The Skeletal System:

Osseous Tissue & Skeletal Structure

Skeletal System Functions

- **Storage of minerals**: calcium salts
  - 98% of the body’s calcium is in bones
- **Blood cell production**: red bone marrow produces new blood cells
- **Support**: body’s “infrastructure”
- **Protection**: many delicate organs are surrounded by bone
- **Leverage/movement**: muscles pull on bone to produce movement at joints

The Skeletal System

- The **skeletal system** includes:
  - Bones, cartilages, ligaments
- **Bone tissue** = osseous tissue
  - Includes living cells and hard matrix
- **Note**: Bones are organs
  - Made up of several tissues types
  - Dynamic: undergo constant remodeling

Bones Are Organs

- A bone is an organ, primarily composed of bone tissue
- **Bone (osseous) tissue** =
  - Cells + solid **Matrix**
    - Calcium salts
- 2 types of osseous tissue:
  - **Compact (dense) bone**
  - **Spongy (trabecular) bone**
- **Periosteum** = outer bone covering
- **Endosteum** = inner cellular lining of bone
Osseous Tissue Components

- **Bone matrix**: 2/3 of bone weight
  - *Calcium phosphate (hydroxyapatite)*
    - Resists compression
  - **Collagen fibers**: 1/3 of bone matrix
    - Resists stretch
    - Together, collagen + hydroxyapatite = extremely strong
- Cells account for about 2–3% of bone tissue.

Bone Cells & Their Roles

- **Osteocytes** = mature bone cells
  - Maintain bone tissue; surrounded by matrix
- **Osteoblasts**: immature, active cells:
  - On inner & outer surfaces of bone.
    - Responsible for **osteogenesis** = make organic components of bone matrix (“osteoid”)
- **Osteoprogenitor cells**: “stem” cells
  - On inner & outer surfaces of bone
    - Divide & differentiate to form new osteoblasts.
- **Osteoclasts** = large multinucleated cells
  - Perform **osteolysis** (dissolve bone matrix)

Cells of Mature Bone

<table>
<thead>
<tr>
<th>Canaliculi</th>
<th>Osteocyte</th>
<th>Matrix</th>
<th>Osteoid</th>
<th>Osteoblast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osteocyte: Mature bone cell that maintains the bone matrix</td>
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<tr>
<td>Osteoblast: Immature bone cell that secretes organic components of matrix</td>
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<tr>
<td>Osteoprogenitor cell</td>
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<tr>
<td>Osteoclast</td>
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<tr>
<td>Matrix</td>
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</tbody>
</table>

Compact vs. Spongy Bone

Compact & spongy bone tissues are arranged differently

- Cylindrical **osteons** form most of compact bone; whereas spongy bone is composed of **trabeculae**
**Osteons: Functional Units of Compact Bone**

- **Lacunae**: small spaces in bone matrix; house osteocytes
- **Lamellae**: layers of matrix around central canals
- **Canaliculi**: small channels connecting lacunae (allow passage of nutrients & wastes)

**The Periosteum & Endosteum**

**Functions of the Periosteum & Endosteum**

- **Periosteal Functions**:
  - Participates in bone growth and repair.
  - Isolates & protects bone from surrounding tissues
    - Attaches bone to the deep fascia
  - Serves as a route & attachment for blood vessels and nerves.
- **Endosteal Function**: active during growth, repair, and remodeling

**Long Bone Regions**

- **Epiphyses**: ends
- **Diaphysis**: shaft
- **Metaphysis**: between epiphyses & diaphysis
Osteogenesis (Bone Development)

- Initially, skeleton is mesenchyme or cartilage
  - **Ossification**: bone replaces pre-existing tissue
    - **Intramembranous** (dermal) = usually from a membrane deep in dermis
      - e.g., roofing bones of skull
    - **Endochondral** = begins with hyaline cartilage model
      - e.g., limb bones
  - **Calcification** = depositing calcium salts into tissues

Intramembranous Ossification: **From Fibrous CT to Bone**

Endochondral Ossification: **From Hyaline Cartilage Model to Bone**

- Bone development from *hyaline cartilage* “model”
- Bone increases size via **interstitial growth** (length) & **appositional growth** (width)
- **Epiphyseal cartilage** = cartilage present in metaphyseal area throughout childhood.
  - Allows bone to continue growth in length.
    - At maturity: epiphyseal closure forms of the epiphyseal line

Endochondral Ossification

- As the cartilage enlarges, chondrocytes near the center of the shaft increase in size. The matrix is replaced by a series of endochondral ossification centers, the shaft is encased in a new bone.
- **Osteogenic layer produces bone collar**
- Blood vessels penetrate the cartilage and invade the central region. Fibroblasts migrate with the blood vessels differentiate into osteoblasts and begin producing spongy bone at a primary ossification center. Osteoclasts then resorb the cartilage then produce compact bone.

- Remodeling occurs as growth continues, creating a marrow cavity.
- The bone of the shaft becomes thicker, and the cartilage near each epiphysis is replaced by shafts of bone. Further growth involves increases in length (length) and diameter (width).
**Endochondral Ossification: Increasing Length**

1. Cartilaginous and osteoblasts migrate into the epiphysis, creating secondary ossification centers.
2. Soon the epiphyses are filled with spongy bone. An articular cartilage remains exposed to the joint cavity, over time it will be reduced to a thin superficial layer. At each metaphysis, an epiphyseal cartilage separates the epiphysis from the diaphysis.

**Epiphyseal Plates Replaced by Epiphyseal Lines**

- **Growth in Width (Appositional Growth)**
  - Bone formation at the surface of the bone produces ridges that parallel a blood vessel.
  - The ridges enlarge and create a deep packet.
  - The ridges meet and fuse, trapping the vessel inside the bone.

- **Appositional Growth & Remodeling**
  - As a bone grows in diameter (width), new bone is added to the outer edge while old bone is removed from the inner edge.
  - Blood vessels become incorporated in the new osteons (previous slide).

- **Epiphyseal Plates Replaced by Epiphyseal Lines**
  - Young child hand
    The arrows indicate the locations of the epiphyseal cartilages.
  - Adult hand
    The arrows indicate the locations of epiphyseal lines.
Blood Supply of Long Bone

Bones have an extensive blood supply.
The nutrient artery and vein serve most of the bone.

Injury and Fracture Repair

Callus formation

Osteoporosis

Inadequate ossification = osteopenia (osteoclasts more active than osteoblasts)
Osteoporosis = reduction of bone mass and changes in structure that compromise bone integrity.

Classification of Bones Based on Shape/Location
**Bone Markings: Surface Features**

- Bone markings = sites of attachment of ligaments, tendons & other CT to bone.
- Also: passageways for blood vessels & nerves

<table>
<thead>
<tr>
<th>Surface Description</th>
<th>Anatomical Term</th>
<th>Definition and Example (See Figure 5.1d)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Process and Projections</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Ears</td>
<td>Process</td>
<td>Anterolateral surface of a bone, making an angle to the rest of the structure (d, e)</td>
</tr>
<tr>
<td>- Trochanter</td>
<td>Trochanter</td>
<td>A large, rough projection (a)</td>
</tr>
<tr>
<td>- Tuberosity</td>
<td>Tuberosity</td>
<td>Rough projection (d)</td>
</tr>
<tr>
<td>- Crest</td>
<td>Crest</td>
<td>A prominent ridge (a)</td>
</tr>
<tr>
<td>- Line</td>
<td>Line</td>
<td>A narrow ridge (e)</td>
</tr>
<tr>
<td>- Spine</td>
<td>Spine</td>
<td>A pyramidal process (e)</td>
</tr>
<tr>
<td><strong>Depressions</strong></td>
<td>Fossa</td>
<td>A shallow depression (d, e)</td>
</tr>
<tr>
<td></td>
<td>Sulcus</td>
<td>A narrow groove (d)</td>
</tr>
<tr>
<td><strong>Openings</strong></td>
<td>Foramen</td>
<td>A rounded opening for blood vessels and/or nerves (b, c)</td>
</tr>
<tr>
<td></td>
<td>Foramen ovale</td>
<td>An opening in the skull (b)</td>
</tr>
<tr>
<td></td>
<td>Sinus sphenoid</td>
<td>A passageway through the substance of a bone (c)</td>
</tr>
<tr>
<td></td>
<td>Sinus maxillaris</td>
<td>A chamber within a bone, normally filled with air (c)</td>
</tr>
</tbody>
</table>

**Bone Markings**

- Tricipital
- Trochanter
- Condyle
- Condyle
- Trochlea
- Foramen
- Fossa
- Sinus
- Canal