Osseous Tissue & Skeletal System

- Functions:
  - support
  - protection
  - movement
  - mineral & growth factor storage
  - blood cell formation
  - Hematopoiesis:
    - Fat (triglyceride) storage
    - hormone production
    - Osteocalcin: helps regulate insulin secretion, glucose levels, metabolism

- Classification of Bones
  - There are 206 bones
    - The Axial skeleton consists of:
      - long axis: skull, vertebral column, rib cage
    - The Appendicular skeleton consists of:
      - upper and lower limbs
      - girdles

- Four shape of bones
  - LONG: longer than they are wide
  - short: bones
  - cube-shaped bones
  - Wrist and ankle bones: sesamoid
  - EX: patella
  - Vary in size and number
  - Form within tendons
  - sesamoid
- Vary in size and numbers in different individuals
  - Within tendons
  - EX. Patella
  - Flat
    - Thin, flat and curved
    - Sternum, scapulae, ribs and skull bones
  - Irregular
    - Complicated shapes
    - Vertebral & hip bones
- Bone Structure
  - Bones are organs because they contain different types of tissues
  - Also called osseous tissue
  - Comprised of
    - Bone
    - Nervous tissue
    - Cartilage
    - Fibrous connective tissue
    - Muscle cells
    - Epithelial cells
    - Blood vessels
  - Levels of structure
    - LARGEST
      - Gross
      - Microscopic
      - Chemical
    - SMALLEST
      - Gross Anatomy
        - Compact bone
          - Dense outer layer
          - Function: protection
          - Appears smooth & solid
        - Spongy bone
          - Honeycomb of small, needle-like flat pieces called: trabeculae
the open spaces between the **trabecular** bone marrow are filled with red or yellow bone marrow.

- Structure of Short, irregular and flat bones
  - Have thin plates of spongy bone called **diploë** which are covered by compact bone.

- Compact bone sandwiched between connective tissue membranes
  - Periosteum: outside of compact bone
  - Endosteum: inside of compact bone
  - No definitive marrow cavity, marrow is scattered through **spongy** bone.
  - **Hyaline** cartilage covers area of bone that is in a moveable joint.

- Structure of long bones
  - Long bones have a:
    - Shaft aka **diaphysis**
    - Bone ends, **epiphyses**
    - And **membranes**
  - Diaphysis: forms long axis of bones
    - Consists of **compact bone** surrounding the central medullary cavity filled with **yellow** marrow in adults.
  - Epiphyses: ends of long bones
    - Consist of **compact** bone externally
    - And **spongy** bone internally
    - **Articular** cartilage that covers joint surfaces
  - Epiphyseal line
    - Between the **diaphysis & epiphysis**
    - Remnant of childhood **epiphyseal plate** where bone growth occurs.

- Membranes
  - Two types
    - **Periosteum**
      - **Fibrous** layer
      - **Osteogenic** layer
    - **Endosteum**
  - Periosteum
Periosteum
- White
- double layered
- Covers external surfaces
- EXCEPT joints
- Fibrous layer
  - outer layer
  - Consists of dense irregular connective tissue
  - Sharpey's fibers that secure to bone matrix
- Osteogenic layer
  - inner layer touching bone
  - Contains primitive osteogenic stem cells that give rise to bone cells
  - Contains nerve fibers and blood vessels onto the shaft of the bone
  - Anchoring points for tendons & ligaments
- Endosteum
  - Delicate connective tissue membrane covering internal bone surface
  - Covers the trabeculae of spongy bone
  - Lines canals that pass through compact bone
  - Like periosteum contains osteogenic cells that differentiate into other bone cells
  - Hematopoietic tissue in bones
    - Red marrow found within trabecular cavities in spongy bone and diploe of flat bones
    - Newborns, medullary cavity and all spongy bone contain red marrow
    - Adults, red marrow is located in heads of femurs and humerus but most active areas of hematopoiesis are flat bones diploe and some irregular bones EX. hip bones
    - Yellow marrow can covert to red if a person comes anemic
- Bone Markings
  - Sites of muscle, ligament and tendons attachment on external surfaces
  - Areas involved in joint formation or conduits for blood vessels and nerves
3 types of markings:

- **Projection**
  - Bulge of bone
  - Increase due to stress from muscle pull or modification from joints
- **Depression**
  - Bowl, groove cut out
  - Passageways for vessels and nerves
  - Role in joints
- **Openings**
  - Hole or canal in bone
  - Serves as passageways for blood vessels and nerves

Microscopic anatomy

- Cells of bone tissue
  - 5 major cell types, all specialized
    - **Osteogenic** cells
    - **Osteoblasts**
    - **Osteocytes**
    - **Bone-lining cells**
    - **Osteoclasts**

- Osteogenic cells
  - Aka **osteoprogenitor** cells
  - Mitotically active stem cells in **prenosteum** & **endosteum**
  - Activate when stimulated
  - Differentiate into **osteoblasts** or **bone-lining cells**
  - Some still remain as osteogenic stem cells

- Osteoblast
  - Immature
  - Bone forming cells
  - Secreted unmineralized bone cells called **osteoid**
  - Osteoid made of **collagen** and calcium binding protein
  - **Collagen** makes up 90% of bone protein
  - **Osteoblasts** are actively mitotic
- Osteocyte
  - mature bone cells that no longer divide
  - Maintain bone matrix and act as stress sensors
  - Respond to mechanical stimuli such as increased force or bone of weightlessness
  - Communicate information to osteoblasts and osteoclasts, so remodeling can occur

- Bone-lining cells
  - Flat cells on the surface
  - Maintain matrix with osteocytes
  - External surface - periosteal cells
  - Internal surface - endosteal cells

- Osteoclast
  - Destructive
  - Derived from hematopoietic stem cells that become macrophages
  - Giant
  - Multinucleated
  - Function in resorption (breakdown of bone)
  - Serve to increase surface area for enzyme degradation of bones

- Compact bone
  - Also called, lamellar bone
  - Consist of:
    - Osteon
      - Also called Haversian system
      - Canals & canaliculi
      - Interstitial & circumferential lamella

- Osteon
  - Structural unit of compact bone
  - Elongated cylinder of parallel running fibers - tiny weight bearing pillars
  - Lamellae:
    - Collagen fibers that run different directions
    - Withstand stress and resist twisting
    - Bone salts are found between
Canals & canaliculi
- Central canal (Haversian canal): run thru core of osteon, contains nerves & blood vessels
- Perforating canals (Volkmann’s canal): canals lined w/ endostium @ right angles - connect blood vessels & nerves to med cav & central canal
- Lacunae: cavities where osteocytes are found
- Canaliculi: hair-like canals connect lacunae to one another and to central canal

Interstitial & circumferential lamella
- Interstitial lamellae:
- Circumferential lamellae

Periosteum
Circumfren
Endostium

Chemical Composition
- Bone is made of: organic & inorganic components
- Organic
  - Includes:
    - Osteogenic cells, osteoblasts, osteocytes, bone-lining cells, osteoclasts and osteoid
    - Osteoid: 1/3 organic bone matrix, secreted by osteoblasts
    - Has: ground substance, collagen fibers, tensile strength
- Inorganic
  - Hydroxyapatites (mineral salt): flexibility of bone
    - Made up ___% of bone by mass
    - Tiny calcium phosphate crystals in and around collagen fibers
    - Responsible for hardness and resistance to compression
- Bone is 1/3 as strong as steel in resisting compression
- Bone is as strong as steel in resisting tension
- Lasts long after death
- Can reveal information about people

Skeletal Cartilages
- Human skeleton begins made up of cartilage, which is replaced by bone, other than in flexible places
- Skeletal cartilage: highly resilient, molded cartilage mostly water, NO blood vessels or nerves!
resist outward expansion of blood vessels for nutrient delivery
dense connective tissue, surrounds like girdle

- Perichondrium:
- Cartilage is made of chondrocytes incased in small cavities within a jelly-like ECM

- Cartilage grows in two ways:
  - appositional
  - interstitial

- Appositional growth:
  - Cells in perichondrium secrete matrix against external face of cartilage
  - New matrix laid down on surface of cartilage

- Interstitial growth:
  - Chondrocytes within lacunae divide and secrete new matrix, expanding cartilage from within
  - New matrix within cartilage

Bone Development:
- Ossification: bone tissue formation, aka osteogenesis, month 2 until early adulthood
  - Begins?
  - Postnatal?
  - Always, sometimes or forever?

Formation of the bony skeleton:
- Up to about 8 weeks, fibrous membranes and hyaline cartilage of fetal skeleton and then replaced with bone
- Two methods:
  - endochondral ossification
  - intramembranous ossification

- Endochondral ossification:
  - All bones below skull, except clavicles
  - Begins late in second month of development
  - Uses previous material, hyaline cartilage, breaking down of hyaline cartilage will allow ossification to begin
  - Begins at primary ossification center in the center of the shaft
  - Steps:
    - Bone collar
    - Central cartilage in diaphysis calcifies, develops cavities
- Periosteal bud
  - Invades cavities, leads to spongy bone formation
  - Bud is made of blood vessels, nerves, red marrow
  - Osteogenic and osteoclasts

- Diaphysis elongates
  - Birth!
  - Secondary ossific center appears in epiphysis

- Epiphyses ossify
  - Hyaline cartilage remains only in growth plates and articular cartilage

- Intramembranous ossification
  - Begins with fibrous connective tissue membranes formed by mesenchymal cells
  - Forms frontal, parietal, occipital, temporal, and clavicles
  - Steps:
    - Ossification centers
      - Mesenchymal cells cluster and become osteoblasts
    - Osteoid
      - Secreted and then calcified
    - Woven bone formed and laid around blood vessels
    - Lamellar bone
      - Outer layer of woven bone forms trabeculae
    - Replaces woven bone

Growth in length of long bones
- Long bones grow lengthwise by interstitial growth, also known as longitudinal growth. This growth occurs at the epiphyseal plate.
- Interstitial growth requires ep cartilage
- 5 zones of epiphyseal plate
  - Resting zone
  - Proliferation zone
  - Hypertrophic zone
  - Calcification zone
  - Ossification zone

<table>
<thead>
<tr>
<th>Resting Zone</th>
<th>Proliferation Zone</th>
<th>Hypertrophic Zone</th>
<th>Calcification Zone</th>
<th>Ossification Zone</th>
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<tbody>
<tr>
<td>inactive part of epiphysis of ep</td>
<td>replication rapidly dividing new cells go to diaphysis = lengthening</td>
<td>oldest chondrocytes closer to diaphysis lawns enlarge &amp; erode intercannalicular spaces surrounding cartilage matrix calcified</td>
<td>ultimately replaced w/ spongy bone long spirals of calcified cartilage</td>
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End of adolescence, chondroblasts divide less
EP things and then is replaced by **bone**
Plate closure: epip & diaphysis fuse
  - Females: 18
  - Males: 21

Growth of width of bones
- Bones lengthen in width via **appositional** growth
- Bones thicken in response to **muscle activity**, **stress** or **added weight**
- Osteoblasts: beneath periosteum, external bone secreted matrix
- Osteoclasts: remove bone on endo surface
- Break down less than build up = thicker, stronger, not too heavy

Hormone regulation of bone growth
- Growth hormone: **most important**, stimulate ep in infancy& childhood
- Thyroid hormone: modulates GH, ensure proportions
- Testosterone: males > e puberty
- Estrogen: **females** growth spurts
- Excess or deficits will result in abnormal skeletal growth

Review: 0