Bone Tissue

Bone Tissue Function
- Support: for soft tissues and body with attachments for muscles
- Protection: armor over internal organs
- Movement: leverage and points on which muscles can act
- Mineral homeostasis: calcium and phosphorus stored in bone act as source for other cells
- Blood cell production: in red marrow
- Energy storage: triglycerides in yellow marrow

General Structure
- Diaphysis
- Epiphyses
- Metaphyses & epiphyseal plate (bone growth)
- Articular cartilage - hyaline
- Periosteum - dense irregular connective tissue, for bone growth & repair
- Medullary cavity
- Endosteum - bone growth

Histology of Bone
- Mature tissue consists of widely separated cells in matrix (25% water, 25% protein fibers, 50% mineral salts)
- Four cell types
  - Osteoprogenitor/osteogenic cells: mitotic precursor cells in periosteum and endosteum
  - Osteoblasts: secrete collagen and create matrix
  - Osteocytes: osteoblasts that are isolated by matrix, maintain matrix
  - Osteoclasts: break down matrix

More Histology
- Minerals salts primarily hydroxyapatite ($\text{Ca}_3(\text{PO}_4)_2\cdot(\text{OH})_2$) & some calcium carbonate
- Crystalization of salts in collagen fibers called calcification or mineralization
- Salts give bone its hardness, collagen its flexibility, together its tensile strength
- Distribution of space between hard components determines type...compact or spongy

Compact Bone
- At least a thin layer covers spongy bone, but primary type in diaphysis
- Supports body weight and resists stress
- Organized into Haversian systems (osteons) with interstitial lamellae between
  - Outer and inner circumferential lamellae
Parts include Haversian (central) canal, perforating canals (both for blood vessels & nerves), lacunae (for osteocytes), and canaliculi (for exchange of nutrients and wastes)
  – Orientation related to bone stress

**Spongy Bone**
- Most of the structure of short, flat, irregular bones and epiphyses of long bones
- Provides marrow storage and some support
- Irregular arrangement of lamellae forming latticework of trabeculae
  – Orientation related to stress
- Intermixed with red marrow
- Nutrient and waste exchange direct into marrow from canaliculi

**Blood Supply**
- Major vessel enters as nutrient artery through nutrient foramen, send branches to Haversian system, and ends in medullae
  – Some bones have more than one e.g. femur
- Periosteal arteries return to outside of bone (periosteum)
- Metaphseal artery
- Epiphyseal artery - vessels that enter proximal and distal ends
- Nerves follow similar path

**Bone Formation**
- Ossification or osteogenesis
- Mesenchymal cells → osteoprogenitors → osteoclasts and osteoblasts
- Two types of ossification (osteogenesis)
  – Intramembranous: → osteoblast in fibrous tissue
  – Endochondral: → chondroblast → chondrocyte → then osteoblast in cartilage

**Intramembranous**
- Typical of portions of skull, mandible, and clavicle
- Osteoblasts secrete matrix themselves becoming osteocytes
- Osteocytes deposit mineral salts (calcification)
- Trabeculae structure similar to spongy bone, spaces vascularized, ultimately becoming marrow
- Periosteum layer forms which reorganizes surface to compact bone

**Endochondral**
- Formation of most long bones
- Development of hyaline cartilage “model” through
  – Interstitial growth: internal chondrocytes dividing and producing more cartilage
  – Apositional growth: peripheral chondroblasts from perichondrium add cartilage
– Internal chondrocytes hypertrophy & burst, changing pH and causing calcification; they die due to lack of nutrients, leaving lacunae

**More Endochondral**

– Penetration by nutrient artery, osteoprogenitors now form osteoblasts in previous perichondrium, forming periosteal bone collar

• Formation of primary ossification center
  – Periosteal bud (osteoblasts, clasts and marrow cells) grow inward due to vascularization, spongy bone replaces calcified cartilage, medullary cavity formed by osteoclasts, outer region reformed into compact bone

**Even More Endochondral**

• Formation of secondary ossification center
  – Entrance of epiphyseal arteries begins process
  – Cartilage replacement similar to primary, but some cartilage remains as articular cartilage and epiphyseal plate, no cavity forms, and change is outward

**Bone Growth**

• Length growth occurs at epiphyseal plate where cartilage continues to grow
  – Four zones: resting, proliferating, hypertrophic and calcified

• Appositional growth occurs under the periosteum forming new osteons around periosteal vessels

**More Bone Growth**

• Growth controlled by hormones
  – Insulin-like growth factors (IGFs) from bone/liver promote cell division and protein synthesis
  – Human growth hormone (hGH) (ant. pituitary) regulates IGF production
  – Thyroid hormones and a variety of nutrients needed
    • Ca, P, F, Mg, Fe, Mn
    • Vitamins C,K, B₁₂ for protein syn., A for osteoblast activity
  – At puberty, sex hormones (estrogen/androgen) affect growth spurt and skeletal modifications
    • Estrogen ultimately closes epiphyseal plate

**Remodeling**

• Process of adding/altering bone structure under mechanical stress, replacing worn or injured bone, or during normal growth
  – Distal portion of femur every 4 months

• Osteoclasts tear down by secreting a protein-digesting enzyme and acid to lower regional pH, and by phagocytizing remnants

• Osteoblasts rebuild

**Bone Repair**

• Formation of clot (fracture hematoma), absence of blood causes cell death, inflammation

• Fibroblasts responsible for production of granulation tissue (procallus)
• Chondroblasts form fibrocartilaginous callus
• As vascularization occurs, osteoblasts form bony callus of spongy bone
• Remodeling

**Source of Calcium**

• Bone stores 99% of body’s calcium
• Fundamentally important to muscle contraction, nerve function, blood clotting and as enzyme co-factor
• Control of calcium blood levels
  – Too low: release of parathyroid hormone (PTH)
  – Too high: release of calcitonin (CT) from thyroid

**Osteoporosis**

• Decrease in bone mass
• Decline in sex hormones reduces osteoblast activity
• Cause shrinkage of backbone, height loss, hunched backs, and fractures
• Exercise and diet are important preventive measures
• For post-menopausal women, estrogen replacement therapy or alternative, calcium supplements, and weight-bearing exercise