Bone
What is bone?

- Specialized form of connective tissue: mineralized collagen matrix, therefore very rigid and strong while still retaining some degree of flexibility.

- Other types of connective tissue:
  - Cartilage: semi-rigid form, glycoprotein rich.
  - Ligaments: flexible bands, rich in collagen fibers, contribute to stability of the joint.
  - Tendons: strong flexible bands, rich in collagen fibers, connect muscles with bone.
Function of bone

- Support
- Protection (Skull)
- Mineral storage (e.g. calcium homeostasis)
- Hematopoiesis (bone marrow - postnatal)
- Locomotion - muscular-skeletal system
- Hearing
The Skeletal System

Parts of the skeletal system

· Bones (skeleton)
· Joints
· Cartilages
· Ligaments (bone to bone) (tendon = bone to muscle)
· Divided into two divisions
· Axial skeleton
· Appendicular skeleton – limbs and girdle
Bone, as an organ

- Endoskeleton
  - axial
    - cranium
    - spine
    - ribs
  - appendicular
    - pectoral girdle
    - pelvic girdle
Bones of the Human Body

The skeleton has 206 bones

- Two basic types of bone tissue
- Compact bone
  - Homogeneous
- Spongy bone
  - Small needle-like pieces of bone
  - Many open spaces
Classification of Bones

Long bones

- Typically longer than wide
- Have a shaft with heads at both ends
- Contain mostly compact bone

• Examples: Femur, humerus
Classification of Bones

Short bones

- Generally cube-shape
- Contain mostly spongy bone
  - Examples: Carpals, tarsals
(a) Long bone
(e.g., humerus of arm)

(b) Short bones
(e.g., carpals of wrist)

(c) Flat bone
(e.g., parietal bone of skull)

(d) Irregular bone
(e.g., vertebra)

Figure 5.1
Classification of Bones

Flat bones

- Thin and flattened
- Usually curved
- Thin layers of compact bone around a layer of spongy bone

Examples: Skull, ribs, sternum
Classification of Bones

Irregular bones

• Irregular shape
• Do not fit into other bone classification categories

• Example: Vertebrae and hip
Gross Anatomy of a Long Bone

Diaphysis
- Shaft
  - Composed of compact bone

Epiphysis
- Ends of the bone
  - Composed mostly of spongy bone
Structures of a Long Bone

Periosteum
- Outside covering of the diaphysis
- Fibrous connective tissue membrane

Sharpey’s fibers
- Secure periosteum to underlying bone

Arteries
- Supply bone cells with nutrients
Articular cartilage
- Covers the external surface of the epiphyses
- Made of hyaline cartilage
- Decreases friction at joint surfaces
Structures of a Long Bone

Medullary cavity
- Cavity of the shaft
- Contains yellow marrow (mostly fat) in adults
- Contains red marrow (for blood cell formation) in infants
Components of Bone

- **Cortical bone** - Structural
- **Trabecular bone** - Structural
- **Bone Marrow** - Structural and RBC production
- **Vessels** - Nutritional
- **Nerves** – Trophical, Functional
Cortical Bone

- Compact Bone
- Shell around vertebral body (and all other bones)
- 1mm thick on sides
- 0.5mm thick on inferior/superior ends
  - Endplates
- 80% Bone Mass
- 20% Bone Surface
Cortical Bone

- **Osteon (Harvesian Canals)**
  - Cylindrical tubes made of concentric lamellae
  - Central opening
    - Blood vessels
    - Neural tissue
    - Lymphatic

- **Periosteum**
  - Fibrous tissue covering
  - Enables attachment of muscles and tendons
Cortical bone

- **Lamellae**
  - Concentric layers of mineralized bone
  - Crisscross pattern at 90°
  - Torsion and bending strength

- **Osteoclasts**
  - Bone resorbing

- **Osteoblasts**
  - Bone forming

Fung 1993
Trabecular Bone

- Cancellous or Spongy
- Lattice structure
- Pores filled with marrow
- 20% Bone Mass
- 80% Bone Surface

(White 1978)
Trabecular Structure

- Plate and rod structure
  - Low loads - rod
  - Higher loads - plate
- Light yet spongy
- Oriented in direction of loads
  - “Wolff’s Law”
Femur Structure
Wolff’s Observations

Changes in trabecular structure after fracture in the femur
Bone Marrow

Consists of stroma, myeloid tissue, fat, lympatic tissues

**Red marrow**
- Involved with the production of RBC
- Consists of haemopoetic tissue
- Highly vascularized

**Yellow marrow**
- Not as vascularized as red marrow
- Large amount of fat cells
- Percentage increases wrt red marrow with age (up to 20yrs)
Mechanisms of bone formation

• **Membranous ossification:**
  flat bones of the skull, clavicle, periosteum
  **how:** direct differentiation of cells within mesenchymal condensations into bone forming cells (osteoblasts)

• **Endochondral ossification:**
  endochondral bones: axial and appendicular skeleton, some bones in the skull
  **how:** replacement of a cartilagenous template by bone
Membranous bone formation
Endochondral Ossification

Diagram depicting the stages of endochondral ossification:
1. Mesenchyme
2. Cartilage
3. Hypertrophic chondrocytes
4. Osteoblasts (bone)
5. Blood vessel
6. Proliferating chondrocytes
7. Epiphyseal cartilage
8. Growth plate
9. Bone marrow
10. Bone
11. Secondary ossification center
Types of bone cells involved in bone homeostasis

- **osteoblasts**
  bone forming cells

- **osteocytes**
  terminal differentiated osteoblast

- **osteoclasts**
  bone resorbing cells
How do cells look?

**Osteoblast**
- mononucleated
- positive for AP (alkaline phosphatase)

**Osteocyte**
- mononucleated
- trapped within lacunae
- serve as mechanosensors

**Osteoclast**
- multinucleated
- positive for TRAP (tartrate-resistant alkaline phosphatase)
Origin of bone cells

- Osteoblasts: mesenchymal
  - e.g. the first ob differentiate within the periosteum and form the bone collar
  - postnatal: bone marrow

- Osteocytes: mesenchymal, terminal differentiated ob

- Osteoclasts: hematopoietic lineage; bone marrow
Postnatal bone cell differentiation
Bone changes with age

Vertebral body of a young person

Vertebral body of an elderly person
Outside factors affecting bone mass

- **Exercise**: muscle contractions stimulate osteoblast function - increased production of bone peak bone mass reached at the age of 30
- **Body weight**: obesity can protect from osteoporotic bone loss
- **Diet affects bone**: minerals and vitamins
- **Menopause in women**: decrease in hormone level can lead to osteoporosis (treatment: HRT)
Changes in bones

• osteopenia:
  (mild)

  Cause: osteoblasts are not active enough and/or osteoclasts are too active

• osteoporosis:
  (severe)

  Cause: osteoblasts are not active enough

• osteopetrosis:

  Cause: osteoclast deficiency or no active OC

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Congenital bone disorders

- Achondroplasia (Fgfr3 act. mutations)
  Dwarfism

- Osteogenesis Imperfecta
  (brittle bones; prenatal form of osteoporosis)

- Marfan syndrome
  (skeletal overgrowth, lengthening of long bones; mutations in Fibrillin gene)

- Osteochondromatosis
  (multiple exostoses)
Terminology of changes in bone

osteopenia: decreased calcification or density of bone
osteoporosis: progressive reduction in quantity of bone
osteopetrosis: excessive formation of dense trabecular bone
osteosclerosis: abnormal hardening or eburnation of bone
osteohypertrophy: overgrowth of bone
osteosarcoma: tumor of the bone
osteochondrodysplasia: extreme bending of long bones
osteochondroma (exostosis): benign cartilaginous neoplasm
osteoblastoma: benign tumor of osteoblasts