Osseous Tissue and Bone Structure
An Introduction to the Skeletal System

• Learning Outcomes
  
  • 6-1 Describe the primary functions of the skeletal system.
  
  • 6-2 Classify bones according to shape and internal organization, giving examples of each type, and explain the functional significance of each of the major types of bone markings.
  
  • 6-3 Identify the cell types in bone, and list their major functions.
An Introduction to the Skeletal System

• Learning Outcomes
  • 6-4 Compare the structures and functions of compact bone and spongy bone.
  • 6-5 Compare the mechanisms of endochondral ossification and intramembranous ossification.
  • 6-6 Describe the remodeling and homeostatic mechanisms of the skeletal system.
  • 6-7 Discuss the effects of exercise, hormones, and nutrition on bone development and on the skeletal system.
An Introduction to the Skeletal System

- **Learning Outcomes**
  - 6-8 Explain the role of calcium as it relates to the skeletal system.
  - 6-9 Describe the types of fractures, and explain how fractures heal.
  - 6-10 Summarize the effects of the aging process on the skeletal system.
An Introduction to the Skeletal System

• The Skeletal System
  • Includes:
    • Bones of the skeleton
    • Cartilages, ligaments, and connective tissues
6-1 Functions of the Skeletal System

- Five Primary Functions of the Skeletal System

1. **Support**
2. **Storage of Minerals** (calcium) and **Lipids** (yellow marrow)
3. **Blood Cell Production** (red marrow)
4. **Protection**
5. **Leverage** (force of motion)
6-2 Classification of Bones

- Bones
  - Are classified by:
    - Shape
    - Internal tissue organization
    - Bone markings (surface features; marks)
6-2 Classification of Bones

• Six Bone Shapes
  
  1. Sutural bones
  2. Irregular bones
  3. Short bones
  4. Flat bones
  5. Long bones
  6. Sesamoid bones
Figure 6-1  A Classification of Bones by Shape

- **Sutural Bones**: Sutures
- **Irregular Bones**: Vertebra
- **Short Bones**: Carpal bones
- **Flat Bones**: Parietal bone
- **Long Bones**: Humerus
- **Sesamoid Bones**: Patella
6-2 Classification of Bones

• Sutural Bones
  • Small, irregular bones
  • Found between the flat bones of the skull

• Irregular Bones
  • Have complex shapes
  • Examples: spinal vertebrae, pelvic bones
Figure 6-1a  A Classification of Bones by Shape

Sutural Bones

Sutural bone

Sutures
Figure 6-1b  A Classification of Bones by Shape

Irregular Bones

Vertebra
Figure 6-1c  A Classification of Bones by Shape

Short Bones

Carpal bones
6-2 Classification of Bones

• **Short Bones**
  - Small and thick
  - Examples: ankle and wrist bones

• **Flat Bones**
  - Thin with parallel surfaces
  - Found in the skull, sternum, ribs, and scapulae
6-2 Classification of Bones

• **Long Bones**
  - Long and thin
  - Found in arms, legs, hands, feet, fingers, and toes

• **Sesamoid Bones**
  - Small and flat
  - Develop inside tendons near joints of knees, hands, and feet
Figure 6-1d  A Classification of Bones by Shape

**d** Flat Bones

- Parietal bone
- External table
- Internal table
- Diploë (spongy bone)
Figure 6-1e  A Classification of Bones by Shape

Long Bones

Humerus
Figure 6-1f  A Classification of Bones by Shape

Sesamoid Bones

Patella
6-2 Classification of Bones

• Bone Markings
  • Depressions or grooves
    • Along bone surface
  • Elevations or projections
    • Where tendons and ligaments attach
    • At articulations with other bones
  • Tunnels
    • Where blood and nerves enter bone
Table 6-1  An Introduction to Bone Markings

<table>
<thead>
<tr>
<th>General Description</th>
<th>Anatomical Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevations and projections</td>
<td>Process</td>
<td>Any projection or bump</td>
</tr>
<tr>
<td></td>
<td>Ramus</td>
<td>An extension of a bone making an angle with the rest of the structure</td>
</tr>
<tr>
<td>Processes formed where tendons or</td>
<td>Trochanter</td>
<td>A large, rough projection</td>
</tr>
<tr>
<td>ligaments attach</td>
<td>Tuberosity</td>
<td>A smaller, rough projection</td>
</tr>
<tr>
<td></td>
<td>Tubercle</td>
<td>A small, rounded projection</td>
</tr>
<tr>
<td></td>
<td>Crest</td>
<td>A prominent ridge</td>
</tr>
<tr>
<td></td>
<td>Line</td>
<td>A low ridge</td>
</tr>
<tr>
<td></td>
<td>Spine</td>
<td>A pointed or narrow process</td>
</tr>
<tr>
<td>Processes formed for articulation</td>
<td>Head</td>
<td>The expanded articular end of an epiphysis, separated from the shaft by a</td>
</tr>
<tr>
<td>with adjacent bones</td>
<td>Neck</td>
<td>A narrow connection between the epiphysis and the diaphysis</td>
</tr>
<tr>
<td></td>
<td>Condyle</td>
<td>A smooth, rounded articular process</td>
</tr>
<tr>
<td></td>
<td>Trochlea</td>
<td>A smooth, grooved articular process shaped like a pulley</td>
</tr>
<tr>
<td></td>
<td>Facet</td>
<td>A small, flat articular surface</td>
</tr>
<tr>
<td>Depressions</td>
<td>Fossa</td>
<td>A shallow depression</td>
</tr>
<tr>
<td></td>
<td>Sulcus</td>
<td>A narrow groove</td>
</tr>
<tr>
<td>Openings</td>
<td>Foramen</td>
<td>A rounded passageway for blood vessels or nerves</td>
</tr>
<tr>
<td></td>
<td>Canal</td>
<td>A duct or channel</td>
</tr>
<tr>
<td></td>
<td>Meatus</td>
<td>A passageway through a bone</td>
</tr>
<tr>
<td></td>
<td>Fissure</td>
<td>An elongated cleft or slit</td>
</tr>
<tr>
<td></td>
<td>Sinus</td>
<td>A chamber within a bone, normally filled with air</td>
</tr>
</tbody>
</table>

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Table 6-1  An Introduction to Bone Markings

<table>
<thead>
<tr>
<th>General Description</th>
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<tbody>
<tr>
<td>Sinus</td>
<td>Tubercle</td>
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<tr>
<td>Trochanter</td>
<td>Head</td>
<td></td>
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<tr>
<td>Head</td>
<td>Sulcus</td>
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<tr>
<td>Neck</td>
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<tr>
<td>Fissure</td>
<td>Foramen</td>
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<tr>
<td>Process</td>
<td>Tuberosity</td>
<td></td>
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<tr>
<td>Ramus</td>
<td>Spine</td>
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<td>Line</td>
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<td>Tubercle</td>
<td>Fossa</td>
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</tr>
<tr>
<td>Condyle</td>
<td>Trochlea</td>
<td></td>
</tr>
<tr>
<td>Skull</td>
<td>Condyle</td>
<td></td>
</tr>
<tr>
<td>Femur</td>
<td>Humerus</td>
<td></td>
</tr>
</tbody>
</table>

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Structure of a Long Bone

- **Diaphysis**
  - The shaft
  - A heavy wall of compact bone, or dense bone
  - A central space called medullary (marrow) cavity

- **Epiphysis**
  - Wide part at each end
  - Articulation with other bones
  - Mostly spongy (cancellous) bone
  - Covered with compact bone (cortex)

- **Metaphysis**
  - Where diaphysis and epiphysis meet
The structure of a representative long bone (the femur) in longitudinal section.
6-2 Classification of Bones

• Structure of a Flat Bone
  • The parietal bone of the skull
  • Resembles a sandwich of spongy bone
  • Between two layers of compact bone
  • Within the cranium, the layer of spongy bone between the compact bone is called the diploë
The structure of a flat bone (the parietal bone)
6-3 Bone (Osseous) Tissue

- Bone (Osseous) Tissue
  - Dense, supportive connective tissue
  - Contains specialized cells
  - Produces solid matrix of calcium salt deposits
  - Around collagen fibers
6-3 Bone (Osseous) Tissue

• Characteristics of Bone Tissue
  • Dense matrix, containing:
    • Deposits of calcium salts
    • Osteocytes (bone cells) within lacunae organized around blood vessels
  • Canaliculi
    • Form pathways for blood vessels
    • Exchange nutrients and wastes
6-3 Bone (Osseous) Tissue

• Characteristics of Bone Tissue
  • Periosteum
    • Covers outer surfaces of bones
    • Consists of outer fibrous and inner cellular layers
6-3 Bone (Osseous) Tissue

- Bone Matrix
  - Minerals
    - Two thirds of bone matrix is calcium phosphate, $\text{Ca}_3(\text{PO}_4)_2$
      - Reacts with calcium hydroxide, $\text{Ca}(\text{OH})_2$
      - To form crystals of hydroxyapatite, $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$
      - Which incorporates other calcium salts and ions
6-3 Bone (Osseous) Tissue

- Bone Matrix
  - Matrix Proteins
    - One third of bone matrix is protein fibers (collagen)
6-3 Bone (Osseous) Tissue

• Bone Cells
  • Make up only 2% of bone mass
  • Bone contains four types of cells
    1. Osteocytes
    2. Osteoblasts
    3. Osteoprogenitor cells
    4. Osteoclasts
Figure 6-3 Types of Bone Cells

Canaliculi

Osteocyte

Matrix

Osteocyte: Mature bone cell that maintains the bone matrix

Osteoprogenitor cell

Medullary cavity

Endosteum

Osteoprogenitor cell: Stem cell whose divisions produce osteoblasts

Osteoblast: Immature bone cell that secretes organic components of matrix

Osteoid

Matrix

Osteoclast

Medullary cavity

Osteoclast: Multinucleate cell that secretes acids and enzymes to dissolve bone matrix

Matrix
6-3 Bone (Osseous) Tissue

- **Osteocytes**
  - Mature bone cells that maintain the bone matrix
  - Live in lacunae
  - Are between layers *(lamellae)* of matrix
  - Connect by cytoplasmic extensions through *canaliculi* in lamellae
  - Do not divide
  - Two major functions of osteocytes
    1. To maintain protein and mineral content of matrix
    2. To help repair damaged bone
Figure 6-3  Types of Bone Cells

Canaliculi  Osteocyte  Matrix

Osteocyte: Mature bone cell that maintains the bone matrix

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6-3 Bone (Osseous) Tissue

- Osteoblasts
  - Immature bone cells that secrete matrix compounds (osteogenesis)
  - Osteoid — matrix produced by osteoblasts, but not yet calcified to form bone
  - Osteoblasts surrounded by bone become osteocytes
Figure 6-3  Types of Bone Cells

Osteoblast: Immature bone cell that secretes organic components of matrix
6-3 Bone (Osseous) Tissue

- **Osteoprogenitor Cells**
  - Mesenchymal stem cells that divide to produce osteoblasts
  - Located in *endosteum*, the inner cellular layer of periosteum
  - Assist in *fracture* repair
Osteoprogenitor cell: Stem cell whose divisions produce osteoblasts
6-3 Bone (Osseous) Tissue

- **Osteoclasts**
  - Secrete acids and protein-digesting enzymes
  - Giant, multinucleate cells
  - Dissolve bone matrix and release stored minerals (osteolysis)
  - Derived from stem cells that produce macrophages
Osteoclast: Multinucleate cell that secretes acids and enzymes to dissolve bone matrix.
6-3 Bone (Osseous) Tissue

- Homeostasis
  - Bone building (by osteoblasts) and bone recycling (by osteoclasts) must balance
    - More breakdown than building, bones become weak
    - Exercise, particularly weight-bearing exercise, causes osteoblasts to build bone
6-4 Compact Bone and Spongy Bone

• The Structure of Compact Bone
  • **Osteon** is the basic unit
    • Osteocytes are arranged in *concentric lamellae*
    • Around a **central canal** containing blood vessels
  • **Perforating canals**
    • Perpendicular to the central canal
    • Carry blood vessels into bone and marrow
6-4 Compact Bone and Spongy Bone

• The Structure of Compact Bone
  • *Circumferential Lamellae*
    • Lamellae wrapped around the long bone
    • Bind osteons together
A thin section through compact bone. By this procedure the intact matrix making up the lamellae appear white, and the central canal, lacunae, and canaliculi appear black due to the presence of bone dust.
Several osteons in compact bone.
The organization of osteons and lamellae in compact bone

Figure 6-5a The Structure of Compact Bone

- Venule
- Capillary
- Periosteum
- Circumferential lamellae
- Osteons
- Perforating fibers
- Vein
- Artery
- Arteriole
- Central canal
- Perforating canal
- Interstitial lamellae
- Concentric lamellae
- Trabeculae of spongy bone (see Fig. 6–6)
The organization of osteons and lamellae in compact bone
Figure 6-5b  The Structure of Compact Bone

The orientation of collagen fibers in adjacent lamellae
6-4 Compact Bone and Spongy Bone

- The Structure of Spongy Bone
  - Does not have osteons
  - The matrix forms an open network of **trabeculae**
  - Trabeculae have no blood vessels
  - The space between trabeculae is filled with **red bone marrow**
    - Which has blood vessels
    - Forms red blood cells
    - And supplies nutrients to osteocytes
  - **Yellow bone marrow**
    - In some bones, spongy bone holds yellow bone marrow
    - Is yellow because it stores fat
Figure 6-6 The Structure of Spongy Bone

- Trabeculae of spongy bone
- Canaliculi opening on surface
- Endosteum
- Lamellae
6-4 Compact Bone and Spongy Bone

- **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
Figure 6-7  The Distribution of Forces on a Long Bone

Body weight (applied force)

Tension on lateral side of shaft

Compression on medial side of shaft
6-4 Compact Bone and Spongy Bone

- Compact Bone is Covered with a Membrane
  - **Periosteum** on the outside
    - Covers all bones except parts enclosed in joint capsules
    - Made up of an outer, fibrous layer and an inner, cellular layer
    - *Perforating fibers*: collagen fibers of the periosteum
      - Connect with collagen fibers in bone
      - And with fibers of joint capsules; attach tendons, and ligaments
Functions of Periosteum

1. Isolates bone from surrounding tissues
2. Provides a route for circulatory and nervous supply
3. Participates in bone growth and repair
The periosteum contains outer (fibrous) and inner (cellular) layers. Collagen fibers of the periosteum are continuous with those of the bone, adjacent joint capsules, and attached tendons and ligaments.
6-4 Compact Bone and Spongy Bone

- Compact Bone is Covered with a Membrane
  - **Endosteum** on the inside
    - An incomplete cellular layer:
      - Lines the medullary (marrow) cavity
      - Covers trabeculae of spongy bone
      - Lines central canals
      - Contains osteoblasts, osteoprogenitor cells, and osteoclasts
      - Active in bone growth and repair
The endosteum is an incomplete cellular layer containing osteoblasts, osteoprogenitor cells, and osteoclasts.
6-5 Bone Formation and Growth

- Bone Development
  - Human bones grow until about age 25
  - Osteogenesis
    - Bone formation
  - Ossification
    - The process of replacing other tissues with bone
6-5 Bone Formation and Growth

- Bone Development
  - Calcification
    - The process of depositing calcium salts
    - Occurs during bone ossification and in other tissues
  - Ossification
    - Two main forms of ossification
      1. Endochondral ossification
      2. Intramembranous ossification
6-5 Bone Formation and Growth

- **Endochondral Ossification**
  - Ossifies bones that originate as hyaline cartilage
  - Most bones originate as hyaline cartilage
  - There are six main steps in endochondral ossification
Figure 6-10  Endochondral Ossification

Enlarging chondrocytes within calcifying matrix

Hyaline cartilage
Figure 6-10  Endochondral Ossification

- Bone formation
- Epiphysis
- Diaphysis
Figure 6-10  Endochondral Ossification

- Medullary cavity
- Primary ossification center
- Superficial bone
- Spongy bone
- Blood vessel
Figure 6-10  Endochondral Ossification

- Hyaline cartilage
- Epiphysis
- Metaphysis
- Periosteum
- Compact bone
- Secondary ossification center
Figure 6-10  Endochondral Ossification

Articular cartilage
Spongy bone
Epiphyseal cartilage
Diaphysis
Figure 6-10  Endochondral Ossification

Epiphyseal cartilage matrix

Cartilage cells undergoing division and secreting additional cartilage matrix

Medullary cavity

Osteoblasts

Osteoid

LM × 250
6-5 Bone Formation and Growth

- **Appositional Growth**
  - Compact bone thickens and strengthens long bone with layers of circumferential lamellae
6-5 Bone Formation and Growth

- **Epiphyseal Lines**
  - When long bone stops growing, after puberty:
    - Epiphyseal cartilage disappears
    - Is visible on X-rays as an *epiphyseal line*

- **Mature Bones**
  - As long bone matures:
    - Osteoclasts enlarge medullary (marrow) cavity
    - Osteons form around blood vessels in compact bone
An x-ray of growing epiphyseal cartilages (arrows)
Figure 6-11b  Bone Growth at an Epiphyseal Cartilage

Epiphyseal lines in an adult (arrows)
6-5 Bone Formation and Growth

• **Intramembranous Ossification**
  
  • Also called *dermal ossification*
    
    • Because it occurs in the dermis
    
    • Produces *dermal bones* such as mandible (lower jaw) and clavicle (collarbone)
  
  • There are three main steps in intramembranous ossification
Mesenchymal cells aggregate, differentiate into osteoblasts, and begin the ossification process. The bone expands as a series of spicules that spread into surrounding tissues.
As the spicules interconnect, they trap blood vessels within the bone.

Osteocytes in lacunae  Blood vessels  Osteoblast layer
Over time, the bone assumes the structure of spongy bone. Areas of spongy bone may later be removed, creating medullary cavities. Through remodeling, spongy bone formed in this way can be converted to compact bone.

Blood vessel
6-5 Bone Formation and Growth

• Blood Supply of Mature Bones

1. Nutrient Artery and Vein
   • A single pair of large blood vessels
   • Enter the diaphysis through the nutrient foramen
   • Femur has more than one pair

2. Metaphyseal Vessels
   • Supply the epiphyseal cartilage
   • Where bone growth occurs

3. Periosteal Vessels
   • Blood to superficial osteons
   • Secondary ossification centers
Figure 6-13  The Blood Supply to a Mature Bone

- Articular cartilage
- Epiphyseal artery and vein
- Metaphyseal artery and vein
- Periosteum
- Compact bone
- Medullary cavity
- Periosteal arteries and veins
- Connections to superficial osteons
- Nutrient artery and vein
- Nutrient foramen
- Metaphyseal artery and vein
- Epiphyseal line

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6-5 Bone Formation and Growth

- Lymph and Nerves
  - The periosteum also contains:
    - Networks of lymphatic vessels
    - Sensory nerves
Figure 6-9  Heterotopic Bone Formation

[Image: An adult male with FOP, posterior view]

a  An adult male with FOP, posterior view

[Image: The skeleton of a man with advanced FOP]

b  The skeleton of a man with advanced FOP
6-6 Bone Remodeling

• **Process of Remodeling**
  • The adult skeleton:
    • Maintains itself
    • Replaces mineral reserves
    • Recycles and renews bone matrix
    • Involves osteocytes, osteoblasts, and osteoclasts
6-6 Bone Remodeling

- Process of Remodeling
  - Bone continually remodels, recycles, and replaces
  - Turnover rate varies:
    - If deposition is greater than removal, bones get stronger
    - If removal is faster than replacement, bones get weaker
6-7 Exercise, Hormones, and Nutrition

• Effects of Exercise on Bone
  • Mineral recycling allows bones to adapt to stress
  • Heavily stressed bones become thicker and stronger

• Bone Degeneration
  • Bone degenerates quickly
  • Up to one third of bone mass can be lost in a few weeks of inactivity
Normal Bone Growth and Maintenance Depend on Nutritional and Hormonal Factors

- A dietary source of calcium and phosphate salts
- Plus small amounts of magnesium, fluoride, iron, and manganese
Normal Bone Growth and Maintenance Depend on Nutritional and Hormonal Factors

- The hormone *calcitriol*
  - Made in the kidneys
  - Helps absorb calcium and phosphorus from digestive tract
  - Synthesis requires vitamin D₃ (*cholecalciferol*)
6-7 Exercise, Hormones, and Nutrition

- Normal Bone Growth and Maintenance Depend on Nutritional and Hormonal Factors
  - Vitamin C is required for collagen synthesis, and stimulation of osteoblast differentiation
  - Vitamin A stimulates osteoblast activity
  - Vitamins K and B_{12} help synthesize bone proteins
Normal Bone Growth and Maintenance Depend on Nutritional and Hormonal Factors

- *Growth hormone* and *thyroxine* stimulate bone growth
- *Estrogens* and *androgens* stimulate osteoblasts
- *Calcitonin* and *parathyroid hormone* regulate calcium and phosphate levels
<table>
<thead>
<tr>
<th>Hormone</th>
<th>Primary Source</th>
<th>Effects on Skeletal System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcitriol</td>
<td>Kidneys</td>
<td>Promotes calcium and phosphate ion absorption along the digestive tract</td>
</tr>
<tr>
<td>Growth hormone</td>
<td>Pituitary gland</td>
<td>Stimulates osteoblast activity and the synthesis of bone matrix</td>
</tr>
<tr>
<td>Thyroxine</td>
<td>Thyroid gland (follicle cells)</td>
<td>With growth hormone, stimulates osteoblast activity and the synthesis of bone matrix</td>
</tr>
<tr>
<td>Sex hormones</td>
<td>Ovaries (estrogens)</td>
<td>Stimulate osteoblast activity and the synthesis of bone matrix; estrogens stimulate epiphyseal closure earlier than androgens</td>
</tr>
<tr>
<td>Testes (androgens)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parathyroid hormone</td>
<td>Parathyroid glands</td>
<td>Stimulates osteoclast (and osteoblast) activity; elevates calcium ion concentrations in body fluids</td>
</tr>
<tr>
<td>Calcitonin</td>
<td>Thyroid gland (C cells)</td>
<td>Inhibits osteoclast activity; promotes calcium loss by kidneys; reduces calcium ion concentrations in body fluids</td>
</tr>
</tbody>
</table>
Figure 6-14 Examples of Abnormal Bone Development

a Pituitary dwarfism  
b Marfan’s syndrome
6-8 Calcium Homeostasis

- The Skeleton as a Calcium Reserve
  - Bones store calcium and other minerals
  - Calcium is the most abundant mineral in the body
    - Calcium ions are vital to:
      - Membranes
      - Neurons
      - Muscle cells, especially heart cells
Figure 6-15  A Chemical Analysis of Bone

<table>
<thead>
<tr>
<th>Composition of Bone</th>
<th>Bone Contains …</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic compounds (mostly collagen) 33%</td>
<td>99% of the body’s Calcium</td>
</tr>
<tr>
<td></td>
<td>4% of the body’s Potassium</td>
</tr>
<tr>
<td></td>
<td>35% of the body’s Sodium</td>
</tr>
<tr>
<td></td>
<td>50% of the body’s Magnesium</td>
</tr>
<tr>
<td></td>
<td>80% of the body’s Carbonate</td>
</tr>
<tr>
<td></td>
<td>99% of the body’s Phosphate</td>
</tr>
<tr>
<td></td>
<td>Total inorganic components 67%</td>
</tr>
<tr>
<td></td>
<td>Calcium 39%</td>
</tr>
<tr>
<td></td>
<td>Potassium  0.2%</td>
</tr>
<tr>
<td></td>
<td>Sodium 0.7%</td>
</tr>
<tr>
<td></td>
<td>Magnesium 0.5%</td>
</tr>
<tr>
<td></td>
<td>Carbonate 9.8%</td>
</tr>
<tr>
<td></td>
<td>Phosphate 17%</td>
</tr>
</tbody>
</table>
6-8 Calcium Homeostasis

• Calcium Regulation
  • Calcium ions in body fluids
    • Must be closely regulated
  • Homeostasis is maintained
    • By calcitonin and parathyroid hormone (PTH)
      • Which control storage, absorption, and excretion
6-8 Calcium Homeostasis

• Calcitonin and Parathyroid Hormone Control
  • Affect:
    1. Bones
      • Where calcium is stored
    2. Digestive tract
      • Where calcium is absorbed
    3. Kidneys
      • Where calcium is excreted
6-8 Calcium Homeostasis

- Parathyroid Hormone (PTH)
  - Produced by parathyroid glands in neck
  - Increases calcium ion levels by:
    1. Stimulating osteoclasts
    2. Increasing intestinal absorption of calcium
    3. Decreasing calcium excretion at kidneys

- Calcitonin
  - Secreted by C cells (parafollicular cells) in thyroid
  - Decreases calcium ion levels by:
    1. Inhibiting osteoclast activity
    2. Increasing calcium excretion at kidneys
Factors That Increase Blood Calcium Levels

These responses are triggered when plasma calcium ion concentrations fall below 8.5 mg/dL.

Low Calcium Ion Levels in Plasma (below 8.5 mg/dL)

Parathyroid Gland Response
Low calcium plasma levels cause the parathyroid glands to secrete parathyroid hormone (PTH).

Bone Response
Osteoclasts stimulated to release stored calcium ions from bone

Intestinal Response
Rate of intestinal absorption increases

Kidney Response
Kidneys retain calcium ions

Calcium released
Calcium absorbed quickly
Calcium conserved

↑Ca²⁺ levels in bloodstream

Decreased calcium loss in urine

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Figure 6-16b  Factors That Alter the Concentration of Calcium Ions in Body Fluids

**Factors That Decrease Blood Calcium Levels**

These responses are triggered when plasma calcium ion concentrations rise above 11 mg/dL.

**High Calcium Ion Levels in Plasma** (above 11 mg/dL)

**Thyroid Gland Response**

Parafollicular cells (C cells) in the thyroid gland secrete calcitonin.

- **Bone Response**
  - Osteoclasts inhibited while osteoblasts continue to lock calcium ions in bone matrix

- **Intestinal Response**
  - Rate of intestinal absorption decreases

- **Kidney Response**
  - Kidneys allow calcium loss

Calcitonin

- Calcium absorbslowly
- Calcium stored
- Less calcitriol
- Increased calcium loss in urine

- Calcium excreted

<table>
<thead>
<tr>
<th>Calcium stored</th>
<th>Calcium absorbed slowly</th>
<th>Calcium excreted</th>
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<tbody>
<tr>
<td></td>
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<td>increased calcium loss in urine</td>
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6-9 Fractures

• Fractures
  • Cracks or breaks in bones
  • Caused by physical stress

• Fractures are repaired in four steps
  1. Bleeding
  2. Cells of the endosteum and periosteum
  3. Osteoblasts
  4. Osteoblasts and osteocytes remodel the fracture for up to a year
6-9 Fractures

• Bleeding
  • Produces a clot (fracture hematoma)
  • Establishes a fibrous network
  • Bone cells in the area die

• Cells of the endosteum and periosteum
  • Divide and migrate into fracture zone
  • Calluses stabilize the break
    • External callus of cartilage and bone surrounds break
    • Internal callus develops in medullary cavity
Immediately after the fracture, extensive bleeding occurs. Over a period of several hours, a large blood clot, or fracture hematoma, develops.

An internal callus forms as a network of spongy bone unites the inner edges, and an external callus of cartilage and bone stabilizes the outer edges.
6-9 Fractures

- Osteoblasts
  - Replace central cartilage of external callus
  - With spongy bone

- Osteoblasts and osteocytes remodel the fracture for up to a year
  - Reducing bone calluses
The cartilage of the external callus has been replaced by bone, and struts of spongy bone now united the broken ends. Fragments of dead bone and the areas of bone closest to the break have been removed and replaced.

A swelling initially marks the location of the fracture. Over time, this region will be remodeled, and little evidence of the fracture will remain.
6-9 Fractures

- Major Types of Fractures
  - Transverse fractures
  - Displaced fractures
  - Compression fractures
  - Spiral fractures
  - Epiphyseal fractures
  - Comminuted fractures
  - Greenstick fracture
  - Colles fracture
  - Pott’s fracture
Figure 6-17 Types of Fractures and Steps in Repair

- Transverse fracture
- Displaced fracture

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Figure 6-17  Types of Fractures and Steps in Repair

Compression fracture

Spiral fracture
Figure 6-17  Types of Fractures and Steps in Repair

Epiphyseal fracture

Comminuated fracture
Figure 6-17  Types of Fractures and Steps in Repair

Greenstick fracture

Colles fracture

Pott's fracture
Age-Related Changes

- Bones become thinner and weaker with age
  - **Osteopenia** begins between ages 30 and 40
  - Women lose 8% of bone mass per decade, men 3%
- The epiphyses, vertebrae, and jaws are most affected
  - Resulting in fragile limbs
  - Reduction in height
  - Tooth loss
6-10 Effects of Aging on the Skeletal System

• **Osteoporosis**
  • Severe bone loss
  • Affects normal function
  • Over age 45, occurs in:
    • 29% of women
    • 18% of men
Figure 6-18  The Effects of Osteoporosis on Spongy Bone

[Images: Normal spongy bone (SEM x 25) vs. Spongy bone in osteoporosis (SEM x 21)]
6-10 Effects of Aging on the Skeletal System

• Hormones and Bone Loss
  • Estrogens and androgens help maintain bone mass
  • Bone loss in women accelerates after menopause

• Cancer and Bone Loss
  • Cancerous tissues release **osteoclast-activating factor**
    • That stimulates osteoclasts
    • And produces severe osteoporosis