Learn and Understand

- Skeleton is more than just bone
- Functions go beyond support
- Bone grows upon existing bone or upon existing cartilage, bone never grows by expanding existing bone from within
- The pattern of bone growth in the fetus aids in birth
- Bones exhibit a trade off between strength and weight
- Many joints do not allow movement
- Synovial joints incorporate numerous adaptations which protect them from damage even when frequently used

Functions of Bones

Seven important functions
- Support
- Protection
- Movement
- Mineral storage
- Blood cell formation
- Triglyceride (fat) storage
- Hormone production
Components of Skeletal System

- Bone
  - Compact or cancellous (spongy)
- Cartilage
  - Hyaline
  - Fibrocartilage
  - Elastic
- Tendons, ligaments

Hyaline Cartilage and Interstitial Growth

Interstitial Growth:
An increase in the size of a tissue by cell division within the interior of a part or structure that is already formed
Cells of Bone Tissue

<table>
<thead>
<tr>
<th>Cell Type</th>
<th>Location</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osteo-progenitor cells</td>
<td>Periosteum, endosteum</td>
<td>When stimulated, divide into osteoblasts or bone lining cells – &quot;osteogenic&quot;</td>
</tr>
<tr>
<td>Osteoblasts</td>
<td>Initially on edge of existing bone, then in matrix (become osteocytes)</td>
<td>Form bone by secreting matrix components which assemble outside of blasts and eventually entrap them in hard matrix</td>
</tr>
<tr>
<td>Osteocytes</td>
<td>Lacunae of bone matrix</td>
<td>Monitor and maintain bone matrix, stimulate bone remodeling in response to physical stress</td>
</tr>
<tr>
<td>Osteoclasts (derived from macrophages)</td>
<td>Edges of existing bone, temporarily occupy an area</td>
<td>Summoned to an area by osteocytes or signaling chemicals, have ruffled border that uses H⁺ and proteolytic enzymes to dissolve bone matrix</td>
</tr>
</tbody>
</table>

Figure 6.7  Microscopic anatomy of compact bone.

Figure 6.6  A single osteon.

Blood & Nervous Supply: good throughout compact bone, indirect supply to cancellous trabeculae

Structural unit of compact bone
Hollow tubes of bone matrix called lamellae
- Collagen fibers in adjacent rings run in different directions
  - Withstands stress – resist twisting

Central (Haversian) canal
Osteon (Haversian system)
Circumferential lamellae
Perforating (Volkmann's) canal
Endosteum lining bony canals and covering trabeculae
Perforating (Sharpey's) fibers
Peripheral blood vessel
Periosteum
Artery with capillaries
Vein
Nerve fiber
Lamellae
Collagen fibers run in different directions
Twisting force

Structural unit of compact bone
Hollow tubes of bone matrix called lamellae
- Collagen fibers in adjacent rings run in different directions
  - Withstands stress – resist twisting
Periosteum
- White, double-layered membrane
- Covers external surfaces except joint surfaces
- Outer fibrous layer of dense irregular connective tissue
  - Sharpey’s fibers secure to bone matrix
- Many nerve fibers and blood vessels
- Anchoring points for tendons and ligaments

Epiphyseal line
- Remnant of childhood bone growth at epiphyseal plate

Spongy Bone
- Trabeculae
  - Align along lines of stress to help resist it
  - No osteons
  - Contain irregularly arranged lamellae and osteocytes interconnected by canaliculi
  - Capillaries in endosteum supply nutrients
Bone Development

- Ossification (osteogenesis)
  - Process of bone tissue formation

  - Formation of bony skeleton
    • Embryonic skeleton ossifies predictably
    • Begins in 2nd month of fetal development
      - Most long bones begin ossifying by 8 weeks
      - Primary ossification centers by 12 weeks
    • At birth, most long bones well ossified (except epiphyses)
    • At age 25 ~ all bones completely ossified and skeletal growth ceases

  - Bone remodeling and repair
    • Lifelong

Approximate size of a human conceptus from fertilization to the early fetal stage
Figure 6.8  Endochondral ossification in a long bone.

Week 9
- Bone collar forms around the hyaline cartilage model.
- Cartilage in the center of the diaphysis calcifies and then develops cavities.
- The diaphysis elongates and a medullary cavity forms. Secondary ossification centers appear in the epiphyses.

Birth
- Articular cartilage.
- Spongy bone.
- Epiphyseal plate cartilage.
- Medullary cavity.

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

Lengthening of Long Bones in Childhood and Adolescence
- Requires presence of epiphyseal cartilage
- Epiphyseal plate maintains constant thickness
  - Rate of cartilage growth on one side balanced by bone replacement on other
- Concurrent remodeling of epiphyseal ends to maintain proportion
- Result of five zones within cartilage
  - Resting (quiescent) zone
  - Proliferation (growth) zone
  - Hypertrophic zone
  - Calcification zone
  - Ossification (osteogenic) zone

Figure 6.10  Growth in length of a long bone occurs at the epiphyseal plate.

- Resting zone
- Proliferation zone: Cartilage cells undergo mitosis.
- Hypertrophic zone: Older cartilage cells enlarge.
- Calcification zone: Matrix calcifies; cartilage cells die; matrix begins deteriorating; blood vessels invade cavity.
- Ossification zone: New bone forms.
Growth in Length of Long Bones

- Near end of adolescence chondroblasts divide less often
- Epiphyseal plate thins then is replaced by bone
- **Epiphyseal plate closure**
  - Bone lengthening ceases
  - Requires presence of cartilage
  - Bone of epiphysis and diaphysis fuses
  - Females – about 18 years
  - Males – about 21 years

Appositional Growth: Growth in Width

- Allows lengthening bone to widen
- Occurs throughout life
- Osteoblasts beneath periosteum secrete bone matrix on external bone
- Osteoclasts remove bone on endosteal surface
- Usually more building up than breaking down
  - Thicker, stronger bone but not too heavy

Bone Homeostasis

- Recycle 5-7% of bone mass each week
  - Spongy bone replaced ~ every 3-4 years
  - Compact bone replaced ~ every 10 years
- Older bone becomes more brittle
  - Calcium salts crystallize
  - Fractures more easily
- Consists of **bone remodeling** and **bone repair**
Figure 6.15  Stages in the healing of a bone fracture.

**Stages of Bone Repair**

1. A hematoma forms.
2. Fibrocartilaginous callus forms.
4. Bone remodeling occurs.

**Joints (Articulations)**

- Site where two or more bones meet
- Functions of joints
  - Give skeleton mobility
  - Hold skeleton together
- Two classifications
  - Functional – based on amount of movement
    - Synarthroses—immovable joints
    - Amphiarthroses—slightly movable joints
    - Diarthroses—freely movable joints
  - Structural – based on binding materials and presence/absence of joint cavity
    - Fibrous joints
    - Cartilaginous joints
    - Synovial joints – has a joint cavity

**Fibrous Joints**

- Bones joined by dense fibrous connective tissue
- No joint cavity
- Most synarthrotic (immovable)
  - Depends on length of connective tissue fibers
- Three types:
  - Sutures
  - Syndesmoses
  - Gomphoses
Figure 8.1a  Fibrous joints.

- Rigid, interlocking joints
- Immovable joints for protection of brain
- Contain short connective tissue fibers
- Allow for growth during youth
- In middle age, sutures ossify and fuse
  - Called Synostoses

Figure 8.1b  Fibrous joints.

- Bones connected by ligaments
- Fiber length varies so movement varies
  - Little to no movement at inferior tibiofibular joint
  - Large amount of movement at interosseous membrane connecting radius and ulna
- Interosseous membrane

Figure 8.1c  Fibrous joints.

- Peg-in-socket joints of teeth in alveolar sockets
- Fibrous connection is the periodontal ligament
Cartilaginous Joints

- Bones united by cartilage
- No joint cavity
- Not highly movable
- Two types:
  - Synchondroses
  - Symphyses

Cartilaginous Joints: Synchondroses

Bar/plate of hyaline cartilage unites bones
- Temporary epiphyseal plate joints
  - Become synostoses after plate closure
- Cartilage of 1st rib with manubrium
  - Many are synarthrotic

- Fibrocartilage unites bone
  - Hyaline cartilage present as articular cartilage
- Strong, flexible amphiarthroses
Synovial Joints: Six Distinguishing Features

1. Articular cartilage: hyaline cartilage
   – Prevents crushing of bone ends

2. Joint (synovial) cavity
   – Small, fluid-filled potential space

3. Articular (joint) capsule
   – Two layers
     • External Fibrous layer
       – Dense irregular connective tissue
     • Inner Synovial membrane
       – Loose connective tissue
       – Makes synovial fluid

4. Synovial fluid
   – Viscous, slippery filtrate of plasma and hyaluronic acid
   – Lubricates and nourishes articular cartilage
   – Contains phagocytic cells to remove microbes and debris
Synovial Joints: Six Distinguishing Features

5. Different types of reinforcing ligaments
   – Capsular
     • Thickened part of fibrous layer
   – Extracapsular
     • Outside the capsule
   – Intracapsular
     • Deep to capsule; covered by synovial membrane

6. Nerves and blood vessels
   – Nerve fibers detect pain, monitor joint position and stretch
   – Capillary beds supply filtrate for synovial fluid

Other Features of Some Synovial Joints

• Fatty pads
  – For cushioning between fibrous layer and synovial membrane or bone

• Articular discs (menisci)
  – Fibrocartilage separates articular surfaces to improve “fit” of bone ends, stabilize joint, and reduce wear and tear

Structures Associated with Synovial Joints

• Bursae
  – Sacs lined with synovial membrane
    • Contain synovial fluid
  – Reduce friction where ligaments, muscles, skin, tendons, or bones rub together

• Tendon Sheaths
  – Elongated bursa wrapped completely around tendon subjected to friction
Three Stabilizing Factors at Synovial Joints

- Shapes of articular surfaces (minor role)
- Ligament number and location (limited role)
- Muscle tendons that cross joint (most important)
  - Muscle tone keeps tendons taut
    - Extremely important in reinforcing shoulder and knee joints and arches of the foot

Knee Joint

- Largest, most complex joint of body
- Three joints surrounded by a single joint cavity
  - Femoropatellar joint
    - Plane joint
    - Allows gliding motion during knee flexion
  - Lateral and medial tibiofemoral joints
    - Femoral condyles with lateral and medial menisci of tibia
    - Allow flexion, extension, and some rotation when knee partly flexed

Figure 8.8c. The knee joint.

- Quadriceps femoris muscle
- Tendon of quadriceps femoris muscle
- Patella
- Lateral patellar retinaculum
- Fibular collateral ligament
- Fibula
- Medial patellar retinaculum
- Tibial collateral ligament
- Patellar ligament
- Tibia

(e) Anterior view of right knee
Figure 8.8d The knee joint.

Figure 8.8a The knee joint.

Figure 8.8e The knee joint.
Figure 8.8b The knee joint.

(b) Superior view of the right tibia in the knee joint, showing the menisci and cruciate ligaments

Anterior Knee

https://www.youtube.com/watch?v=JxjS1zT0g

Posterior Knee
Optional Slides:

• Stages in bone repair that accompany a Figure 6.15
• Structural and functional differences between cartilage and bone
• Structural and functional differences between cancellous bone and compact bone

Stages of Bone Repair: HEMATOMA Forms

• Torn blood vessels hemorrhage
• Clot (hematoma) forms
• Site swollen, painful, and inflamed

Stages of Bone Repair: Fibrocartilaginous Callus Forms

• Capillaries grow into hematoma
• Phagocytic cells clear debris
• Fibroblasts secrete collagen fibers to span break and connect broken ends
• Fibroblasts, cartilage, and osteogenic cells begin reconstruction of bone
  – Create cartilage matrix of repair tissue
  – Osteoblasts form spongy bone within matrix
• Mass of repair tissue called fibrocartilaginous callus
**Stages of Bone Repair: Bony Callus Forms**

- Within one week new trabeculae appear in fibrocartilaginous callus
- Callus converted to bony (hard) callus of spongy bone
- ~2 months later firm union forms

**Stages of Bone Repair: Bone Remodeling Occurs**

- Begins during body callus formation
- Continues for several months
- Excess material on diaphysis exterior and within medullary cavity removed
- Compact bone laid down to reconstruct shaft walls
- Final structure resembles original because responds to same mechanical stressors

<table>
<thead>
<tr>
<th>Cartilage Characteristics</th>
<th>Bone Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>living components</td>
<td>osteogenic cells, osteoblasts, osteoclasts, osteocytes</td>
</tr>
<tr>
<td>matrix</td>
<td>inorganic calcium hydroxyapatite and protein: Ca₅(PO₄)₃ – 65% (and related Ca minerals) collagen, proteoglycan – 35%</td>
</tr>
<tr>
<td>sheath</td>
<td>periosteum, endosteum</td>
</tr>
<tr>
<td>growth</td>
<td>Apposition: endochondral and intramembranous</td>
</tr>
<tr>
<td>blood &amp; nervous supply</td>
<td>good blood supply at perichondrium, none within cartilage</td>
</tr>
<tr>
<td>types</td>
<td>Woven (temporary) and lamellar cancellous and compact</td>
</tr>
<tr>
<td>benefits</td>
<td>smooth articulation surfaces, flexible, resilient, strong but lighter than bone</td>
</tr>
<tr>
<td></td>
<td>rigid strength, protection, reservoir</td>
</tr>
</tbody>
</table>
| Cancellous  
<table>
<thead>
<tr>
<th>(Trabecular, Spongy)</th>
<th>Compact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trabeculae covered with endosteum, encased in compact bone</td>
<td>Osteons cemented together by interstitial lamellae – endosteum internally, periosteum externally</td>
</tr>
<tr>
<td>Creates a network of spaces for bone marrow</td>
<td>Essentially a solid mass</td>
</tr>
<tr>
<td>No direct blood supply to the bone matrix, rich blood supply to the marrow-containing cavities</td>
<td>Network of blood vessels throughout</td>
</tr>
<tr>
<td>Strong yet lighter than compact, orientation reflects lines of stress</td>
<td>Strongest, densest bone available</td>
</tr>
<tr>
<td>Epiphyses of long bones, internal portions of short, flat, and irregular bones</td>
<td>Shafts of long bones, thin outer covering of most bones</td>
</tr>
</tbody>
</table>