The Skeletal System

Functions
1. Support
   • For the body and soft organs
2. Protection
   • For brain, spinal cord and vital organs
3. Movement
   • Levers for muscle action
4. Mineral reservoir
   • Calcium and phosphorous
5. Hematopoiesis
   • Marrow cavities

Bone
• Osseous tissue
  • Hydroxyapatite (85%)
  • Calcium carbonate (10%)
  • Inorganic minerals
    • Magnesium, sodium, fluoride
  • Organic material
    • Collagen
    • Chondroitin sulfate

Bone consists of multiple tissues
A single bone may be considered an organ

Bones are organs comprised of more than just osseous tissue

Endosteum

(c)
Figure 6.2
Bone Classification

General Bone Features
- Long bone anatomy (Humerus)
- Diaphysis
- Epiphysis
- Metaphysis
  - Epiphyseal growth plate or line
  - Articular cartilage
  - Periosteum
  - Medullary cavity
  - Endosteum

Figure 6.3a-b
Proximal epiphysis (b)
Epiphyseal line
Articular cartilage
Periosteum
Spongy bone
Compact bone
Medullary cavity (lined by endosteum) (b)
Anatomy of a long bone

Figure 6.3c
Yellow bone marrow
Compact bone
Periosteum
Perforating (Sharpey’s) fibers
Nutrient arteries
Outer layer of periosteum = dense irregular fibrous sheath
Endosteum

A Closer Look
- Osteoblasts (OB)
- Osteoclasts (OC)
- Periosteum (PO)
- Sharpey’s Fibers (SF)
Bone Histology

- Cells
  - Osteogenic (osteoprogenitor) cells
  - Stem cells in periosteum and endosteum → osteoblasts
  - Osteoblasts
    - Bone forming cells

(a) Osteogenic cell
(b) Osteoblast

- Stem cell
- Matrix-synthesizing cell responsible for bone growth

Bone Histology

- Cells
  - Osteocytes
    - Mature bone cells
    - Maintain bone matrix

Bone Histology

- Cells
  - Osteoclasts
    - Break down (resorb) bone matrix
    - Related to macrophages
Bone Histology

- Primary bone types
  - Compact
  - Spongy

- (c) Osteocyte
  - Mature bone cell
    - that maintains the bone matrix

- (d) Osteoclast
  - Bone-resorbing cell

- Compact bone
  - covers all spongy bone and the shafts of long bones
Bone Histology

- Bone marrow
  - Types
    - Red
      - Red blood cells
      - Hematopoiesis
    - Yellow
      - Replaces red with age
      - Fat storage
    - Gelatinous
      - Mostly water, fat, and protein

Skeletal System 17

Label the following:

1. Proximal epiphysis
2. Distal epiphysis
3. Epiphyseal line
4. Articular cartilage
5. Spongy bone
6. Compact bone
7. Medullary canal
8. Periosteum
9. Endosteum
10. Diaphysis
11. Nutrient artery
12. Marrow
13. Perforating (Sharpey’s) fibers

Turn in
Bone Formation & Maintenance

* Ossification (osteogenesis)
  * Stages
    * Bone formation
      * Begins in the 2nd month of development
    * Postnatal bone growth
      * Until early adulthood
    * Bone remodeling and repair
      * Lifelong

Types of Ossification

1. Endochondral ossification
   * Bone forms by replacing hyaline cartilage
   * Forms most of the skeleton
2. Intramembranous ossification
   * Bone develops from fibrous membrane
   * Forms flat bones

Endochondral Ossification

* Uses hyaline cartilage models
  * Requires breakdown of hyaline cartilage prior to ossification

**Week 9**

1. Bone collar forms around hyaline cartilage model.

2. Cartilage in the center of the diaphysis calcifies and then develops cavities.

3. The periosteal bud invades the internal cavities and spongy bone begins to form.
The diaphysis elongates and a medullary cavity forms as ossification continues. Secondary ossification centers appear in the epiphyses in preparation for stage 5.

The epiphyses ossify. When completed, hyaline cartilage remains only in the epiphyseal plates and articular cartilages.

**Intramembranous Ossification**
- Forms flat bones
  - Skull roof, lower jaw, clavicles
- Uses a fibrous membrane model formed from mesenchymal cells

**Ossification centers** appear in the fibrous connective tissue membrane.
- Selected centrally located mesenchymal cells cluster and differentiate into osteoblasts, forming an ossification center.
Bone matrix (osteoid) is secreted within the fibrous membrane and calcifies.
- Osteoblasts begin to secrete osteoid, which is calcified within a few days.
- Trapped osteoblasts become osteocytes.

Woven bone and periosteum form.
- Accumulating osteoid is laid down between embryonic blood vessels in a random manner. The result is a network (instead of lamellae) of trabeculae called woven bone.
- Vascularized mesenchyme condenses on the external face of the woven bone and becomes the periosteum.

Lamellar bone replaces woven bone, just deep to the periosteum. Red marrow appears.
- Trabeculae just deep to the periosteum thicken, and are later replaced with mature lamellar bone, forming compact bone plates.
- Spongy bone (diploë), consisting of distinct trabeculae, persists internally and its vascular tissue becomes red marrow.

Bone Maintenance
- Bone is dynamic throughout human lifespan
- Remodeling has several functions
  - Replacement and repair
  - Release of calcium
  - Response to stress (modification of density)

Bone Remodeling
- Deposit
  - Where bone is injured or added strength is required
  - Osteoblasts
- Resorption
  - Releases minerals from bone
  - Osteoclasts

Control of Remodeling
- Hormones
  - Growth Hormone
  - Calcitonin
  - Parathyroid Hormone (PTH)
  - Sex hormones
Hormonal Control of Blood Ca\textsuperscript{2+}

\[ \text{↓ Blood Ca}\textsuperscript{2+} \text{ levels} \]
\[ \text{↓ Parathyroid glands release PTH} \]
\[ \text{↓ PTH stimulates osteoclasts to degrade bone matrix and release Ca}\textsuperscript{2+} \]
\[ \text{↑ Blood Ca}\textsuperscript{2+} \text{ levels} \]

Bone Maintenance

- Bone deposition
  - Occurs where bone is injured or added strength is needed
- Development requires proper nutrition
  - Vitamins C, D, and A
  - Calcium and phosphorus

Bone Disorders

- Poor nutrition
- Hormonal changes/imbalances
- Trauma
- Developmental errors
- Infection
- Tumors

Nutritional Disorders

- Rickets
**Nutritional Disorders**

- Osteomalacia

**Hormonal Disorders**

- Osteoporosis
  - Loss of bone mass
    - Bone resorption > deposit
  - Vertebral bodies and neck of femur

**Infections**

- Osteomyelitis
  - Inflammation of bone due to infection

**Risk factors**

- Lack of estrogen
- Low calcium or vitamin D
- Petite body form
- Immobility
- Low levels of TSH
- Diabetes mellitus

**Treatment and prevention**

- Calcium, vitamin D, and fluoride supplements
- Weight-bearing exercise throughout life
- Hormone (estrogen) replacement therapy
- Controversial because of increased cardiovascular disease, cancer
- Drugs to increase bone mineral density
- Fosamax, selective estrogen receptor modulators (SERMs), statins (don’t work)
Bone Fractures
- Incomplete
- Does not cross entire bone
- Complete
- Bone is broken into two pieces
- Comminuted
- Three or more pieces
- Displaced
- Bone ends don’t line up
- Open versus closed

Fractures
- Pathological
  - Secondary to coexisting disease
    - Osteoporosis
    - Cancer
    - Malnutrition
    - Cushing’s syndrome
    - Osteogenesis imperfecta

Bone Fractures
- Transverse
- Spiral
- Impacted
- Depressed
- Greenstick

Fracture Repair
1. Fracture hematoma forms within 6-8 hrs
   - Torn blood vessels hemorrhage
     - Clot (hematoma) forms
     - Swollen, painful and inflamed

Fracture Repair
- Local periosteum and surrounding blood vessels are torn
  - Inflammation
    - Open vs. closed
  - Swelling
    - Hemorrhage (bleeding)
  - Blood clots → fracture hematoma

Fracture Repair
- A hematoma forms.
**Fracture Repair**

2. Fibrocartilaginous callus forms
   - Capillaries grow into area
   - Osteoblasts begin forming spongy bone within 1 week
   - Fibroblasts secrete collagen fibers to connect bone ends

   **2 wks**

3. Bony callus formation
   - New trabeculae form a bony (hard) callus
   - Continues until firm union is formed in ~2 months

   **3 Bony callus forms.**

4. Bone remodeling
   - In response to mechanical stressors over several months
   - Final structure resembles original bone

   **Healed fracture**

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**Figure 6.15, step 2**

**Figure 6.15, step 3**

**Figure 6.15, step 4**
Traction
- Uses gravity and/or tension
- Immobilizes
- Reduces pain
- Maintains bone length
- Does not realign fracture

Developmental Errors
- Skull
  - Hydrocephalus
    - Excess CSF causes pressure

Developmental Errors
- Skull
  - Cleft palate
Disorders of the Spinal Column

Figure 7.16

Cervical curvature (concave) - 7 vertebrae, C1–C7
Thoracic curvature (convex) - 12 vertebrae, T1–T12
Lumbar curvature (concave) - 5 vertebrae, L1–L5
Sacral curvature (convex) - 5 fused vertebrae, sacrum
Coccyx - 4 fused vertebrae

Anterior view
Right lateral view

Spinous process
Transverse processes
Intervertebral discs
Intervertebral foramen

Disorders of the Spinal Column

Scoliosis

Lordosis

Kyphosis

Spina Bifida

Spina bifida occulta
Meningocele
Myelomeningocele

Disorders of the Spinal Column

- Herniated disc
  - Causes and risk factors
  - Location
  - Treatment

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Vertebral spinous process
(posterior aspect of vertebra)
Spinal nerve root
Transverse process
Herniated portion of disc
Anulus fibrosus of disc
Nucleus pulposus of disc
Spinal cord
(c) Superior view of a herniated intervertebral disc