Chapter 6
Skeletal System:
Bones and Bone Tissue

Skeletal System Functions

• **Support.** Bone is hard and rigid; cartilage is flexible yet strong. Cartilage in nose, external ear, thoracic cage and trachea. Ligaments- bone to bone
• **Protection.** Skull around brain; ribs, sternum, vertebrae protect organs of thoracic cavity
• **Movement.** Produced by muscles on bones, via tendons. Ligaments allow some movement between bones but prevent excessive movement
• **Storage.** Ca and P. Stored then released as needed. Fat stored in marrow cavities
• **Blood cell production.** Bone marrow that gives rise to blood cells and platelets

Components of Skeletal System

• **Bone**
• **Cartilage:** three types
  – **Hyaline**
  – **Fibrocartilage**
  – **Elastic**
Skeletal Cartilages

CHONDROCYTES (cartilage cells) are found in LACUNAE (spaces) within an EXTRACELLULAR MATRIX. Cartilage is surrounded by an outer membrane called the PERICHONDRIUM (“peri” means to surround).

Types of cartilage:

- HYALINE cartilage – most abundant cartilage; provides support through flexibility; most cartilage of the human body is composed of hyaline cartilage.
- ELASTIC cartilage – contains many elastic fibers; able to tolerate repeated bending; only found in the ear and epiglottis of the larynx.
- FIBROCARTILAGE – resists strong compression and strong tension; an intermediate between hyaline and elastic cartilage; only found in the knees, pubic symphysis, and intervertebral discs.

Location of cartilage

- Ear (elastic cartilage) and nose (hyaline cartilage).
- Articular cartilages (in joints) and costal cartilage (connect to ribs) – both are made of hyaline cartilage.
- Intervertebral discs and pubic symphysis – both are made of fibrocartilage.

- Larynx (hyaline cartilage), except for the epiglottis (elastic cartilage).
• Bones are organs that contain several different types of tissues, including connective tissues (e.g. bone, blood, and cartilage), nervous tissue, and other tissues.

• http://www.youtube.com/watch?v=8d-RBoJRYVs
  • Good bone Video

Bone Shapes

• **Long**
  – Ex. Upper and lower limbs

• **Short**
  – Ex. Carpals and tarsals

• **Flat**
  – Ex. Ribs, sternum, skull, scapulae

• **Irregular**
  – Ex. Vertebrae, facial

Classification of Bones

• **Long bones** – longer than wide; a shaft plus ends, e.g. humerus and femur

• **Short bones** – roughly cube-shaped; e.g. bones of the hand and feet

• **Flat bones** – thin and flattened, usually curved; e.g. sternum

• **Irregular bones** – various shapes; do not fit into other categories; e.g. vertebra

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Spongy Bone vs. Compact Bone

- **Spongy bone** (cancellous bone) - internal network of bone; lighter and less dense than compact bone; contains “little beams” of bone called TRABECULAE; open spaces between trabeculae are filled with RED BONE MARROW or YELLOW BONE MARROW
- **Compact bone** - dense, outer layer of bone; appears very solid

Long Bone Structure

- **Diaphysis**
  - Shaft
  - Compact bone
- **Epiphysis**
  - End of the bone
  - Cancellous bone
- **Epiphyseal plate**: growth plate
  - Hyaline cartilage; present until growth stops
- **Epiphyseal line**: bone stops growing in length
- **Medullary cavity**: In children medullary cavity is red marrow, gradually changes to yellow in limb bones and skull (except for epiphyses of long bones). Rest of skeleton is red.
  - Red marrow
  - Yellow marrow
Structure of a long bone

- **DIAPHYSIS** - "shaft" of the bone; high amount of compact bone; contains the **MEDULLARY CAVITY**
- **MEDULLARY CAVITY** - hollow cavity that is filled with **YELLOW BONE MARROW** for storage of fat; lined with an inner membrane called the **ENDOSTEUM**
- membranes: **ENDOSTEUM** (lines the medullary cavity) and **PERIOSTEUM** (outer bone membrane held in place by SHARPEY'S FIBERS)

Bone Marrow Types

- The two types of bone marrow are "**red marrow**" (Latin: medulla ossium rubra), which consists mainly of hematopoietic tissue, and "**yellow marrow**" (Latin: medulla ossium flava), which is mainly made up of fat cells. Red blood cells, platelets, and most white blood cells arise in red marrow.
How does it grow?

- The **epiphyseal plate** is the area of growth in a long bone. It is a layer of hyaline cartilage where ossification occurs in immature bones. On the **epiphyseal (epiphysis) side** of the epiphyseal plate, cartilage is formed. On the **diaphyseal (diaphysis) side**, cartilage is ossified, allowing the diaphysis to grow in length.

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**Long Bone Structure, cont.**

- **Periosteum**
  - Outer is fibrous
  - Inner is single layer of bone cells including osteoblasts, osteoclasts and osteochondral progenitor cells
  - Fibers of tendon become continuous with fibers of periosteum.

  **Sharpey’s fibers**: some periosteal fibers penetrate through the periosteum and into the bone. Strengthen attachment of tendon to bone.

- **Endosteum**: similar to inner layer of periosteum. Lines all internal spaces including spaces in cancellous bone.
Flat, Short, Irregular Bones

- **Flat Bones**
  - No diaphyses, epiphyses
  - Sandwich of cancellous between compact bone

- **Short and Irregular Bone**
  - Compact bone that surrounds cancellous bone center; similar to structure of epiphyses of long bones
  - No diaphyses and not elongated

- Some flat and irregular bones of skull have sinuses lined by mucous membranes.

Bone Histology

- **Bone matrix**. Like reinforced concrete. Rebar is collagen fibers, cement is hydroxyapatite
  - Organic: collagen and proteoglycans
  - Inorganic: hydroxyapatite. CaPO_{4} crystals

- **Bone cells** (see following slides for particulars)
  - Osteoblasts
  - Osteocytes
  - Osteoclasts
  - Stem cells or osteochondral progenitor cells

- **Woven bone**: collagen fibers randomly oriented
- **Lamellar bone**: mature bone in sheets
- **Cancellous bone**: trabeculae
- **Compact bone**: dense
Microscopic Structure of Bone - like all connective tissues, bone tissue is composed of cells, fibers, and extracellular material. Compact bone (fig. 6.6) - composed of osteons (columns of bone); also known as a Haversian system.

- Osteons have layers of bone called lamellae. Circumferential lamellae surround all of the osteons of a bone (collectively) helping to resist twisting of the bone as a whole; the “criss-crossing” patterns of lamellae help individual osteons of bone resist twisting forces (fig. 6.5).
- Central canals, containing a blood vessel, are found at the center of an osteon.
- Perforating (Volkman’s) canals, also containing a blood vessel, connect adjacent osteons.

Spongy bone (fig. 6.3b and 6.4)

- Composed of trabeculae (“little beams” of bone); no osteons are present; unlike compact bone, it does not have a well-designed Haversian system.
Histology of Bone Cells:

- Visit the following link and view slide numbers 40, 43, 47, 49, and 50. For each be sure to read the text along with viewing the slide. Also, your PowerPoint program needs to be in “slide-show” mode or the hyperlink will not be clickable.

  http://www.meddean.luc.edu/lumen/MedEd/Histo/frames/frames7.html

- Pay particular attention to the osteocytes, lacunae, and canaliculi.

Histology of Bone Cells:

- Visit the following link and click on slide #7. Be sure to read the text along with viewing the slide. Also, your PowerPoint program needs to be in “slide-show” mode or the hyperlink will not be clickable.

  Histoweb

- Pay particular attention to the osteoclast; note that osteoclasts are large and multinucleate.

chemical composition of bone

- inorganic components - approx. 65% of bone; minerals of the bone; mostly HYDROXYAPATITE (calcium + phosphate); makes bone hard so that it can resist compression

- organic components - approx. 35% of bone; mainly composed of bone cells and fibers; collagen fibers act like “rebar in concrete” — they give bone flexibility so that it is not too brittle
Bone Matrix

- If mineral removed, bone is too bendable
- If collagen removed, bone is too brittle

Bone Cells

- **Osteoblasts**
  - Formation of bone through ossification or osteogenesis.
  - Collagen produced by E.R. and golgi. Released by exocytosis.
  - Precursors of hydroxyapatite stored in vesicles, then released by exocytosis.
  - **Ossification**: formation of bone by osteoblasts. Osteoblasts communicate through gap junctions. Cells surround themselves by matrix.

Osteocytes

- **Osteocytes.** Mature bone cells. Stellate. Surrounded by matrix, but can make small amounts of matrix to maintain it.
  - **Lacunae**: spaces occupied by osteocyte cell body
  - **Canaliculi**: canals occupied by osteocyte cell processes
  - Nutrients diffuse through tiny amount of liquid surrounding cell and filling lacunae and canaliculi. Then can transfer nutrients from one cell to the next through gap junctions.
Osteoclasts and Stem Cells

- **Osteoclasts.** Resorption of bone
  - Ruffled border: where cell membrane borders bone and resorption is taking place.
  - $\text{H}^+$ ions pumped across membrane, acid forms, eats away bone.
  - Release enzymes that digest the bone.
  - Derived from monocytes (which are formed from stem cells in red bone marrow)
  - Multinucleated and probably arise from fusion of a number of cells

- **Stem Cells.** Mesenchyme (Osteochondral Progenitor Cells) become chondroblasts or osteoblasts.

Woven and Lamellar Bone

- **Woven bone.** Collagen fibers randomly oriented.
  - Formed
    - During fetal development
    - During fracture repair
- **Remodeling**
  - Removing old bone and adding new
  - Woven bone is remodeled into lamellar bone
- **Lamellar bone**
  - Mature bone in sheets called lamellae. Fibers are oriented in one direction in each layer, but in different directions in different layers for strength.

Cancellous (Spongy) Bone

- **Trabeculae:** interconnecting rods or plates of bone. Like scaffolding.
  - Spaces filled with marrow.
  - Covered with endosteum.
  - Oriented along stress lines
Compact Bone

- Central or Haversian canals: parallel to long axis
- Lamellae: concentric, circumferential, interstitial
- Osteons or Haversian system: central canal, contents, associated concentric lamellae and osteocytes
- Perforating or Volkmann’s canal: perpendicular to long axis. Both perforating and central canals contain blood vessels. Direct flow of nutrients from vessels through cell processes of osteoblasts and from one cell to the next.

Compact Bone

- Osteons (Haversian systems)
  - Blood vessel-filled central canal (Haversian canal)
  - Concentric lamellae of bone surround central canal
  - Lacunae and canaliculi contain osteocytes and fluid
- Circumferential lamellae on the periphery of a bone
- Interstitial lamellae between osteons. Remnants of osteons replaced through remodeling

Circulation in Bone

- Perforating canals: blood vessels from periosteum penetrate bone
- Vessels of the central canal
- Nutrients and wastes travel to and from osteocytes via
  - Interstitial fluid of lacunae and canaliculi
  - From osteocyte to osteocyte by gap junctions
Endochondral Ossification

Growth in Bone Length
- **Appositional growth** only
  - Interstitial growth cannot occur because matrix is solid
  - Occurs on old bone and/or on cartilage surface
- Growth in length occurs at the epiphyseal plate
- Involves the formation of new cartilage by
  - Interstitial cartilage growth
  - Appositional growth on the surface of the cartilage
- **Closure of epiphyseal plate**: epiphyseal plate is ossified becoming the epiphyseal line. Between 12 and 25 years of age
- **Articular cartilage**: does not ossify, and persists through life

Growth at Articular Cartilage
- Increases size of bones with no epiphyses: e.g., short bones
- Chondrocytes near the surface of the articular cartilage similar to those in zone of resting cartilage
Factors Affecting Bone Growth

- Size and shape of a bone determined genetically but can be modified and influenced by nutrition and hormones
- Nutrition
  - Lack of calcium, protein and other nutrients during growth and development can cause bones to be small
  - Vitamin D
    - Necessary for absorption of calcium from intestines
    - Can be eaten or manufactured in the body
    - Rickets: lack of vitamin D during childhood
    - Osteomalacia: lack of vitamin D during adulthood leading to softening of bones
  - Vitamin C
    - Necessary for collagen synthesis by osteoblasts
    - Scurvy: deficiency of vitamin C
    - Lack of vitamin C also causes wounds not to heal, teeth to fall out

Factors Affecting Bone Growth, cont.

- Hormones
  - Growth hormone from anterior pituitary. Stimulates interstitial cartilage growth and appositional bone growth
  - Thyroid hormone required for growth of all tissues
  - Sex hormones such as estrogen and testosterone
    - Cause growth at puberty, but also cause closure of the epiphyseal plates and the cessation of growth

Calcium Homeostasis

- Bone is major storage site for calcium
- The level of calcium in the blood depends upon movement of calcium into or out of bone.
  - Calcium enters bone when osteoblasts create new bone; calcium leaves bone when osteoclasts break down bone
  - Two hormones control blood calcium levels: parathyroid hormone and calcitonin.
Effects of Aging on Skeletal System

- Bone matrix decreases. More brittle due to lack of collagen; but also less hydroxyapatite.
- Bone mass decreases. Highest around 30. Men denser due to testosterone and greater weight. African Americans and Hispanics have higher bone masses than Caucasians and Asians. Rate of bone loss increases 10 fold after menopause. Cancellous bone lost first, then compact.
- Increased bone fractures
- Bone loss causes deformity, loss of height, pain, stiffness
  - Stooped posture
  - Loss of teeth

Bone Fractures

- Open (compound)- bone break with open wound. Bone may be sticking out of wound.
- Closed (simple)- Skin not perforated.
- Incomplete- doesn’t extend across the bone. Complete- does
- Greenstick: incomplete fracture that occurs on the convex side of the curve of a bone
- Hairline: incomplete where two sections of bone do not separate. Common in skull fractures
- Comminuted fractures: complete with break into more than two pieces
Types of Fractures (Table 6.2)

- **comminuted** - the bone fragments into 3 or more pieces
- **compression** - the bone is crushed

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Types of Fractures (Table 6.2)

- **spiral** - the bone is twisted as it breaks; a common sports fracture
- **epiphyseal** - the epiphysis separates from the diaphysis at the epiphyseal plate; very serious in children and teenagers because their bones are still growing

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Types of Fractures (Table 6.2)

- **depressed** - broken bone is pressed inward
- **Greenstick (hairline)** - bone breaks incompletely as in a green tree branch; only one side of the bone breaks; common in children because of their relatively “soft” bones

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Bone Fractures, cont.

- Impacted fractures: one fragment is driven into the cancellous portion of the other fragment.
- Classified on basis of direction of fracture
  - Linear
  - Transverse
  - Spiral
  - Oblique
- Dentate: rough, toothed, broken ends
- Stellate radiating out from a central point.

Bone Disorders

- **OSTEOPOROSIS** (fig. 6.14) - characterized by low bone mass; bone reabsorption outpaces bone deposition; occurs most often in women after menopause

Osteomalacia vs. Rickets

- **OSTEOMALACIA** - occurs in adults; bones are not adequately mineralized
- **RICKETS** - occurs in children; bones are not adequately mineralized; a lack of Vitamin D in the diet in areas receiving inadequate sunlight for Vitamin D production is usually the cause (recall that Vitamin D is produced in the skin in response to sunlight); Vitamin D is necessary for proper absorption of calcium

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Bone Disorders

- OSTEOSARCOMA - bone cancer

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http://www.flickr.com/photos/robhengxr/2287695353/