Lecture Overview

- Introduction to the skeletal system
- Function and classification of bones
- Structure of bones
- Bone development and growth
- Bone homeostasis
- Factors affecting bone growth, development and repair
- Functions of bone

Overview of the Skeletal System

- The human skeleton contains a total of 206 bones
  - 80 Axial
  - 126 Appendicular

- Bone is also called osseous tissue and is a hard (supporting) form of connective tissue composed of two (2) types of bone
  - Compact bone (osteons are the main units)
  - Spongy (cancellous) bone
Skeletal System Functions

• **Support and Protection**
  - gives shape to head, etc.
  - supports body’s weight
  - protects thoracic organs and brain

• **Body Movement**
  - interacts with muscles
  - bones act as rigid bar of a lever

• **Blood Cell Formation**
  - hematopoiesis
  - red marrow

• **Inorganic Salt Storage**
  - calcium
  - phosphate
  - magnesium
  - sodium
  - potassium
  - electrolyte and acid/base balance

Components of Bone

Recall that Bone is a supporting connective tissue with cells and a matrix

• **Cells** (osteo-)

• **Matrix**
  - Organic Component (Osteoid) – approx. 35% (wt.)
    - Fibers = collagen
    - Ground Substance = proteoglycans, glycoproteins
  - Inorganic Component – approx. 65% (wt.)
    - Hydroxyapatites = Ca$^{2+}$ PO$_4^3-$ salts
      (Ca$_{10}$(PO$_4$)$_6$(OH)$_2$)

Cells of Bone Tissue

• **Osteoprogenitor** (osteogenic) – Mesenchymal precursors of osteoblasts

• **Osteoblasts** – mesenchymal-derived; secrete matrix of bone (osteogenesis, i.e., creation of new bone)

• **Osteocytes** - osteoblasts trapped in lacunae (mature cells that maintain bone)

• **Osteoclasts** – monocyte-derived; break down (*eat*) bone (this is called osteolysis)
Structure of a Long Bone

**Epiphyseal plates**

**Proximal epiphysis**

You should be able to label a diagram like this for the exam

**Diaphysis**

**Metaphysis**

**Distal epiphysis**

Compact and Spongy Bone

Each bone in the skeleton contains two forms of osseous tissue:

- **Compact bone** (cortical) – solid (with osteons as structural units); found on outer parts of bone
- **Spongy (cancellous, trabecular) bone** – network of struts and plates (trabeculae); found within the inner parts of bone

Compact Bone

- **Osteon** (Haversian) containing blood vessels and nerves
- **Periosteum**
- **Central canal**
- **Perforating canal**
- **Nerve**
- **Blood vessels**
- **Bone matrix**
- **Canaliculus**
- **Osteocyte**
- **Lacuna (space)**
Periosteum and Endosteum

Periosteum is dense irregular CT, vascular, and supplied with nerves; it aids in growth/repair.

Figure from: Martini, Anatomy & Physiology, Prentice-Hall, 2001

Spongy (Cancellous) Bone

- Spongy bone is NOT arranged in osteons
- Matrix forms struts and plates called trabeculae
- Located where bones are not heavily stressed or stress arrives in different directions
- Lightweight and strong
- Supports and protects cells of the red marrow

Figure from: Martini, Anatomy & Physiology, Prentice-Hall, 2001

Trabeculae of Spongy Bone

Notice how the trabeculae of spongy bone can be seen oriented along lines of mechanical stress applied by the weight of the body.

Figure from: Saladin, Anatomy & Physiology, McGraw Hill, 2007
Bone Growth and Development

Ossification (osteogenesis) – replacement of other tissues with bone (different than calcification)

Bone is formed by replacement of other types of connective tissue in one of two ways:

Intramembranous Ossification
- bones originate within sheetlike layers of fibrous or mesenchymal connective tissues
- broad, flat bones
- skull bones, clavicle (collarbone), mandible
- forms the intramembranous bones

Endochondral Ossification
- bones begin as hyaline cartilage
- most bones of the skeleton
- forms the endochondral bones

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Intramembranous vs. Endochondral Ossification

For Intramembranous and Endochondral Ossification you should know:
1) The starting material for each process
2) Which bones form by each process
Growth at the Epiphyseal Plate

First layer of cells
- proximal end of epiphysis
- resting cells
- anchors epiphyseal plate to epiphysis

Second layer of cells
- many rows of young cells
- undergoing mitosis
- active growth occurs here

Third layer of cells
- older cells
- left behind when new cells appear
- cells enlarging and becoming calcified

Fourth layer of cells
- thin
- dead cells
- calcified intercellular substance

Fractures involving the epiphyseal plate are of great concern.
If not repaired correctly, bone may prematurely stop elongating, or growth may be unequal with respect to the unaffected limb.

Figure from: Hole's Human A&P, 12th edition, 2010
Homeostasis of Bone Tissue

Bone remodeling is a process that continues throughout life, and is accomplished by two processes:

1) Bone Resorption (destruction of bone) – action of osteoclasts and parathyroid hormone (PTH)
2) Bone Deposition (creation of bone) – action of osteoblasts and calcitonin

Factors Affecting Bone Remodeling, Growth, and Repair

- Mineral salts, especially Calcium and Phosphorus
- Vitamins A, C, and D
  - Deficiency of Vitamin A – retards bone development
  - Deficiency of Vitamin C – results in fragile (brittle) bones
  - Deficiency of Vitamin D – rickets, osteomalacia
- Growth factors and Hormones
  - Sex Hormones – promote bone formation; stimulate ossification (closure) of epiphyseal plates
  - Insulin-like growth factors (IGFs) – stim. by hGH
  - Insufficient Growth Hormone – pituitary dwarfism
  - Excessive Growth Hormone – gigantism, acromegaly
  - Insufficient Thyroid Hormone – delays bone growth
- Physical Stress (exercise) – stimulates bone growth

Bone is an Inorganic Salt Reservoir

Hydroxyapatite = Ca$^{10+}$ salts [Ca$_{10}$(PO$_4$)$_6$(OH)$_2$]
Calcium Homeostasis

Parathyroid hormone (PTH) $\uparrow$ blood calcium

Calcitonin $\downarrow$ blood calcium

Blood Cell Formation

- **Hematopoiesis** is the process of blood cell formation (also called ‘hemopoiesis’)

  - At different points in development, hematopoiesis takes place in the:
    - Yolk sac (embryo)
    - Liver and spleen (fetus)
    - Red bone marrow (fetus, newborn, and adult)
Blood Cell Formation Takes Place in the Red Bone Marrow

- **Red marrow** functions in development of
  - **Myeloid cells** - red blood cells, platelets, eosinophils, basophils, neutrophils, and monocytes
  - **Lymphocytic cells** – T lymphocytes and B lymphocytes

- **Adult red marrow** is primarily found in the spongy bone of the skull, ribs, sternum, clavicles, vertebrae, pelvis, and epiphyses of long bones

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Bone Mass in Men vs. Women

![Graph showing the comparison of bone mass in men and women over age](www.arc.org.uk/.../6028/images/6028_3.gif)

Osteoporosis

![Image of osteoporosis](http://www.usbjd.org/projects/images/The%2520Progression%2520of%2520Osteoporosis.jpg)

[Figures from: Martini, Anatomy & Physiology, Prentice-Hall, 2001]
Bone Fractures

A greenstick fracture is incomplete, and the break occurs on the convex surface of the bone in the bone.

A comminuted fracture is complete and fragments the bone.

A fissured fracture involves an incomplete longitudinal break.

A transverse fracture is complete, and the break occurs at a right angle to the axis of the bone.

An oblique fracture occurs at an angle other than a right angle to the axis of the bone.

Healing of Fractures

1. Hematoma forms.
2. Hematoma is converted to fibrous tissue and cartilage.
3. Fibrocartilaginous callus forms.
4. Bony callus forms.
5. Bony callus of spongy bone.
6. Healed fracture.
7. Bone remodeling occurs.