Bone (Osseous tissue)
Functions of the skeletal system

• Structural support
• Mineral storage & lipids (yellow marrow)
• Blood cell formation (red marrow)
• Protection of organs
• Leverage for muscles
Composition of bone

• Calcium (Ca) accounts for much of the bone mass.
• The Ca crystals give bone its strength
  – Hydroxyapatite, $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$

Collegen fibers give bones its flexibility

These two give bone its unique properties
Composition of Bone

- Calcium: 39%
- Potassium: 0.2%
- Sodium: 0.7%
- Magnesium: 0.5%
- Carbonate: 9.8%
- Phosphate: 17%

Total inorganic components: 67%

Amount in bone as percentage of the total amount in the body

- Calcium: 99%
- Potassium: 4%
- Sodium: 35%
- Magnesium: 50%
- Carbonate: 80%
- Phosphate: 88%
The organic compounds need a nutrient supply.
Cells of bone

- Osteoprogenitor cells - mesenchymal cells
- Osteoblasts - (secretes bone matrix)
- Osteocytes (former osteoblasts that are trapped in the matrix they secreted)
• Osteoclast- cells that release acids to degrade bone (mechanism to release Ca into the blood)

• Osteoblasts & osteoclasts –regulate Ca levels in the blood.
Two types of bone

- Compact bone - dense and solid
- Spongy bone - open framework

- Both types found in most bones of the body
- Same chemical composition
- Spongy bone is deep to the compact bone
Compact bone

- **Osteon** - structural unit of compact bone
- **Three types of lamelle:**
  - Interstitial-between osteons
  - Concentric-rings
  - Circumferential-outer edge
Compact Bone (100x)
Spongy bone

- **Trabeculae** - pieces that form the framework of spongy bone

- Light weight but still strong
Cancellous (Spongy) Bone (100x)
Articular surface of head of femur
Trabeculae of spongy bone
Cortex
Marrow cavity
Compact bone
(c) Epiphysis, sectional view

Fig 5.3
Periosteum & endosteum

- **Periosteum** - a thick connective tissue membrane on the surface of bone
- Not on the articular (joint) surface
- Like pantyhoses over a leg

- **Endosteum** - membrane covering the trabeculae & medullary cavity of bone
Six classes of bone based on shape

- **Long**- humerus, radius, tibia
- **Short**- cube shaped bones, carpal & tarsal
- **Flat**- sternum, ribs, parietal
- **Irregular**- odd shapes, bones of the face and vertebrae
- **Suture**- small bones filling in the space between skull bones
- **Sesamoid**- patella
Fig 5.13

(a) Long bone

(b) Short bones

Carpal bones
• Average person 206 bones
• extra sesamoid bones + suture bones= ??
Bone development

- Two mechanisms of bone development (ossification):
  - Intramembranous ossification
  - Endochondral ossification
Intramembranous ossification

• During growth bone tissue replaces connective tissue proper (dermis)
• Flat & sesamoid bones develop this way
• Causes appositional growth-increase in the width of a bone
(b) Appositional growth and remodeling
Step 1: Mesenchymal cells aggregate, differentiate into osteoblasts, and begin the ossification process. The bone expands as a series of spicules that spread into surrounding tissues. (LM × 32)

Step 2: As the spicules interconnect, they trap blood vessels within the bone. (LM × 32)

Step 3: Over time, the bone assumes the structure of spongy bone. Areas of spongy bone may later be removed, creating marrow cavities. Through remodeling, spongy bone formed in this way can be converted to compact bone.
Endochondral ossification replaces cartilages of embryonic skull

Intramembranous ossification produces the roofing bones of the skull

Primary ossification centers of the diaphyses (bones of the lower limb)

Future hip bone
Endochondral ossification

- During growth bone tissue replaces hyaline cartilage
- Long bones develop this way
- Causes appositional growth &
- **interstitial growth**- increase in bone length
basic outline

step 1
• Mesenchyme>chondroblasts>chondrocytes>cartilage

step 2
• Swelling of chondrocytes>chondrocytes die>blood vessels grow into the lacunae>osteoblasts>bone
**Step 1:** As the cartilage enlarges through appositional and interstitial growth, chondrocytes near the center of the shaft increase greatly in size. The matrix is reduced to a series of small struts that soon begin to calcify. The enlarged chondrocytes then die and disintegrate, leaving cavities within the cartilage.

**Step 2:** Blood vessels grow around the edges of the cartilage, and the cells of the perichondrium convert to osteoblasts. The shaft of the cartilage then becomes ensheathed in a superficial layer of bone.

**Step 3:** Blood vessels penetrate the cartilage and invade the central region. Fibroblasts migrating with the blood vessels differentiate into osteoblasts and begin producing spongy bone at a primary ossification center. Bone formation then spreads along the shaft toward both ends.

**Step 4:** Remodeling occurs as growth continues, creating a marrow cavity. The bone of the shaft becomes thicker, and the cartilage near each epiphysis is replaced by shafts of bone. Further growth involves increases in both length (Steps 5-6) and diameter (Fig. 5.9).

(a) Steps in endochondral ossification
Step 5: Capillaries and osteoblasts migrate into the epiphyses to create secondary ossification centers.

Step 6: Soon each epiphysis is filled with spongy bone. An articular cartilage remains exposed to the joint cavity; over time it will be reduced to a thin superficial layer. At each metaphysis, an epiphyseal cartilage separates the epiphysis from the diaphysis.

(b) Light micrograph of an epiphyseal cartilage
Primary ossification center is the diaphysis

Secondary ossification center is the epiphyses

Epiphyseal line/plate
Endochondral ossification replaces cartilages of embryonic skull.

Intramembranous ossification produces the roofing bones of the skull.

Primary ossification centers of the diaphyses (bones of the lower limb).

Future hip bone.

(a)

(b)
(a) Epiphyseal cartilages

(b) Epiphyseal lines
Bone growth regulation

- Dietary source of Ca & vitamins A, C, & D

- Hormones (endocrine system):
  - Parathyroid hormone-increase Ca uptake
  - Calcitonin-increase Ca loss in urine
  - Growth hormone & Thyroxine-stimulate bone growth
Fracture

Fig 5.11

Step 1: Immediately after the fracture, extensive bleeding occurs. Over a period of several hours, a large blood clot, or fracture hematoma, develops.

Step 2: An internal callus forms as a network of spongy bone unites the inner surfaces, and an external callus of cartilage and bone stabilizes the outer edges.

Step 3: The cartilage of the external callus has been replaced by bone, and struts of spongy bone now unite the broken ends. Fragments of dead bone and the areas of bone closest to the break have been removed and replaced.

Step 4: A swelling initially marks the location of the fracture. Over time, this region will be remodeled, and little evidence of the fracture will remain.

Compound fracture - breaks the skin

Simple fracture - internal bone injury
A **Pott's fracture** occurs at the ankle and affects both bones of the leg.

**Comminuted fractures**, such as this fracture of the femur, shatter the affected area into a multitude of bony fragments.

**Transverse fractures**, such as this fracture of the ulna, break a shaft bone across its long axis.

**Spiral fractures**, such as this fracture of the tibia, are produced by twisting stresses that spread along the length of the bone.

**Displaced fractures** produce new and abnormal bone arrangements; **nondisplaced fractures** retain the normal alignment of the bones or fragments.
A Colles’ fracture, a break in the distal portion of the radius, is typically the result of reaching out to cushion a fall. In a greenstick fracture, such as this fracture of the radius, only one side of the shaft is broken, and the other is bent. This type of fracture generally occurs in children, whose long bones have yet to ossify fully.

Epiphyseal fractures, such as this fracture of the femur, tend to occur where the bone matrix is undergoing calcification and chondrocytes are dying. A clean transverse fracture along this line generally heals well. Unless carefully treated, fractures between the epiphysis and the epiphyseal cartilage can permanently stop growth at this site.

Compression fractures occur in vertebrae subjected to extreme stresses, such as those produced by the forces that arise when you land on your seat in a fall.
Lab 6
Proximal epiphysis

diaphysis

Distal epiphysis

Articular surface of head of femur

Spongy bone

Compact bone

Marrow cavity

Posterior view

Sectional view

(a) Femur
Compact Bone (100x)
Cancellous (Spongy) Bone (100x)
Dense regular CT

- Fibroblast
- Collagen
Intramembranous Ossification (100x)

Intramembranous ossification produces flat bones of the skull. This ossification process begins with mesenchyme forming a sheet of tissue with a large supply of blood vessels. Eventually osteogenic cells give rise to osteoblasts which form spongy bone first and eventually both spongy bone and compact bone.
Endochondral ossification