OSSEOUS TISSUE & BONE STRUCTURE
PART I: OVERVIEW & COMPONENTS

The Skeletal System
• Skeletal system includes:
  - bones of the skeleton, cartilages, ligaments, and connective tissues

What are the functions of the skeletal system?

Functions of the Skeletal System
• Support
• Storage of minerals (calcium)
• Storage of lipids (yellow marrow)
• Hematopoeisis (red marrow)
• Protection
• Leverage (force of motion)

Bone Shapes
• Long bones
  • Arms, legs, hands,...
• Flat bones
  • Skull, sternum,...
• Sutural bones
  • In sutures of skull
• Irregular bones
  • Vertebrae, pelvis, ...
• Short bones
  • Ankle, wrist, ...
• Sesamoid bones
  • patella

Bone Markings
• Depressions or grooves:
  - along bone surface
• Projections:
  - where tendons and ligaments attach
  - at articulations with other bones
• Tunnels:
  - where blood and nerves enter bone
Long Bones
- Diaphysis:
  - the shaft
- Epiphysis:
  - wide part at each end
  - articulation with other bones

The Diaphysis
- A heavy wall of compact bone
- A central space called marrow cavity
- Marrow cavity is filled with yellow marrow

The Epiphysis
- Mostly spongy (cancellous) bone
- Surrounded by compact bone

Flat Bones
- Resembles a sandwich of spongy bone
- Between 2 layers of compact bone
Bone (Osseous) Tissue
• Dense, supportive connective tissue
• Contains specialized cells
• Produces solid matrix of calcium salt deposits (inorganic components)
• Around collagen fibers (organic components)

Components of Bone
• Organic Components (tensile strength)
  - flexibility and tensile strength
  - Collagen Fibers “rebar” (95%) along force lines
  - 5-10% ground substance (proteoglycans)
• Inorganic Components (compression strength)
  - hardness of bone
  - Hydroxyapatite $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$
  - Calcium phosphate - $\text{Ca}_3(\text{PO}_4)_2$
  - Calcium hydroxide - $\text{Ca}($OH$)_2$
  - Calcium carbonate - $\text{CaCO}_3$
  - Magnesium, sodium, fluoride, ...

Periosteum
Membrane that covers the outside of bones.
• Covers all bones, except parts in joint capsules
• Collagen fibers of the periosteum:
  - connect with collagen fibers in bone
  - and with fibers of joint capsules, attached tendons, and ligaments

Endosteum
Membrane that covers the inside of bones.
• Lines the marrow cavity, central canals

Osteocytes
• Mature bone cells that maintain the bone matrix
  - Live in lacunae between lamellae
  - Connect by cytoplasmic extensions through canaliculi in lamellae

Homeostasis
• Bone building (by osteocytes) and bone recycling (by osteoclasts) must balance:
  - more breakdown than building, bones become weak
What is the difference between compact bone and spongy bone?

Compact Bone
Osteon = Haversion System
• The basic unit of mature compact bone
  - central canal - contains blood vessels
  - lamellae (concentric) - contains bone matrix
  - lacunae - each contains an osteocyte
  - canaliculi - contain nutrients for osteocytes
  - Volkmann canals - contains blood vessels
• Arranged parallel to direction of stress

Spongy Bone
• Open network of trabeculae (scaffolding) arranged along the axis of force
• The space between trabeculae is filled with red bone marrow:
  - which has blood vessels
  - forms red blood cells
  - and supplies nutrients to osteocytes
Weight-Bearing Bones

• The femur transfers weight from hip joint to knee joint:
  - causing tension on the lateral side of the shaft
  - and compression on the medial side

Ossification

• The 2 main forms of ossification are:
  - Endochondral ossification “inside cartilage”
  - Intramembranous ossification “between membranes”

Endochondral Ossification

• Ossifies bones that originate as hyaline cartilage
• Occurs at epiphyseal plates/lines
• Most bones originate as hyaline cartilage

Endochondral Ossification: Steps 5 & 6

5. Capillaries and osteoblasts enter the epiphyses:
   - creating secondary ossification centers
6. Epiphyses fill with spongy bone:
   - cartilage within the joint cavity is articulation cartilage
   - cartilage at the metaphysis is epiphyseal cartilage (growth plate)

Endochondral Ossification

Epiphyseal cartilage

• Diaphysis side:
  - Osteoblasts invade the cartilage and replace it with bone
• Epiphysis side:
  - Chondroblasts make new cartilage

Epiphyseal Plates & Lines

• When long bone stops growing, after puberty:
  - epiphyseal cartilage disappears and is visible on X-rays as an epiphyseal line
Intramembranous Ossification
- Formation of flat bones and some other bones.
- No cartilage ‘model’ used
- Forms from an ossification center
- Skull bones grow with brain (max ~10 yrs)
- Facial bones continue until the end of growth

There are 3 main steps in intramembranous ossification...

Intramembranous Ossification Steps
1. Ossification center forms:
   - Mesenchymal cells differentiate into osteoblasts
2. Blood vessels grow into the area:
   - to supply the osteoblasts
3. Spongy bone develops and is remodeled into:
   - osteons of compact bone
   - periosteum
   - or marrow cavities
Remodeling

- The adult skeleton: maintains itself and replaces mineral reserves
- Remodeling: recycles and renews bone matrix
  - involves osteocytes, osteoblasts, and osteoclasts

Increase/Decrease Bone

- Exercise
  - Heavily stressed bones become thicker and stronger
- Inactivity (bed rest)
  - Up to 1/3 of bone mass can be lost in a few weeks of inactivity
- Space flight

Vitamins & Minerals

- Vitamins
  - Vitamin C is required for collagen synthesis, and stimulates osteoblasts
  - Vitamin A stimulates osteoblast activity
  - Vitamins K and B₁₂ help synthesize bone proteins
- Minerals
  - Calcium, phosphate salts, magnesium, fluoride, iron, and manganese

Blood Calcium Homeostasis

- Parathyroid Hormone
  - made by the Parathyroid Gland
  - increases blood calcium levels
  - Primary means of calcium regulation
- Calcitonin
  - made by the thyroid gland
  - decreases blood calcium levels
  - promotes calcium storage (bone) and/or removal (kidney)

The Skeleton as Calcium Reserve

- Bones store calcium and other minerals
- Calcium is the most abundant mineral in the body
Hormones that affect bone

- Growth Hormone
  - promotes bone development
- Pathology
  - Giantism
  - Pituitary dwarfism
  - Acromegaly

Hormones that affect bone

- Growth Hormone
  - promotes bone development
- Androgens
  - promotes bone development
- Cortisol (stress hormone)
  - increase osteoclast activity
- Thyroxine (thyroid hormone)
  - increases osteoblast activity, and collagen synthesis
- Calcitriol:
  - is made in the kidneys with vitamin D₃ (cholecalciferol)
  - helps absorb calcium and phosphorus from digestive tract

**KEY CONCEPTS**

- Calcium and phosphate ions in blood are lost in urine
- Ions must be replaced to maintain homeostasis
- If not obtained from diet, ions are removed from the skeleton, weakening bones
- Exercise and nutrition keep bones strong
What how do bone fractures heal?

Fractures

- Fractures:
  - cracks or breaks in bones
  - caused by physical stress
- Fractures are repaired in 4 steps

Fracture Repair Steps

1. Bleeding:
   - produces a clot (fracture hematoma)
   - establishes a fibrous network
2. Cells of the endosteum and periosteum create calluses to stabilize the break:
   - external callus of cartilage and bone surrounds break
   - internal callus of spongy bone develops in marrow cavity
3. Osteoblasts:
   - replace central cartilage of external callus
   - with spongy bone
4. Osteoblasts and osteocytes remodel the fracture for up to a year:
   - reducing bone calluses