Outline

I. Overview of the skeletal system
II. Function of bones
III. Bone structure
IV. Bone cells
V. Cartilage
VI. Tendons and ligaments
VII. Joints
VIII. Bone development
IX. Hormonal regulation of bone growth
X. Homeostasis
XI. Disorders of the skeletal system

Skeletal System

- The skeletal system is composed of different types of connective tissues:
  - **Bones** – rigid structure
  - **Cartilage** – soft, cushions the joints
  - **Ligaments** – attach bone to bone
  - **Tendons** – attach muscle to bone

- Tendons link the skeletal and the muscular systems.
Functions of Bone
1. Supports and gives shape to the body.
2. Protects soft body parts.
3. Produces blood cells.
4. Stores minerals (calcium and phosphate).
5. Stores fat.
6. Along with the muscles, permits flexible body movement.

Bone Structure
- Bones contain different types of tissue:
  - Calcified tissue = osseous tissue
  - Blood vessels
  - Nerves
  - Contain collagen fibers that give flexibility

- This combination of calcified tissue and collagen fibers makes the bone strong but flexible.
Bone Structure

- All bones have two layers:
  - Compact bone – dense mineralized outer layer
  - Spongy bone – inner layer with open network filled with marrow

Typical Long Bone Architecture

- Epiphysis – rounded end of the typical long bone, composed mainly of red bone marrow where blood cells are made
- Diaphysis – shaft of the typical long bone, has a cavity filled with yellow marrow where fat is stored
- Periosteum – fibrous outer covering of the bone that contains nerves, blood vessels, and lymphatic vessels
  - Functions in bone repair and growth
**Bone is Living Tissue!**

The structural unit of compact bone is an **Osteon**. Mature, living bone cells (osteocytes) are found in small spaces (lacunae) and connect through canals (canaliculi) to the central canal (Haversian).

**Compact Bone Structure**

- **Osteon** – structural unit of the compact bone
  - Osteon structure:
    - **Central canal (Haversian)** – contains blood vessels and nerves
    - **Osteocytes** – mature bone cells that maintain bone structure, density, and minerals
      - Found in cavities called **lacunae**
    - **Canaliculi** are canals that connect the lacunae to the central canal

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**Figure 5.1c The structure of bone**

- (c) A light micrograph of compact bone showing an osteon.
Bone Cells: Osteoblasts

- **Osteoblasts** = bone-forming cells

- Immature cells that secrete material called "bone ground substance":
  - This is non-cellular matrix that surrounds the cells.

- Osteoblasts mature into osteocytes after they have secreted enough material.

Bone Cells: Osteoclasts

- **Osteoclasts** = bone-absorbing cells

- These are bone cells on the outer edge of bones.

- They release enzymes that eat away at the bone, releasing minerals.
Q: The arrow is pointing to:
1. Diaphysis
2. Epiphysis

Q: Immature cells that secrete calcified material are:
1. Osteoclasts
2. Osteocytes
3. Osteoblasts

Q: Osteocytes are found in cavities called:
1. Central canals
2. Collagen
3. Lacunae
4. Vellus

Bone Development and Growth
- The skeleton begins to form at about 6 weeks after conception.
- Most bones grow through adolescence, but some bones continue to grow through about age 25.
- Bone continue to change throughout life:
  - Osteoclasts remove the bone matrix, while osteoblasts build up the matrix.
  - Ossification – formation of bones
Figure 5.3  Steps of bone formation in long and short bones, from an embryo into childhood

**Cartilage in Bones**

- Two regions of cartilage remain at each end of the long bone:
  - The cap that covers the surfaces that rub against other bones.
  - A plate of cartilage called the epiphyseal plate, or growth plate.

**Bone Growth**

- Bone growth is stimulated by growth hormone during childhood.
- Thyroid hormones ensure that the skeleton grows with the proper proportions.
- At puberty, increasing levels of male or female sex hormones initially stimulate cartilage cells to divide, but eventually allow for the growth plates to fuse, and bone can no longer increase in length.
Hormonal Regulation of Bone Growth

- **Growth hormone (GH)** – directly stimulates growth of the epiphyseal plate and stimulates bone growth in general

- **Vitamin D** – converted to a hormone that causes the intestines to absorb calcium

- **Sex hormones** – adolescents experience a growth spurt due to an increased level of hormones

Hormonal Regulation of Bone Calcium Levels

- **Parathyroid hormone (PTH)** – produced by the parathyroid gland
  - Accelerates bone recycling and increases blood calcium

- **Calcitonin** – produced by the thyroid gland
  - Decreases blood calcium levels, and deposits calcium into the bone

- **Homeostasis** – maintaining a balance of calcium levels in blood and in bone
Healing Broken Bones

- Broken bones and fractures are the same thing.
- Bone fractures are healed by fibroblasts and osteoblasts.
- When a break occurs, there is bleeding followed by a clot.
- Fibroblasts secrete collagen fibers that form a **callus** linking the two parts of the bone.
  - This is later replaced by bone.

Bone Fractures are Healed by Fibroblasts and Osteoblasts

**Figure 5.4 (1 of 2)**

**Step 1:** Within hours after the fracture, a blood clot forms.

**Step 2:** A cartilaginous callus is formed by invading fibroblasts.

**Figure 5.4 (2 of 2)**

**Step 3:** Osteoblasts form new bone, converting the cartilaginous callus to a bony callus.

**Step 4:** The fracture is healed and bone is remodeled, restoring bone to original shape.
Q: This hormones accelerates bone recycling and increases blood calcium:
1. Growth hormone
2. Calcitonin
3. Parathyroid hormone

Q: Calcitonin is produced by the ______ gland.
1. Parathyroid
2. Thyroid
3. Anterior pituitary
4. Hypothalamus

Cartilage
- Cartilage – flexible connective tissue that is not as strong as bone tissue
- Function: cushions joints, provides flexibility
- Where found:
  - Ends of long bones, nose, ends of ribs, larynx and trachea, disks between vertebrae, knee joint, ear flaps, and epiglottis
- Cartilage cells are called chondrocytes.
- Cartilage lacks blood vessels, so it is very slow to heal!
Tendons and Ligaments

- **Ligaments** – connective tissue that connects bone to bone

- **Tendons** – connective tissue that connects muscle to bone

Figure 5.13b

(1) Ligaments hold bones together, support the joint, and direct the movement of the bones.

Synovial Joints

- Freely movable joints held together by ligaments.

- **Synovial membrane** – produces synovial fluid, an excellent lubricant for the joints

- **Bursae** – fluid-filled sacs, reduce friction

- **Menisci** – cartilage between the bones, acts as a cushion

- **Cartilage** is also found at the ends of the bones.
Synovial Joints

A layer of cartilage on the articular surfaces of the bones reduces friction as the bones move.

The joint cavity is filled with synovial fluid, which serves as a shock absorber and lubricant.

The synovial membrane forms the inner surface of the joint cavity and secretes synovial fluid.

Femur

Bursa

Fat pad

Tibia

Q: Cartilage cells are called:
1. Fibrocytes
2. Osteocytes
3. Chondrocytes

Q: This type of connective tissue connects bone to bone:
1. Ligaments
2. Tendons
Q: Fluid-filled sacs are called:

1. Synovia
2. Menisci
3. Bursae

Disorders of the Skeletal System

- Osteoarthritis – deterioration of cartilage at joints
- Rheumatoid Arthritis – chronic inflammatory disorder of the joints
- Sprain – when ligaments are torn or stretched
- Bursitis – inflammation of bursa
- Tendonitis – inflammation of tendon sheath
- Fracture – broken bone:
  - Simple = bone breaks but does not penetrate through the skin
  - Compound = bone breaks and protrudes through the skin

Osteoporosis

- Occurs when more bone is reabsorbed than is formed:
  - Homeostasis is not maintained, and more calcium is taken out of the bones than is replaced.

  - Estrogen and testosterone help maintain bone density.

  - After menopause, women produce less estrogen and this can lead to reduced bone density.
Risk Factors for Osteoporosis

- Post-menopausal
- Not enough exercise
- Poor diet, not enough calcium in the diet
- Smoking
- Low vitamin D levels
- Certain hormonal disorders

Treatment

- Exercise
- Increased calcium in the diet:
  - Calcium supplements may be needed.
  - The type of calcium supplement is important.
- Estrogen replacement therapy
- Prescription drugs

Recommended Calcium Intakes*

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<th>Age</th>
<th>Amount mg/day</th>
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<tr>
<td>6 months - 1 year</td>
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Decreased Calcium Absorption

- Oxalic acid – potent inhibitor of calcium absorption
  - Found in high concentrations in spinach and rhubarb, and in somewhat lower concentrations in sweet potato and dried beans
- Sodium – increased sodium intake results in increased loss of calcium in the urine
- Protein – as dietary protein intake increases, the urinary excretion of calcium also increases
- Caffeine – caffeine in large amounts increases urinary calcium content for a short time

Important Concepts

- Read chapter 5
- What are the four components of the skeletal system, and what are their functions?
- What are the functions of bone?
- What are the two layers of bone?
- What is the periosteum, and what is its function?
- What is the structure of the osteon, and what are the features found in the osteon?
**Important Concepts**

- What are the three types of bone cells and their functions?
- What are the functions of cartilage, tendons, and ligaments?
- What are the parts of synovial joints and their functions?
- What are the hormones involved in bone growth and homeostasis? Which glands produce calcitonin and parathyroid hormones?

**Important Concepts**

- What are the disorders of the skeletal system we discussed in this lecture?
- How do bones heal?
- What is osteoporosis, what are the risk factors for osteoporosis, and what can you do to prevent it?

**Definitions**

- Compact bone, osteon, central canal (Haversian canal), spongy bone, epiphysis, diaphysis, periosteum, lacunae, callus, fibroblasts, osteoblasts, osteocytes, osteoclasts, chondrocytes, growth hormone, parathyroid hormone (PTH), calcitonin, vitamin D, epiphyseal plate, growth plate