KINESIOL 1Y03

23: Bone Tissue I

Skeletal System

tissue types: bone, cartilage, dense connective, epithelium, adipose, nervous, and blood vessels

support: bones, cartilage, and ligaments provide support

- ***bones***: *hard and rigid; complex and dynamic*
- ***cartilage***: *flexible; second strongest tissue in the body; in nose, auricle, trachea, and joints*
- ***ligaments***: *dense regular collagenous; connect bones to bones*

protection: protects the brain, organs of the thoracic cavity, and spinal cord

- ***skull***: *protects the brain*
- ***ribs, sternum, and vertebrae***: *protect the thoracic cavity and spinal cord*

movement: muscle contractions need to pull on something; almost all skeletal muscles attach to bones on at least one end, typically moving across a joint

- ***tendons***: *connect muscles and bones*
- ***facial muscles***: *an exception to the need for attachment to bone for movement to occur*

storage: calcium, phosphorus, and fat are stored in the bone and can be released

- ***calcium***: *required for presynaptic terminals, muscle contractions, etc.*
- ***phosphorus***: *required for ATP, metabolism, and growth/maintenance of cells/tissues*
- ***fat***: *stored as yellow bone marrow*

blood cell production: red bone marrow produces all the blood cells in the body

- ***newborn***: *all cavities are filled with red BM*
- ***aging***: *yellow BM starts replacing it; the ends of long bones (arms and legs) and irregularly shaped bones maintain their red BM*

Cartilage

properties: firm, smooth, resilient, non-vascular

- ***resilient***: *bounces back to original shape after being pressed; due to high water content*
- ***non-vascular***: *does not have a direct blood supply; similar to epithelial tissue (blood supply surrounds tissue, and nutrients and gases diffuse through)*

composition: cartilage cells and matrix

- ***water***: *70-85% of matrix; gives resiliency and allows easy diffusion of nutrients and oxygen*
- ***ground substance***: *proteoglycans; trap water*
- ***protein***: *collagen, sometimes elastin; strength*

classification: based on type, amount, and organization of protein; classified as hyaline, elastic, or fibrocartilage

bone development: we build a cartilage skeleton as an embryo, and most bone is built as cartilage first before ossifying

Hyaline Cartilage

location: most common; often associated with bone; e.g., bridge of nose, rings of trachea, and joints

articular cartilage: hyaline cartilage found on the surface of moveable joints

development: forms during embryological development, creating the cartilage skeleton; this undergoes ossification until you are ~40 years old

Elastic Cartilage

location: regions where we need flexibility; e.g., auricle

composition: lots of elastin

Fibrocartilage

location: regions where we need more support and structure; e.g., intervertebral discs, meniscus

meniscus: pad of cartilage between the joints

composition: lots of highly organized, dense collagen protein fibers

Cartilage Histology

chondrocytes: main cell type; mature cells; located in lacunae

chondroblasts: immature chondrocytes; build the matrix of collagen and proteoglycans, becoming chondrocytes once they are trapped within; located along the surface of the cartilage

perichondrium: double layer of connective tissue where blood and nerves are located

- ***outer layer***: *dense irregular connective tissue and fibroblasts (produces proteins); includes blood and nervous tissue supply*
- ***inner layer***: *chondroblast cell layer, including osteochondral progenitor cells (produces cartilage)*
- ***articular and fibrocartilage***: *no perichondrium; this is why it is so difficult to repair*

Cartilage Growth

appositional growth: new cartilage forms just underneath the outside layer of the perichondrium; more common as we age

interstitial growth: mature chondrocytes divide; they push away from each other and secrete more matrix; this is unique to cartilage, which has so much water that the cells can move around; more common in childhood

Bone Histology

dynamic: bone is constantly being broken down and replaced

inorganic matrix: 65%; mostly crystallized mineral salt, which provides weight bearing strength (and differentiates form cartilage)

- ***hydroxyapatite***: *calcium phosphate crystals*
- ***calcification***: *adding these cells to the matrix; also called mineralization and ossification*
- ***acid***: *breaks down inorganic matrix*

organic matrix: 35%; collagen, proteoglycans, and water, which provides flexible strength

- ***somewhat resilient***: *less proteoglycans and water than cartilage*
- ***enzymes***: *can break down proteins, leaving only inorganic materials (brittle bones)*

osteoblasts: cells that build matrix (both organic and inorganic); found in lacunae

- ***matrix vesicles***: *formed by pinching off a portion of the membrane > concentrates Ca and P together > forms hydroxyapatite > exocytosis into collagen framework > ossification*

osteochondral progenitor cells: stem cells that can become osteoblasts or chondroblasts; found in the perichondrium and allow us to keep making cells throughout our lifetime

osteocytes: mature osteoblasts trapped in the matrix within a lacuna; considered inactive, but maintains the ability to produce components for bone matrix maintenance

- ***canaliculi***: *channels between lacunae which allows transport of nutrients and gases (start off as connecting cell extensions when building the matrix)*

osteoclasts: large, multi-nuclear cells on the surface of bones; break down osteocytes

- ***resorption***: *break down of bone*
- ***reabsorption***: *return of minerals into the bloodstream*
- ***structure***: *formed from the fusion of monocytes (white blood cells)*
- ***mechanism***: *attach to bone via podosomes (protein attachments) > creates sealed compartment > portion of membrane extends into ruffled border (increases surface area) > releases acids and enzymes > bone fragments taken up and released into extracellular space and blood*

NOTE: review of MODULE 8 was recommended (part of TEST 3 NOTES)

KINESIOL 1Y03

24: Bone Tissue II

Bone Classification

classification: based on organization of collagen fibers in the matrix
woven bone: randomly oriented collagen fibers; quick and fast way of making a bone, but is eventually remodeled by osteoclasts and osteoblasts
lamellar bone: more organized collagen; mature bone organized in sheets/layers (lamellae); seen in all the bones

__classification__: based on amount and organization of matrix
__spongy__: also known as cancellous, trabecular
__compact__: also known as cortical

Compact Bone

composition: dense with fewer spaces; very organized sheets of lamellar bone
location: 80% of the skeleton by mass; outside of all bones, and most of the shafts of long bones
function: gives bones strength
periosteum: lines outside of bone; similar to perichondrium

__outer layer__: dense fibrous connective tissue; has blood supply (periosteal vein and artery)
__inner layer__: osteogenic; contains osteoblasts, osteoclasts, and osteochondral progenitor

endosteum: lines medullary cavity side of bone; only has osteogenic layer
medullary cavity: spaces within the bone
perforating (Volkmann's) canal: pathways running perpendicular to the length of the bone which allow blood vessels to enter; connects central canals
central (Haversian) canals: parallel tunnels within the bone for blood vessels
lamellae: rings of calcified matrix
concentric lamellae: form concentric circles around the central canal

__osteocytes__: sandwiched between lamellae
__canaliculi__: connect layers

circumferential lamellae: bundle the osteons together; several layers

__outer circumferential lamellae__: runs around the outside of the entire bone
__inner circumferential lamellae__: layer that spongy bone forms off of

interstitial lamellae: fill spaces between the circles of concentric lamellae; shortened pieces of lamellar bone leftover from broken-down osteons
blood supply: nutrients move outwards from the central canals towards the cells; vessels found within and around bone
osteon (Haversian system): central canal and contents, associated concentric lamellae, and osteocytes

Spongy Bone

composition: less bone matrix, more space; porous appearance; protected by a layer of compact bone; osteochondral progenitor cells throughout
location: 20% of the skeleton by mass; inside of bones; fills spaces of bones that are irregularly shaped, and the ends of long bones; forms a thin layer in regions where there are cavities inside of bones (e.g., shaft of long bones)
function: provides strength without extra mass
trabeculae: matrix is organized into connecting rods or plates, oriented along the lines of stress
cavities: filled with bone marrow and blood vessels; nutrients diffuse inwards towards cells
osteocytes: found sandwiched in lacunae between lamella; connected by canaliculi
outer layer: osteoclasts and osteoblasts (mostly osteoblasts)

Long Bone Structure

long bone: longer in length than width; e.g., femur (thigh bone)
epiphysis: region closest to the end of the bone; mostly spongy, typically filled with red bone marrow

__proximal epiphysis__: region closer to the trunk
__distal epiphysis__: region farther from the trunk
__articular cartilage__: surrounds epiphysis

diaphysis: shaft of the bone; mostly compact with a thin layer of spongy inside
metaphysis: connects epiphysis and diaphysis
periosteum: surrounds bone
medullary cavity: inside of shaft region; contains yellow bone marrow in adults, except for the proximal epiphysis of long bones, and pelvic bones (responsible for producing blood cells as an adult); lined with endosteum
epiphyseal line: between epiphysis and diaphysis (or metaphysis)

__epiphyseal plate__: layer of hyaline cartilage which is initially found here; allows the bone to grow in length; ossified once it has reached its final length

Bone Development

osteogenesis: process of forming bone tissue; begins in the embryo at 8 weeks
mesenchyme cells: stem cells which produce all connective tissue; stimulated into osteochondral progenitor cells when blood vessels invade future-bone regions
processes: intramembranous or endochondral; both start with woven bone, and have identical end results

Intramembranous

description: bone formation in connective tissue membranes
locations: skull bones, mandible, part of clavicle
mechanism: mesenchyme > creates collagen connective tissue membrane > osteochondral progenitor cells turn into osteoblasts > membrane is ossified

Endochondral

description: bone formation in cartilage
locations: base of skull, part of clavicle, other bones
mechanism: mesenchyme > osteochondral progenitor cells > chondroblasts > hyaline cartilage skeleton > [8 weeks] > blood vessels invade perichondrium > progenitor cells become osteoblasts > perichondrium becomes periosteum

Bone Growth

appositional growth: formation of new bone on the surface of old bone
directions: grows in length and thickness
remodeling: continuous osteoblast and osteoclast activity throughout lifetime

__cycle__: skeleton is replaced every 10 years
__stress__: stimulates osteoblasts
__medullary cavity__: formed by destroying inside and rebuilding outside
__epiphysis__: can grow underneath the articular cartilage (which doesn't get ossified)

Bone Lengthening

layers: forms 5 layers/regions; cartilage remains on the epiphyseal side, while bone forms on the diaphyseal side

__zone of resting cartilage__: slowly dividing chondrocytes (interstitial growth); provides an anchor point for the epiphysis
__zone of proliferating cartilage__: rapidly dividing chondrocytes; divides into "stacks of coins"
__zone of hypertrophy__: chondrocytes enlarge and grow, secreting matrix vessels that contain hydroxyapatite
__zone of calcified cartilage__: chondrocytes die off, blood vessels and osteoblasts from the endosteum invade, and bone starts calcifying
__ossified bone__: developing bone of diaphysis

Bone Thickening

groove: osteoblasts beneath the periosteum lay down bone around a periosteal blood vessel
ridges: heighten and eventually meet, forming a tunnel; periosteum is pinched off; inside layer become endosteum
endosteum: osteoblasts form concentric lamellae towards the blood vessel
periosteum: osteoblasts form new circumferential lamellae

summary sheet by Jasmine Ah Yong for KINESIOL 1Y03 (2022)

KINESIOL 1Y03

25: Axial & Hyoid

Skeletal System

206 bones: in the human adult skeleton; children have more before they fuse
axial skeleton: bones along the longitudinal axis; head, neck, and trunk
- ***bones***: *80 in total; skull, hyoid bone, vertebrae, ribs, sternum, auditory ossicles*
- ***skull***: *series of bones that make up the facial bones and the cranial case*

appendicular skeleton: limbs, pelvic and pectoral girdles
- ***bones***: *126 in total*
- ***girdle***: *attachment site between axial and appendicular*

Surface Features

ridges: point of attachment for muscle onto bone; e.g., spine on scapula
projections: point of attachment for muscles and ligaments crossing a joint
- ***process***: *smaller*
- ***tuberosity***: *larger knob*
- ***tubercles***: *rounded bumps*

openings: space for things to run through
- ***foramina***: *holes for blood vessels and nerves*
- ***canal***: *tunnel*

depressions: lowered regions
- ***fossa***: *shallow*
- ***notches***:
- ***grooves***:

Bone Structure

body: largest part
head: end
neck: connects body and head
margin/border: outside edge
condoyle: smooth, rounded articular surface
facet: small, flattened articular surface

Skull

function: protects the brain; supports organs of vision, hearing, smell, and taste
bones: 8 cranial, 14 facial; associated with 6 auditory ossicles (malleus, incus, stapes) and 1 hyoid bone
joints: 22 bones are connected by immovable joints
"surface" bones: occipital, parietal, temporal, frontal, nasal, zygomatic, maxilla, mandible
sutures: immovable joints where the bones of the skull articulate with each other
anterior nasal septum: made of hyaline cartilage
alveolar processes: spaces for teeth in maxilla and mandible

Cranial Bones

cranial bones: 8 bones that make up the brain case
parietal (2): make up the sides and roof of the cranial cavity
temporal (2): make up the inferior lateral aspects of the cranial cavity (part of the floor)
- ***mastoid process***: *bony feature behind the ear; attachment point for neck muscles*
- ***styloid process***: *looks like the end of a pencil; attachment point for tongue and neck muscles*
- ***external auditory (acoustic) canal (meatus)***: *pathway for soundwaves*
- ***zygomatic process***: *starts forming a region of the cheekbone*
- ***mandibular fossa***: *articulation with mandible*
- ***jugular foramen***: *where veins leave the cranial cavity; more posterior*
- ***carotid foramen***: *where arteries enter the cranial cavity; more anterior*

frontal (1): forehead, roof of orbit, anterior cranial floor; formed from 2 bones that fuse anteriorly by age 6
occipital (1): posterior inferior; base of most of the cranium
- ***external occipital protuberance***: *bump on back of skull; joints to ligaments which hold skull upright*
- ***foramen magnum***: *large round hole where spinal cord and brainstem connect*
- ***occipital condoyles***: *rounded, rocker-shaped bony features anterior and lateral to foramen magnum; allows movement of skull relative to C1 vertebra (nodding and tilting head)*

sphenoid (1): mostly on the inside of skull; butterfly/bat shaped (has greater and lesser wings); portion of lateral skull, cranial floor, and orbit; articulates with all other cranial bones
- ***sella turcica***: *depression in body; houses the pituitary gland*

ethmoid (1): also hard to see >:(
- ***cribriform plate***: *foramina for olfactory neurons; separates nasal and cranial cavities*
- ***perpendicular plate***: *superior and posterior portion of nasal septum*
- ***middle and superior nasal conchae***: *ridges*
- ***crista galli***: *superior projection; attachment point for falx cerebri; cribriform plate extends from here*

Facial Bones

facial bones: 14 bones that make up the underlying structure of the face and support the teeth (which are not bones)
maxilla (2): form upper jaw, floors of orbit, some of nasal cavity, most of hard palate
- ***palatine processes***: *large portion of roof of mouth; associated with horizontal plate of palatine; 2 portions fuse together during embryological development*
- ***cleft lip***: *issue with fusing in soft portion*
- ***cleft palate***: *issue with fusing palatine processes; fails to divide oral and nasal cavity; a plate is placed in the roof of mouth until surgery can be done*

zygomatic (2): cheekbones and portion of the orbit
- ***temporal process***: *connects with the zygomatic process (forms zygomatic arch)*

palatine (2): L-shaped; forms back of oral cavity and some of nasal cavity
lacrimal (2): smallest; within the eye orbit
- ***lacrimal groove***: *helps form the nasolacrimal canal*

nasal (2): forms upper portion of the bridge of the nose, and anterior portion of roof of nasal cavity
inferior nasal conchae (2): create ridges for turbulent flow of air
vomer (1): elongated plow-shape; forms inferior and posterior portion of nasal septum
mandible: largest and strongest bone; not actually attached (only moveable bone of the skull); articulates with temporal bone at mandibular fossa

Orbit

orbit: cavity containing the eye; made of 7 bones
roof: frontal, sphenoid
lateral: sphenoid, zygomatic
floor: maxilla, zygomatic, palatine
medial: maxilla, lacrimal, ethmoid, sphenoid
supraorbital margin: in frontal bone; thickened region that prevents damage to the eye when we get hit

Hyoid Bone

location: not part of the skull, but it's in the region; just below the chin; unpaired floating bone (no articulations) below mandible
shape: u-shaped; large body with projections off the side
function; attachment point for tongue and neck muscles (elevate larynx during speech and swallowing)

KINESIOL 1Y03

iv: DEXA & Osteoporosis

D(E)XA Scan

D(E)XA: dual energy x-ray absorptiometry
function: 15-30 minute noninvasive imaging test to measure bone density and body composition; measures inorganic components
mechanism: 2 low-dose x-rays with distinct energy peaks are sent through; one is absorbed mainly be soft tissue and the other by bone; differential attenuation provides an estimate of bone mineral, fat, and lean soft tissue mass
purpose: in clinical situations, typically to measure bone density; in research situations, often to measure changes in muscle

Osteoporosis

definition: deterioration of bone mineral content, which leads to weakening of the bones and increased risk of fracture
diagnosis: based on standard deviation from someone (20s-30s) with a healthy bone mineral content; 2 standard deviations below = osteoporotic
impact: risk of fractures from activities of daily living
prevention: much easier than fixing it once it's advanced
cellular cause: osteoclasts > osteoblasts
- ***while growing***: *osteoclasts < osteoblasts*
- ***at peak height***: *osteoclasts = osteoblasts*
- ***post-35***: *osteoclasts > osteoblasts*

estrogen: facilitates coupling of osteoblasts and osteoclasts; menopause causes rapid deterioration
testosterone: facilitates coupling in males
weight-bearing activity: prescribed to place site-specific stress on the bones, which activates osteoblast cells
- ***site-specific exercise***: *fat loss isn't site-specific, but bone growth is*

bisphosphonate drugs: cause apoptosis of osteoclasts; e.g., Fosamax

Necrosis

necrosis: cell or tissue death
complications: if blood is cut off from the femoral head ("hip" fracture), the tissue and marrow dies; the necrotic tissue collapses