Bone Tissue

Dr. Heba Kalbouneh
Associate Professor of Anatomy and Histology
Functions

- Support
- Protection (protect internal organs)
- Movement (provide leverage system for skeletal muscles, tendons, ligaments and joints)
- Mineral homeostasis (bones act as reserves of minerals important for the body like calcium or phosphorus)
- Hematopoiesis: blood cell formation
- Storage of adipose tissue: yellow marrow
Types of Bones:

- Gross observation:

  **Compact (cortical) bone:**
  a dense area near the surface, which represents 80% of the total bone mass.

  **Cancellous (trabecular or spongy) bone:**
  deeper areas with numerous interconnecting cavities, consisting about 20% of total bone mass.
Spongy bone

Compact bone
Types of Bone:

- Anatomical:
  - Long
  - Short
  - Flat
  - Irregular
  - Sesamoid
Head, Proximal end, Epiphysis

Shaft, Body, Diaphysis

Distal end, Epiphysis
LONG BONES

Articular cartilage
Cancellous bone
Epiphyseal Line
Marrow cavity
Periosteum
Compact bone

Epiphysis Head
Diaphysis Shaft
Epiphysis

Spongy Bone
Compact Bone
Spongy Bone
BONE ANATOMY

**Diaphysis**: long shaft of bone

**Epiphysis**: ends of bone

**Metaphysis**: b/w epiphysis and diaphysis

**Epiphyseal (growth) plate** (layer of hyaline cartilage that allows the bone to grow in length).

The cartilage in the epiphyseal plate is replaced by bone at the age of 18-21, and the resulting bony structure is called the **epiphyseal line**.

**Articular cartilage**: thin layer of hyaline cartilage covering the part of the epiphysis where the bone forms an articulation (joint).

**Function**: reduces friction and absorbs shock.

Articular cartilage lacks a perichondrium and lacks blood vessels, repair of damage is limited.
**Periosteum:** bone covering (pain sensitive)

**Sharpey’s fibers:** thick bundles of collagen that extend from the periosteum into the bone extracellular matrix

**Medullary cavity:** Hollow chamber in bone
- red marrow produces blood cells
- yellow marrow is adipose

**Endosteum:** thin layer lining the medullary cavity
Periosteum

1. Outer Fibrous
   Dense irregular ct

2. Inner Cellular
   osteogenic
Diaphysis
Epiphysis
Metaphysis
Epiphyseal (growth) plate/line
Medullary canal (cavity)
Compact bone
Cancellous (spongy) bone
Compact (cortical) bone

✓ An osteon (or Haversian system): concentric lamellae surrounding a small canal containing blood vessels, nerves, loose CT and lined by endosteum.

✓ Between successive lamellae are lacunae (each with one osteocyte).

✓ The outer boundary of each osteon is called the cement line.

✓ The central canal communicate with the marrow cavity and the periosteum and with one another through transverse Perforating canals (or Volkmann’s canal).
PERIOSTEUM & ENDOSTEUM

- Surfaces of bone are covered by tissue layers with bone forming cells.
  - External surfaces: **Periosteum**.
  - Internal surfaces: **Endosteum**.
- **Functions:**
  - Nutrition of bone.
  - Continuous supplying of osteoblasts from progenitor cells for bone growth or repair.

**Endosteum:**
- Lines the internal cavity of the bone.
- Covers trabeculae of spongy bone.
- Composed of a single layer of flat osteoprogenitor cells.
- Has the same functions as periosteum.

**Periosteum:**
- Outer fibrous
  - Some fibers penetrate through bone substance ⇒ Sharpey’s fibers.
- Inner cellular contains osteoprogenitor cells.
A single osteon in cross-section

- Cement layer
- Lamellae (bone layers)
- Haversian canal / central canal (a longitudinal canal containing 1 or 2 blood vessels, nerves, ± a lymph vessel and fluid)
- Canaliculi (tiny canals containing cytoplasmic processes of osteocyte)
- Lacuna (space containing osteocyte)
Types of lamella:

- Outer circumferential
- Concentric
- Interstitial
- Inner circumferential

**Interstitial lamellae**
- Scattered among the intact osteons.
- Are numerous irregularly shaped groups of parallel lamellae.
- Are lamellae remaining from osteons partially destroyed by osteoclasts during growth and remodeling of bone.

**Outer circumferential**: located immediately beneath the periosteum.

**Inner circumferential**: located around the marrow cavity.
Short, Irregular, and Flat Bones

- Spongy bone (mainly) covered by compact bone
- Spongy bone of flat bones is called *diploë*
- Have no diaphysis or epiphyses
- Contain bone marrow between the trabeculae
Spongy bone

- Haphazard arrangement of trabeculae
- No osteons
- Lighter and porous
- Trabeculae: Arches, rods, plates of bone, Branching network of bony tissue, Strong in many directions
- Spaces filled with red/yellow bone marrow
- Osteocytes get nutrients directly from circulating blood
- Short, flat and irregular bone are made up of mostly spongy bone

Dr. Heba Kalbouneh
Bone Matrix:

- **Inorganic matter** = ~ 67% of dry weight.
  - Most of ions are: $\text{Ca}^{+2}$ & $\text{PO}^{-4}$
  - Others: Mg, K, HCO3, Citrate.
  - $\text{Ca}^{+2}$ & $\text{PO}^{-4}$ form $\text{C}_{10}(\text{PO}_4)_6(\text{OH})_2 = \text{hydroxyapatite}$

- **Organic matter** = collagen type I & ground substance.
Bone cells:

- **Osteocyte** (maintains bone tissue)
- **Osteoblast** (forms bone matrix)
- **Osteogenic cell** (stem cell)
- **Osteoclast** (resorbs bone)

**Situated inside lacuna**

**Found in both the periosteum and the endosteum**
Osteoblasts
Bone building cells

Osteoclasts
Bone cutting cells

Bone deposition

Bone resorption

Bone remodeling
Osteoprogenitor Cells

- Derived from **embryonic mesenchymal cells**
- Located in the inner cellular layer of the periosteum and in the endosteum.
- Have the potential to differentiate into osteoblasts.
Osteoblast

- Responsible for synthesis of the organic components of the matrix.
- Deposition of inorganic components also depends on osteoblasts.
- When active, appear cuboidal-columnar, typical protein synthesizing cells.
- The newly laid matrix is not calcified and called **osteoid**.
- Osteoblast $\Rightarrow$ Osteocyte
- **Inactive** osteoblasts are flat cells that cover the bone surface. These cells resemble **bone lining cells** in both the endosteum and periosteum.
- Secrete alkaline phosphatase (ALP) and osteocalcin, their circulating levels are used clinically as markers of osteoblast activity.

✓ The newly deposited matrix is not immediately calcified. It stains lightly or not at all compared with the mature mineralized matrix, which stains heavily with eosin.
✓ Because of this staining property of the newly formed matrix, osteoblasts appear to be separated from the bone by a light band.
✓ This band represents the **osteoid**, the nonmineralized matrix, between the osteoblast layer and the preexisting bone surface.
Osteocyte

- Smaller than osteoblasts, almond shaped, with fewer rER, and condensed Golgi.
- Situated inside lacuna, one cell in each lacuna.
- Cells have processes (filopodial) passing through canaliculi in the thin surrounding matrix.
- Adjacent cells make contact through gap junctions in the processes.
- Involved in maintenance of matrix.
**Osteoclast**

- Large, branched motile, multinucleated cells.
- Originates from fusion of monocytes.
- Secretes collagenase and some enzymes.
- **When active,** they lie in Howship’s lacuna:
  - Enzymatically etched depression on the surface.
- The surface facing the matrix shows irregular foldings; **ruffled border.**
  - The ruffled border is surrounded by **clear zone:**
    - Clear of organelles, rich in actin.
    - Creates microenvironment for bone resorption.
Osteoclast

Nucleus

Golgi

Lysosomes

\[ \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}^+ + \text{HCO}_3^- \]

Ruffled border

Bone matrix

Microenvironment of low pH and lysosomal enzymes

Blood capillary

Section of circumferential clear zone
Clinical Application

Osteoporosis
Decalcified bone:
Because of its hardness, bone cannot be sectioned routinely. Bone matrix is softened by immersion in a decalcifying solution before paraffin embedding.
Decalcified bone section
Ground bone section
**Lamellar Bone**

- Most bone in adults, **compact or cancellous**, is organized as **lamellar bone**.
- Is multiple layers or lamellae of calcified matrix.
- The lamellae are organized either parallel to each other (cancellous) or concentrically around a central canal (compact).
- In each lamella = mainly collagen fibers type I

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**Woven Bone**

- Is nonlamellar.
- Is the first bone tissue to appear in embryonic development and in fracture repair.
- Temporary, is replaced in adult by lamellar bone.
- Random deposition of type I collagen fibers.
- Lower mineral content.
- Easily penetrated by x-ray.
- Number of osteocytes is relatively high.

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**Histological Classification**

- **Primary = Immature = Woven**
- **Secondary = Mature = Lamellar**
Terms:

- Matrix
- periosteum
- Osteoprogenitor cells (osteogenic cells)
- Osteoblasts
- Osteocytes
- Lacuna
- Osteoclasts
- Canaliculi
- Filopodial process
- Haversian canal, system
- Osteon
- Volkmann canal
- Endosteum
- Osteoid
Bone tissue

Practical part

Dr. Heba Kalbouneh
Associate Professor of Anatomy and Histology
VOLKMANN’S CANAL
Red bone marrow
Trabecular bone
Trabecular Bone H&E

- Adipocytes
- Lamellar bone matrix
- Osteocyte in lacuna
- Calcified cartilage

Dr. Heba Kalbouneh
Red bone marrow
Trabecular bone
A: OSTEOBLAST
B: OSTEOCYTE
C: OSTEOID
D: (Label not visible)
E: OLD BONE

Dr. Heba Kalbouneh
Osteocyte
Osteocytes

Dr. Heba Kalboushel
Identify

A: Osteoclast
B: Osteoblast