Bone Histology & Fracture Healing
Connective Tissue:

Fibro-cartilage

Cartilage (continued)

(i) Fibrocartilage

Description: Matrix similar but less firm than in hyaline cartilage; thick collagen fibers predominate.

Function: Tensile strength with the ability to absorb compressive shock.

Location: Intervertebral discs; pubic symphysis; discs of knee joint.
Tendons
Dense Regular

Connective tissue proper: Dense connective tissue (e and f)

(e) Dense regular connective tissue

Description: Primarily parallel collagen fibers; a few elastin fibers; major cell type is the fibroblast.

Function: Attaches muscles to bones or to muscles; attaches bones to bones; withstands great tensile stress when pulling force is applied in one direction.

Location: Tendons, most ligaments, aponeuroses.
Hyaline Cartilage

- Provides support, flexibility, and resilience
- Is the most abundant skeletal cartilage
- Is present in these cartilages:
  - Articular – covers the ends of long bones
  - Costal – connects the ribs to the sternum
  - Respiratory – makes up the larynx and reinforces air passages
  - Nasal – supports the nose
HYALINE CARTILAGE

A The chondrocytes are located in C lacunae
B The matrix contain collagen fibers that are so fine they are not visible in tissue preparations.
Hyaline cartilage
Histology of bone tissue

Cellularity
4 cell types make up osseous tissue
   Osteoprogenitor
   Osteoblasts
   Osteocytes
   Osteoclasts

Supportive Connective Tissue

Extracellular Matrix
   25% Water
   25% Protein or organic matrix
      95% Collagen Fibers
      5% Chondroitin Sulfate
   50% Crystalized Mineral Salts
      Hydroxyapatite (Calcium Phosphate)
      Other substances: Lead, Gold,
      Strontium, Plutonium, etc.
Cells of Bone Tissue

- **Osteogenic cell** (develops into an osteoblast)
- **Osteoblast** (forms bone tissue)
- **Osteocyte** (maintains bone tissue)
- **Osteoclast** (functions in resorption, the destruction of bone matrix)

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Osteo-progenitor cells:

- derived from mesenchyme
- bone connective tissue is derived from
  - unspecialized stem cells
  - Undergo mitosis and develop into **Osteoblasts**
  - found on inner surface of periosteum and endosteum.
Osteoblasts:
- Large cell responsible for the synthesis and mineralization of bone (bone forming cells) during both initial bone formation and later bone remodeling.
  - found on surface of bone form a closely packed sheet
  - no ability to mitotically divide
  - collagen secretors
They arise from the differentiation of osteogenic cells in the periosteum, the tissue that covers the outer surface of the bone, and in the endosteum of the marrow cavity.

Osteocytes:
- mature bone cells
- derived form osteoblasts
- do not secrete matrix material
- cellular duties include exchange of nutrients and waste with blood.
Osteoblasts:
Osteoclasts
- bone resorping cells found in pits in the bone surface which are called resorption bays, or Howship's lacunae.
- growth, maintenance and bone repair
  - Osteoclasts are large multinucleate cells differentiate from another type of cell called a macrophage.
  - Osteoclasts are formed by the fusion of many cells derived from circulating monocytes in the blood.
Types of Bone tissue:

- **Woven bone** – Irregular – immature – fetus/#
- **Lamellar bone** – regular – mature.

- Circumferential
- Concentric
- Interstitial
- Trabecular

- **Compact & Spongy** – lamellar bone
- Enchondral / intramembranous formation.
Called lamellar bone (groups of elongated tubules called lamella)

- *It is arranged in units called *osteons* (The *Haversian systems*).
- Osteons contain blood vessels, lymphatic, nerves – blood vessels and nerves penetrate periosteum through horizontal openings called perforating (Volkmann’s) canals.
- Surrounding this canal are concentric rings of osteocytes along with the calcified matrix.
Histology of Bone Tissue

Canaliculi
Concentric lamellae
Osteon
Interstitial lamellae
Inner circumferential lamella
Blood vessels
Lymphatic vessel
See Figure 6.3b,c for details

Medullary cavity
Trabeculae
Spongy bone

(a) Osteons (Haversian systems) in compact bone and trabeculae in spongy bone
- Osteons are aligned in the same direction along lines of stress. These lines can slowly change as the stresses on the bone changes.
- Central (Haversian) canals run longitudinally.
- Around canals are concentric lamella
- Osteocytes occupy lacunae (“little lakes”) which are between the lamella
- Radiating from the lacunae are channels called canaliculi. (finger like processes of osteocytes)
Histology of Compact Bone

- Osteon is concentric rings (lamellae) of calcified matrix surrounding a vertically oriented blood vessel
- Osteocytes are found in spaces called lacunae
- Osteocytes communicate through canaliculi filled with extracellular fluid that connect one cell to the next cell
- Interstitial lamellae represent older osteons that have been partially removed during tissue remodeling
Trabeculae are thin plates of bone called trabeculae oriented along lines of stress.
Spaces in between these struts are filled with red marrow where blood cells develop.
Found in ends of long bones and inside flat bones such as the hipbones, sternum, sides of skull, and ribs.

No true Osteons.
**BONE FORMATION**

- All embryonic connective tissue begins as mesenchyme.
- Bone formation is termed *osteogenesis* or *ossification* and begins when mesenchymal cells provide the template for subsequent ossification.

- Two types of ossification occur.
  - *Intramembranous ossification* is the formation of bone directly from or within fibrous connective tissue membranes.
  - *Endochondrial ossification* is the formation of bone from hyaline cartilage models.
Intramembranous Ossification

- Also called dermal ossification because it normally occurs in the deeper layers of the skin.
  - Mesenchymal cells (osteoprogenitor cells) differentiate into osteoblasts
  - The osteoblasts begin to deposit the organic bone matrix, the osteoid.
  - The matrix separates osteoblasts located in lacunae within the matrix.
  - The collagen fibres of the osteoid form a woven network this type of bone is also called **WOVEN BONE**.
  - The osteoid calcifies leading to the formation of primitive trabecular bone.
Intramembranous Ossification

1. Development of center of ossification
   - Blood capillary
   - Center of ossification
   - Mesenchymal cell
   - Osteoblast
   - Collagen fiber

2. Osteocytes deposit mineral salts (calcification)
   - Osteocyte in lacuna
   - Canaliculus
   - Osteoblast
   - Newly calcified bone matrix

3. Formation of trabeculae
   - Mesenchyme condenses
   - Blood vessel
   - Trabeculae
   - Osteoblast

4. Development of periosteum, spongy bone, and compact bone tissue
   - Periosteum:
     - Fibrous layer
     - Osteogenic layer
   - Spongy bone tissue
   - Compact bone tissue

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Endochondral Ossification

- Developing bones are deposited as a hyaline cartilage model and then this cartilage is replaced by bone tissue.
- A *periosteal bud* invades the cartilage model and allows osteoprogenitor cells to enter the cartilage.
- At these sites, the cartilage is in a state of hypertrophy (very large lacunae and chondrocytes) and partial calcification, which eventually leads to the death of the chondrocytes.
- Osteoprogenitor cells mature into osteoblasts, which use the framework of calcified cartilage to deposit new bone.
- All bones of the body
Endochondral Ossification

4 Development of secondary ossification center in epiphysis

5 Formation of articular cartilage and epiphysseal plate
Video
Zones of Growth in Epiphyseal Plate

- Zone of resting cartilage
  - anchors growth plate to bone
- Zone of proliferating cartilage
  - rapid cell division (stacked coins)
- Zone of hypertrophic cartilage
  - cells enlarged & remain in columns
- Zone of calcified cartilage
  - thin zone, cells mostly dead since matrix calcified
  - osteoclasts removing matrix
  - osteoblasts & capillaries move in to create bone over calcified cartilage
Only by appositional growth at the bone’s surface
Periosteal cells differentiate into osteoblasts and form bony ridges and then a tunnel around periosteal blood vessel.
Concentric lamellae fill in the tunnel to form an osteon.
Bone Fractures

Terms:
Closed/Open
Partial/Complete
Displaced/Non-displaced
Simple/Compound

Other Fractures:
Spiral
Transverse
Longitudinal
Pathologic

(a) Open fracture
(b) Comminuted fracture
(c) Greenstick fracture
(d) Impacted fracture
(e) Pott’s fracture
(f) Colles’ fracture
1. Formation of a fracture hematoma

Immediately after the fracture, there is a sharp fracture line with associated soft tissue swelling. At the fracture Site, there is abundant hematoma with beginning fibroblastic penetration.
Steps in Fracture Repair

2. Fibrocartilaginous Callus Formation

At 2 weeks there is much visible callus. There is also bone resorption and osteoporosis, both difficult to see in this case because of the overlying callus. There has been migration of chondroblasts into the area and cartilage is beginning to cover the ends of the fracture. New osteous tissue is produced enchondrally.
3. Bony Callus Formation

At 2 months, bony callus with sharp margins bridges the fracture and the fracture line itself begins to disappear.
3. Bony Callus Formation
Steps in Fracture Repair

4. Bone Remodeling

At 5-6 months, the marrow cavity is continuous and the compact bone of the diaphysis has been reformed.
video