Bone Tissue
- tissues and organs of the skeletal system
- histology of osseous tissue
- bone development
- physiology of osseous tissue

Bone as a Tissue
- osteology – the study of bone
- skeletal system - composed of bones, cartilages, ligaments, tendons
  - strong flexible framework of the body
  - cartilage – forerunner of most bones
    - covers many joint surfaces of mature bone
- ligaments
- tendons

Functions of the Skeleton
- support –
- protection –
- movement –
- electrolyte balance –
- acid-base balance –
- blood formation –

Shapes of Bones
- long bones
- short bones
- flat bones
- irregular bones

Anatom of a Long Bone
- epiphyses and diaphysis
- compact and spongy bone
- marrow cavity
- articular cartilage
- Periosteum
  - Inner: osteogenic stem cells
  - Outer: collagen fibers
- Endostium
- Nutrient Foramen

Anatomy of a Flat Bone
- diploe – spongy layer in the cranium
  - absorbs shock
  - marrow spaces lined with endosteum

Figure 7.1
Figure 7.3
Histology of Osseous Tissue

- Connective tissue cells, fibers, and ground substance
- four principal types of bone cells
  - osteogenic (osteoprogenator) cells
  - osteoblasts
  - osteocytes
  - osteoclasts

1. osteogenic (osteoprogenator) cells - stem cells found in endosteum, periosteum, and in central canals

2. osteoblasts - bone forming cells
   - single layer of cells under endosteum and periosteum
   - are nonmitotic
   - synthesize soft matrix which hardens by mineral deposition
   - stress and fractures stimulate osteogenic cells

3. osteocytes – former osteoblasts that have become trapped in the matrix
   - lacunae – tiny cavities where osteocytes reside
   - canaliculi – little channels that connect lacunae
   - cytoplasmic processes reach into canaliculi

Cells of Osseous Tissue

- matrix of osseous tissue (by dry weight), ~ one-third organic and ~ two-thirds inorganic matter
- organic matter synthesized by osteoblasts
  - collagen, carbohydrate – protein complexes, such as glycosaminoglycans, proteoglycans, and glycoproteins
- inorganic matter
  - 85% hydroxyapatite (crystallized calcium phosphate salt)
  - 10% calcium carbonate
  - other minerals (fluoride, sodium, potassium, magnesium)

Compact Bone

- Osteon is the functional unit of compact bone

- nutrient foramina – on bone surface
- perforating (Volkmann’s) canals – transverse or diagonal canals
- central canals – vertical canals
- circumferential lamellae
- interstitial lamellae
Spongy Bone

- sponge-like appearance
- spongy bone consists of:
  - slivers of bone called spicules
  - thin plates of bone called trabeculae
  - spaces filled with red bone marrow
- few osteons and no central canals
- provides strength with minimal weight
  - trabeculae develop along bone’s lines of stress

Bone Development

- ossification or osteogenesis – the formation of bone
- human fetus and infant, bone develops by two methods:
  1. intramembranous ossification
  2. endochondral ossification

Bone Marrow

- red marrow (myeloid tissue)
  - in nearly every bone in a child
- hemopoietic tissue – produces blood cells and is composed of multiple tissues
  - in adults, found in skull, vertebrae, ribs, sternum, part of pelvic girdle, and proximal heads of humerus and femur
- yellow marrow found in adults

Intramembranous Ossification

Endochondral Ossification

Fetal Skeleton at 12 Weeks
Bone Growth and Remodeling

- **Interstitial growth** - bones grow in length – cartilage!
- **Appositional growth** - bones increase in width throughout life
  - the deposition of new bone at the surface
- **Bone remodeling** occurs throughout life - 10% per year
  - Wolff’s law of bone –
    - Osteoclasts & osteoblasts
    - Lines of stress

Interstitial Growth: Zones of the Metaphysis

<table>
<thead>
<tr>
<th>Zone</th>
<th>Description</th>
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<tbody>
<tr>
<td>Zone of reserve cartilage</td>
<td></td>
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<tr>
<td>Typical histology of resting hyaline cartilage</td>
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<tr>
<td>Zone of cell proliferation</td>
<td></td>
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<tr>
<td>Chondrocytes lining up in rows of small flattened lacunae</td>
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<tr>
<td>Zone of cell hypertrophy</td>
<td></td>
</tr>
<tr>
<td>Cessation of mitosis; enlargement of chondrocytes &amp; thinning of lacuna walls</td>
<td></td>
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<tr>
<td>Zone of cartilage breakdown</td>
<td></td>
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<tr>
<td>Temporary calcification of cartilage matrix</td>
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<tr>
<td>Zone of bone deposition</td>
<td></td>
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<tr>
<td>Resorption of bone, formation of osteoid</td>
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</tbody>
</table>

Cartilaginous Epiphyseal Plates

**Vs. Epiphyseal Lines**

Bone Growth in Width – Appositional growth

1. Osteoblasts in endosteum build new concentric lamellae inward toward center of tunnel, forming new osteon.
2. Bone grows outward as osteoclasts in periosteum build new concentric lamellae. Osteon formation repeats as new periosteal ridges form over blood vessels.

Bone Growth in Width

1. Ridges in periosteum create groove for periosteal blood vessels.
2. Periodical ridges fuse, forming an endosteal-lined tunnel.

At bone surface – periosteum cells → osteoblasts (create matrix)
Osteoblasts in Endostium deposit matrix and OSTEON is made.
Physiology of Osseous Tissue

- a mature bone remains a metabolically active organ
  - involved in its own maintenance of growth and remodeling
  - exerts a profound influence over the rest of the body by exchanging minerals with tissue fluid
  - disturbance of calcium homeostasis in skeleton disrupts function of other organ systems

Mineral Deposition

- mineral deposition (mineralization) - calcium phosphate, and other ions are taken from the blood plasma and deposited in bone tissue
  - osteoblasts produce collagen fibers that spiral the length of the osteon
  - fibers become encrusted with minerals that harden the matrix
  - calcium and phosphate ion concentration must reach a critical value called the solubility product for crystal formation to occur
  - most tissues have inhibitors
    - osteoblasts neutralize these inhibitors and allow salts to precipitate in the bone matrix
  - abnormal calcification (ectopic ossification)

Mineral Resorption

- mineral resorption – the process of dissolving bone and releasing minerals into the blood
  - performed by osteoclasts
  - hydrogen pumps in membrane secrete H+ into space between osteoclast and bone surface
  - chloride ions follow by electrical attraction
  - hydrochloric acid (pH 4) dissolves bone minerals
  - acid phosphatase enzyme digests the collagen

Control of Calcium

calcitriol, calcitonin, and PTH maintain normal blood calcium concentration

Calcitriol Synthesis and Action (Vit. D)

Correction for Hypercalcemia

Blood \(\text{Ca}^{2+}\) excess 
- Reduced osteoclast activity 
- Less bone resorption 
- Increased osteoblast activity 
- More bone deposition 
- Blood \(\text{Ca}^{2+}\) returns to normal
**Correction for Hypocalcemia**

- Blood Ca\(^{2+}\) deficiency
- Parathyroid hormone secretion
- Increased osteoclast activity
- Reduced osteoblast activity
- More urinary phosphate excretion
- Less urinary calcium excretion
- Conservation of calcium

**Phosphate Homeostasis**

- Important molecules with P?
  - no immediate functional disorders if low or high
- calcitriol promotes its absorption by small intestine & promotes bone deposition
- PTH lowers blood phosphate level by promoting its urinary excretion

**Other Factors Affecting Bone**

- 20 or more hormones, vitamins, and growth factors affect osseous tissue
- bone growth especially rapid in puberty & adolescence
  - surges of growth hormone, estrogen, and testosterone occur and promote ossification
    - girls grow faster than boys
    - males grow for a longer time and taller

**Fractures and Their Repairs**

- **stress fracture** – break caused by abnormal trauma to a bone
- **pathological fracture** – break in a bone weakened by some other disease
- **closed reduction** – bone fragments are manipulated into normal positions
- **open reduction** – involves surgical exposure of the bone

**Healing of Fractures**

- hematoma formation
- granulation tissue formation
- osteoblasts deposit a temporary bony collar around the fracture to unite the broken pieces while ossification occurs.
- bone remodeling: small bone fragments are removed by osteoclasts, while osteoblasts deposit bone matrix and then convert it to compact bone.
Osteoporosis

• **osteoporosis** – most common bone disease
  – severe loss of bone density

• bones loses mass and becomes brittle due to loss of organic matrix and minerals
  – affects spongy bone the most since it is most metabolically active

• estrogen maintains density in both sexes inhibits resorption by osteoclasts

Spinal Osteoporosis