BONE TISSUE

Components

Bone matrix

Organic

- Collagen++
- Proteoglycans
- Glycoproteins

Inorganic

Calcium hydroxyapatite +++

Cells

- Osteoblast
- Osteocytes
- Osteoclasts

Functions

- Main constituent of the adult skeleton
- Provides solid support for the body, protects vital organs such as those in the cranial and thoracic cavities,
- Encloses internal (medullary) cavities containing bone marrow.
- Bone tissue also serves as a reservoir of calcium, phosphate, and other ions.

Bone



Bone cells

1. Osteoblast
 2. Osteocytes
 3. Osteoclasts



Cells

- Osteocytes are found in cavities (lacunae) between bone matrix layers (lamellae), with cytoplasmic processes in small canaliculi that extend into the matrix.
- Osteoblasts growing cells which synthesize and secrete the organic components of the matrix
- Osteoclasts which are giant, multinucleated cells involved in removing calcified bone matrix and remodeling bone tissue

Osteoblasts

- Originating from mesenchymal stem cells.
- Produce the organic components of bone matrix
- Located exclusively at the surfaces of bone matrix.
- Active ones are located exclusively at the surfaces of bone matrix (integrins)

Osteoblasts

When their synthetic activity is completed:

- Some osteoblasts differentiate as osteocytes entrapped in matrix-bound lacunae.
- Some flatten and cover the matrix surface as bone lining cells
- The majority undergo apoptosis.

Osteocytes



- Surrounded by the material they secrete and then differentiate as osteocytes.
- Processes in canaliculi 250-300 nm.
 - Osteocytes communicate with one another and with nearby osteoblasts and bone lining cells via gap junctions at the ends of their processes
 - The most abundant cells in bone,
 - Exhibit significantly less RER, smaller Golgi complexes, and more condensed nuclear chromatin than osteoblasts
 - Maintain the calcified matrix, and their death is followed by rapid matrix resorption

Mineralization in bone matrix

Osteoid

Collagen I Glycoproteins proteoglycans

Osteocalcin

Vit. K-dependant polypeptid. Bind ca ²⁺ (with other GPs)

Matrix vesicles.

Alkaline phosphatase. Raises PO4 ^{3–} Formation of hydroxyapatite



Osteoclast

- Very large, motile cells with multiple nuclei.
- Resorption cavities (Howship lacunae)
- Osteoclast's circumferential sealing zone where integrins tightly bind the cell to the bone matrix.
- The sealing zone surrounds a **ruffled border** of microvilli and other cytoplasmic projections close to this matrix.







Periosteum & Endosteum

- External and internal surfaces of all bones
- Periosteum is a dense connective tissue, containing mostly bundled type I collagen, but also fibroblasts and blood vessels
- Type I collagen (Fibrillar collagens types I, II, and III).
- Bone is vascularized by small vessels that penetrate the matrix from the periosteum.
- Endosteum covers all trabeculae around the marrow cavities.

TYPES OF BONE

Type of Bone	Histological Features	Major Locations
Woven bone, newly calcified	Irregular and random arrangement of cells and collagen; lightly calcified	Developing and growing bones; hard callus of bone fractures
Lamellar bone, remodeled from woven bone	Parallel bundles of collagen in thin layers (lamellae), with regularly spaced cells between; heavily calcified	All normal regions of adult bone
Compact bone , ~80% of all lamellar bone	Parallel lamellae or densely packed osteons, with interstitial lamellae	Thick, outer region (beneath periosteum) of bones
Cancellous bone, ~20% of all lamellar bone	Interconnected thin spicules or trabeculae covered by endosteum	Inner region of bones, adjacent to marrow cavities

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Osteon

Osteon (Haversian system):

- Complex of concentric lamellae
- 100-250 µm in diameter
- Surrounding a central canal that
- Contains small blood vessels, nerves, and endosteum

Osteogenesis

- Intramembranous ossification: osteoblasts differentiate directly from mesenchyme
- Endochondral ossification: a preexisting matrix of hyaline cartilage is eroded and invaded by osteoblasts

Intramembranous ossification



Intramembranous Ossification

- Most flat bones form this way (bones of the skull, jaws, scapula and clavicle)
- Within the condensed mesenchyme begins in <u>ossification centers</u>----osteoblasts----woven bone with osteocytes in lacunae and canaliculi.
- The anatomical bone forms gradually as woven bone matrix is replaced by compact bone that encloses a region of cancellous bone with marrow and larger blood vessels.
- Mesenchymal regions that do not undergo ossification give rise to the endosteum and the periosteum.
- The fontanelles or "soft spots" on the heads of newborn infants are areas of the skull in which the membranous tissue is not yet ossified.

Endochondral ossification



Endochondral ossification

- Takes place within hyaline cartilage shaped as a small version of the bone to be formed.
- Forms most bones of the body (well studied in developing long bones).
- First occurs within a bone collar (osteoblasts that differentiate within the perichondrium (transitioning to periosteum)).
- The collar impedes diffusion of oxygen/nutrients into the underlying cartilage--local chondrocytes hypertrophy-- compress the matrix---calcification (osteocalcin and alkaline phosphatase)—death.

Endochondral ossification

- The hypertrophic chondrocytes eventually die, creating empty spaces within the calcified matrix.
- Primary ossification center: blood vessels from the perichondrium (periosteum) penetrate the bone collar--- osteoprogenitor cells---- produce woven bone (first trimester)
- **Secondary ossification centers**: appear later at the epiphyses.

Cartilage remain:

- Articular cartilage: persists through adult life.
- Epiphyseal cartilage (epiphyseal plate or growth plate): connects each epiphysis to the diaphysis--- longitudinal growth.

Proliferative zone:

- The cartilage cells divide---enlarge- matrix release.
- Become organized into columns.

Zone of hypertrophy:

- Contains swollen terminally differentiated chondrocytes.
- Increased vascularization.

Zone of calcified cartilage:

- Chondrocytes about to undergo apoptosis.
- Release matrix vesicles and osteocalcin.
 Zone of ossification:
- Bone tissue first appear
- Capillaries and osteoprogenitor cells invade the vacant chondrocytic lacunae.
- Osteoblasts settle in a layer over the spicules of calcified cartilage matrix and secrete osteoid (becomes woven bone)
- Woven bone is then remodeled as lamellar bone.



Epiphyseal plate

Osteoporosis

- Frequently found in immobilized patients and in postmenopausal women,
- Is an imbalance in skeletal turnover so that bone resorption exceeds bone formation---calcium loss---reduced bone mineral density (BMD).
- Individuals at risk are routinely tested for BMD by dual-energy x-ray absorptiometry (DEXA scans).

Osteopetrosis

- Genetic disease.
- Characterized by dense, heavy bones ("marble bones"),
- The osteoclasts lack ruffled borders and bone resorption is defective.
- Overgrowth and thickening of bones--obliteration of the marrow cavities--depressing blood cell formation---anemia and the loss of white blood cells.

>> MEDICAL APPLICATION

The network of dendritic processes extending from osteocytes has been called a "mechanostat," monitoring areas within bones where loading has been increased or decreased, and signaling cells to adjust ion levels and maintain the adjacent bone matrix accordingly. **Lack of exercise** (or the weightlessness experienced by astronauts) leads to **decreased bone density**, due in part to the lack of mechanical stimulation of these cells.