysis to stop. Allosteric regulation- stops enzyme involved in first step in glycolysis which stops all the rest.
- 3) To prevent this, the body undergoes anaerobic respiration and converts peruvic acid into lactic acid to allow glycolysis to continue. However, this only releases a few ATP.
- 4) Buildup of lactic acid—>acidosis—> fatigue
- 5) There is a 30 second safety net-only enough ATP for short time. Then tissues start to suffer.

How Muscles Store Energy

1) Muscles use ATP for energy. Get ATP from glucose.

glucose + $\text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{energy}$. The energy is used to attach a phosphate to ADP, forming ATP.

2) When the high energy bond of ATP is broken by ATPase, energy is released.

ATP \rightarrow ADP + P + energy

3) 3 things can happen to the energy:

A) it can be lost as heat (skeletal muscles are major source of heat in body)

B) it can be used:

- 1) muscle contraction
- 2) maintaining ion gradients
- 3) biosynthesis

C) it can be stored via **creatine**

- 1) creatine is 20x more concentrated than ATP
- 2) it traps energy from ATP breakdown
- 3) Does so by attaching to phosphate, forming creatine-P = high-energy bond
- 4) ATPase cannot breakdown creatine, so can stay in cell longer
- 5) can reverse process to get ATP. Use creatinekinase to break down creatine-

P into creatine + P + energy and the energy can be used for ATP-synthesis.

4) Have to constantly convert ADP into ATP b/c only 30 second supply of ATP. Have to send glucose + oxygen back to brain.

5) Myoglobin stores oxygen in muscle tissue. Allows body to reform ATP.

2 Ways Muscle Can Contract

1) **isometric contraction**

A) muscle fibers remain the *same distance*, but tension builds up in the muscle

B) ex- holding hands together while pushing or pulling them, pushing against wall

2) **isotonic contraction**

A) *same tension*, but muscle fibers shorten

B) ex- lifting weights, biceps have same tension, but when there's movement = isotonic

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Things Having To Do With Parts of Muscle Cells

1) sarcolemma

- A) cell membrane
- B) phospholipid bilayer
- C) can regulate flow of ions via ion channels

2) sodium ions

- A) high outside cell- 135-145 mM
- b) low inside cell- 10 mM

3) potassium ions

- A) low outside cell- 3.5-5.1 mM
- B) high inside cell- 140 mM

4) ion channels

- A) found on cell membrane
- B) if ion channels open, ions can passively diffuse in and out of cell

5) sodium-potassium pump

- A) used to get sodium out of cell and potassium in cell actively- against conc gradient
- B) requires ATP

6) anions- proteins, HPO_4^{2-} , H_2PO_4^-

- A) Trapped in cell
- B) proteins too big to get out
- C) phosphates negatively charged as is cell membrane, so repel each other

7) multi-nuclei- pushed to side of cell b/c so much protein

8) sarcoplasmic reticulum

- A) system of canals and passageways that intercalate through the cell
- B) 3 functions:
 - 1) attaches cell membrane to nuclear membrane
 - 2) proteins synthesis- associated with ribosomes in rough ER
 - 3) stores things

9) cisternae

- A) bulbous expansions of SR
- B) store calcium ions

10) Z-lines

- A) highly arranged proteins found throughout the entire length of cell
- B) embedded in them are thin myofilaments called **actin**
- C) between actin, there are thick myofilaments called **myosin**.
 - 1) it's a linear protein made of amino acids.

11) sarcomere

- A) distance from one z-line to the next
- B) *functioning unit of skeletal muscle cell*
- C) a cell contains around 50, 000 of them

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12) **actin and myosin**

- A) 3 sections of sarcomeres
 - 1) only actin = **I-Band**
 - 2) only myosin = **H-Band**
 - 3) both = **A-Band**
- B) pattern of actin and myosin forms striations
 - 1) actin-light colored
 - 2) myosin-dark-colored
- C) they walk over each other when cell contracts, so need to establish cross-bridges
 - 1) cross-bridges are attached to actin and facing myosin
- D) need calcium in order to form cross-bridges

How A Muscle Cell Contracts

- 1) motor nerve cell has same conditions as cell
 - A) high sodium and low potassium outside
 - B) low sodium and high potassium inside
 - C) anions-proteins and phosphates inside
- 2) motor nerve cell synthesizes **ACH**- acetylcholine- which is a neurotransmitter.
 - A) ACH gets packaged into transport vesicles by Golgi complex and shipped to surface
- 3) 3 stages of sending an action potential:
 - A) **polarized neuron**
 - 1) inside cell- negative charge, outside cell- positive charge
 - 2) ion channels are closed and sodium is pumped out
 - B) **depolarized neuron**
 - 1) ion channels open 1 at a time and sodium diffuses in
 - 2) electrochemical phenomena = action potential- propagates along the neuron
 - 3) At the end calcium goes into the cell, causing the transport vesicle to bind to the nerve cell membrane
 - 4) transport vesicles open up and ACH is released into the synapse while Golgi membrane replenishes the cell membrane
 - C) **repolarized neuron**
 - 1) cell goes back to original conditions
 - 2) sodium is pumped back outside and potassium is returned to the inside
 - 3) refractory period as nerve cell recovers and reestablishes original conditions- can't send signals
- 4) ACH diffuses across **neuromuscular junction**- small space b/t neuron and muscle cell
- 5) ACH binds to receptors on sarcolemma = **motor end plate**
- 6) 4 stages of muscle cell sending an action potential:
 - A) **polarization**
 - 1) ion channels closed
 - 2) sodium pumped outside, inside is negative

B) depolarization—> sliding filament theory

- 1) ion channels open 1 at a time
- 2) sodium diffuses in and potassium out. More sodium coming in than K out.
- 3) action potential moves along sarcolemma until t-tubules which are near cisternae\
- 4) ion channels for calcium open up in cisternae, and cisternae release calcium
- 5) intracellular calcium level goes up
- 6) cross bridges then form b/t actin and myosin

C) muscle contraction

- 1) actin and myosin walk over each other
- 2) z-lines drawn closer together and muscle cell shortens

D) repolarization

- 1) muscle cell returns to original conditions
- 2) ACH gets broken down into acetate and choline via **acetylcholinesterase**
- 3) nerve cell then takes acetate and choline back and makes more ACH = reuptake
- 4) Calcium is put back in cisternae via **calsequestrin** and **calcium ATPase**
- 5) This allows relaxation of muscles as cross bridges break apart and sarcomeres

separate back to resting length

- 6) **refractory period**- where recovers and can't contract